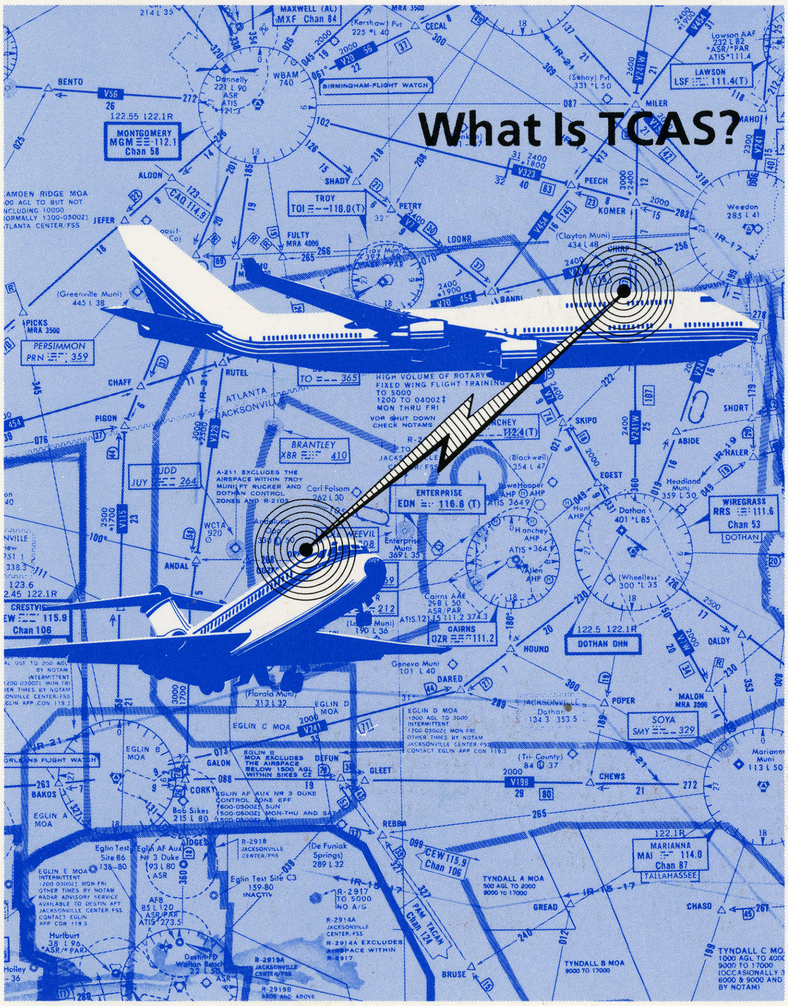
Rockwell Avionics

Collins

instruction guide

Collins Air Transport Division

What Is TCAS?



CONTENTS

List of Illustrations

Glossary

Advisory	A message given to the pilot that contains information relevant to collision avoidance. Synonymous with alert.
ARINC	Aeronautical Radio, Inc.
ASA	Aircraft Separation Assurance. The prevention of collisions between aircraft.
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System. A secondary surveillance radar using ground based interrogators and airborne transponders capable of operation in Modes A and C.
Alarm	An aural signal to the pilot that recommends immediate attention to the display(s).
Alert	A message given to the pilot containing information relevant to collision avoidance. Synonymous with advisory.
BCD	Binary Coded Decimal
Bearing	The horizontal angle of an intruder aircraft relative to the nose of the TCAS-equipped aircraft.
BITE	Built-In Test Equipment
Coasted Track	A track that is continued based on previous track characteristics in the absence of surveillance data reports.
Corrective Advisory	A resolution advisory that instructs the pilot to deviate from current vertical rate (e.g. DON'T CLIMB when the aircraft is climbing).

CPA	Closest Point of Approach
Desensitization	TCAS sensitivity level (threat volume) reduction.
Downlink	A signal propagated from the transponder.
DPSK	Differential Phase Shift Keying
ELM	Extended Length Message
False Advisory	An advisory caused by a false track or TCAS malfunction.
False Track	A track created by erroneous surveillance data.
Intruder	An altitude reporting aircraft that is being considered as a potential threat and that is being processed by the threat detection logic.
Magnetic Bearing	The direction of another aircraft from own aircraft measured from magnetic north.
MODE A	The pulse format for an identification code interrogation of a ATCRBS transponder.
MODE C	The pulse format for an altitude information interrogation of an ATCRBS transponder.
MODE S	Mode Select. A transponder format to allow discrete interrogation and data link capability.
PAM	Pulse Amplitude Modulation
Performance Monitoring	A feature of the TCAS equipment that implements the function of determining the operating capability of the TCAS equipment, including interfacing systems. The performance monitoring function is initiated routinely and automatically by the TCAS

equipment; no external or flight crew stimulation is required. The performance monitor feature of the TCAS equipment also provides to the pilot an indication of the operating status of the equipment.

PPM Pulse Position Modulation

Preventative Advisory A resolution advisory that instructs the pilot to avoid certain deviations from current vertical rate.

PWM Pulse-Width Modulation

RA Resolution Advisory

Radar Mile The time interval (approximately 12.359 µseconds) required for radio waves to travel 1 nmi and return (for a total of 2 nmi).

Resolution Advisory A display indication given to the pilot recommending a maneuver to increase vertical separation relative to an intruding aircraft. A resolution advisory is also classified as corrective or preventive. (Resolution advisory airspace is 750 feet above and below the aircraft and approximately 30 seconds distant with respect to closure speed of the aircraft.)

Self-Test Tests of the TCAS equipment and displays which are initiated by the flight crew and are used to determine the operational status of the equipment. Self-test differs from performance monitoring in that it is initiated by the flight crew and is not performed continually or automatically.

Sense A direction that a resolution advisory may take: either CLIMB or DESCEND.

Sensitivity Level Command An instruction given to the TCAS equipment for control of its threat volume.

Squitter The transmission of a specified reply format, by the Mode S transponder, at a minimum rate without the need to be interrogated.

SSR Secondary Surveillance Radar System

TA Traffic Advisory

Tau Tau is the minimum time the flight crew needs to discern a collision threat and take evasive action. It represents the performance envelope (speed and path of aircraft) divided by the closure rate of any intruder aircraft.

TCAS Traffic Alert and Collision Avoidance System

TCAS I A baseline system that provides a warning (TA) to the flight crew of the presence of another aircraft (potential collision threat) within the surveillance area. No avoidance maneuver is suggested.

TCAS II A collision avoidance system providing traffic information (within approximately 30 nmi of the aircraft) to the flight crew, in addition to resolution advisories (for vertical maneuvers only). A TCAS II-equipped aircraft will coordinate with TCAS II equipped intruder aircraft to provide complementary maneuvers.

TCAS III TCAS III is not totally defined at the time of publication, but it is intended to be the same as TCAS II except for the additional capability to generate resolution advisories in the horizontal plane (e.g. "TURN LEFT", "TURN RIGHT").

Target An aircraft within the surveillance range of TCAS.

Threat A target that has satisfied the threat detection logic and thus requires a traffic or resolution advisory.

Total Radiated Power (TRP) The effect of TCAS transmissions on the beacon environment is measured in terms of the total radiated power. For a lossless antenna, the TRP is equal to the net power delivered to the antenna input terminals. If the antenna is not lossless but has vertical pattern that is similar to that of a matched quarter-wave stub, the TRP may be approximated by the following:

$$TRP = P \times G \times (BW/360°),$$

Where P is the net power delivered to the antenna input terminals, G is the peak antenna gain relative to a matched quarter-wave stub, and BW is the 3-dB azimuth beamwidth in degrees (BW = 360° for omnidirectional antenna).

Track Estimated position and velocity of a single aircraft based on correlated surveillance data reports.

Traffic Advisory Information given to the pilot pertaining to the position of another aircraft in the immediate vicinity. The information contains no suggested maneuvers. (Traffic advisory airspace is 1200 feet above and below the aircraft and approximately 45 seconds distant with respect to closure speed of the aircraft.)

Traffic Density The number of transponder equipped aircraft within R nautical miles (nmi) of own aircraft, divided by $\pi \times (R\ nmi)^2$. Transponder equipped aircraft include Mode-S and ATCRBS Mode A and Mode C, and excludes own aircraft.

VSL Advisory Vertical Speed Limit advisory. A VSL advisory may be preventive or corrective.

Whisper-Shout A sequence of ATCRBS interrogations and suppressions of varying power levels transmitted by TCAS equipment to reduce severity of synchronous interference and multipath problems.

Typical TCAS System Components
Figure 1

INTRODUCTION

This instruction book presents the theory and principles of TCAS operation and answers common questions about TCAS operations.

WHAT IS TCAS II?

TCAS II is an abbreviation for traffic alert and collision avoidance system. TCAS is a system that is designed to alert a flight crew to the potential of conflicts with other aircraft within the area. The system uses the existing ATCRBS system and the capabilities of Mode S transponders to coordinate with other TCAS equipped aircraft. TCAS II provides two types of advisories to the flight crew; a traffic advisory which informs the flight crew that there are other aircraft in the vicinity, and a resolution advisory that advises the flight crew a corrective or preventative action is required to avoid an intruder aircraft. Figure 1 shows some typical hardware components.

THE TCAS II SYSTEM

TCAS II equipment consists of a receiver-transmitter, displays (a resolution advisory VSI and a traffic advisory indicator), one omnidirectional antenna (bottom) and one directional antenna (top), and a Mode S transponder (with two transponder L-band antennas and control panel). Figure 2 shows a typical system interconnect.

TCAS Receiver-Transmitter

The TCAS receiver-transmitter contains the computational processors required to determine if the path of nearby aircraft will interfere with the flight path of the TCAS equipped aircraft.

Display

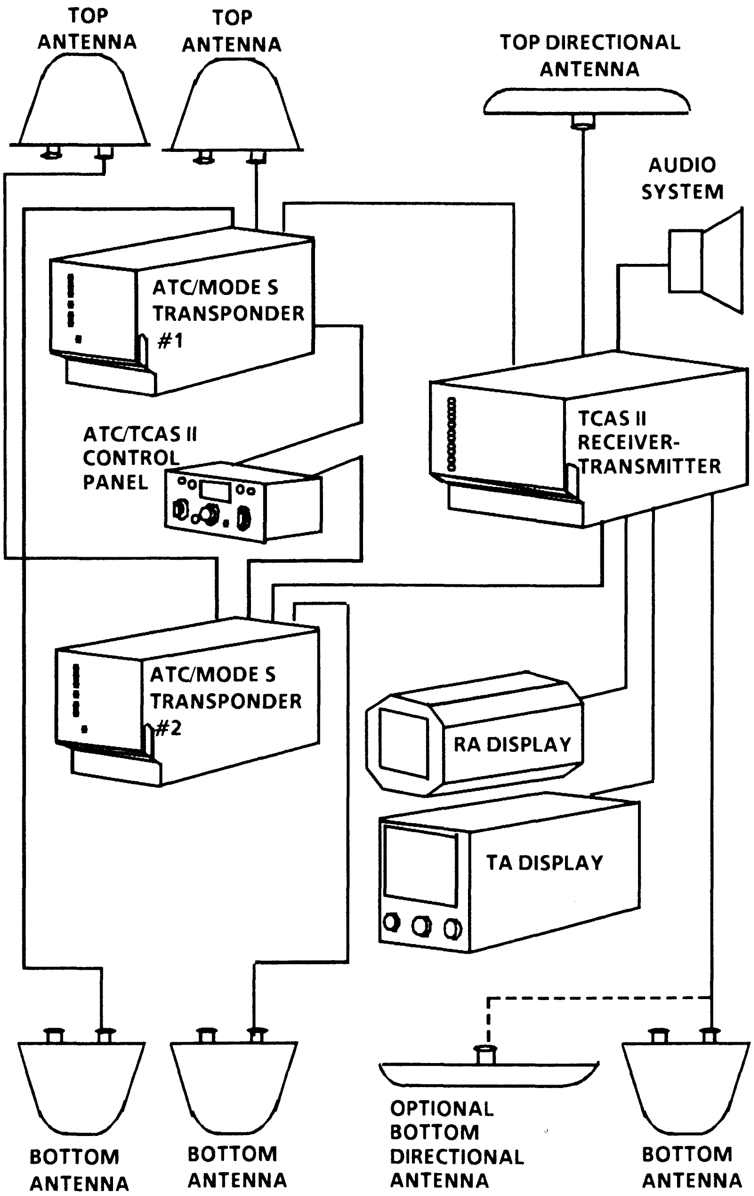
The display will present RA's (resolution advisories) and/or TA's (traffic advisories). The display can be either a dedicated display or part of another display (such as weather radar). The display will present visual alerts to the pilot identifying the aircraft within the immediate area as a threat or advisory. Typically, resolution advisories will be displayed by the vertical speed indicator.

Antennas

An omnidirectional antenna (bottom) and a directional antenna (top) or two directional antennas are used with the TCAS system to determine the bearing and altitude of transponder-equipped aircraft responding to the interrogations of the TCAS transmitter-receiver. Two additional antennas are required for the Mode S transponder associated with the TCAS system.

Mode S transponder

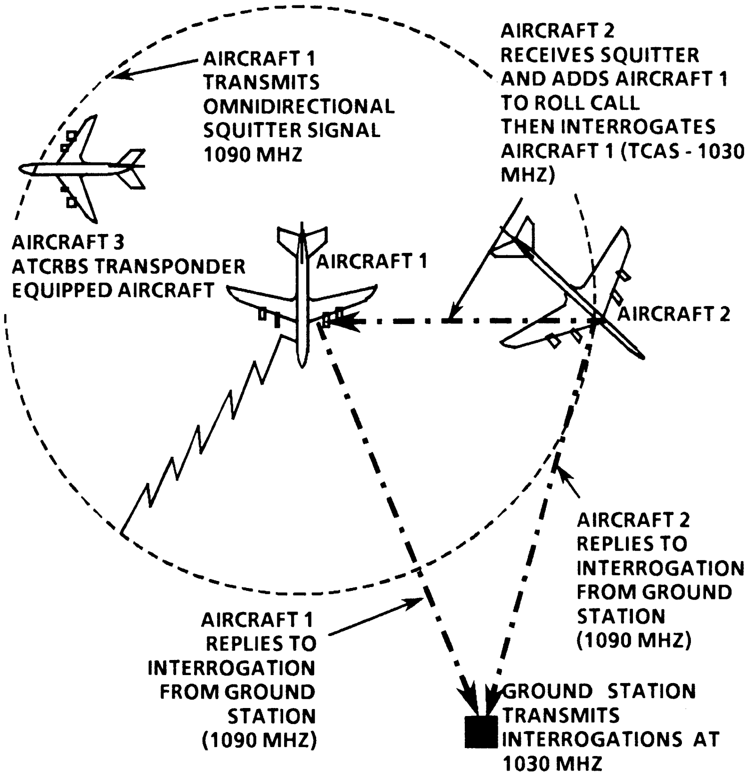
The Mode S transponder provides the communication capabilities (data link) required for TCAS, as well as the ATCRBS transponder functions (mode A and mode C operation). The Mode S transponder consists of the transponder receiver-transmitter, two omnidirectional L-band antennas, a control panel, and an altitude encoder.



Typical TCAS System Interconnect
Figure 2

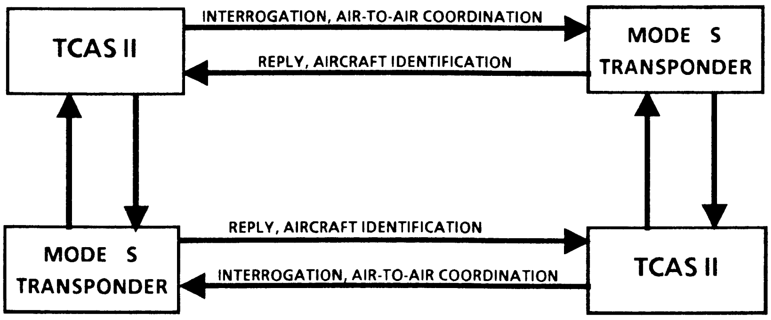
TYPICAL OPERATION

The airborne operation of the TCAS equipment will be more apparent if the operation of the equipment during a flight is explained. Refer to figure 3.



Typical TCAS Operation
Figure 3

A TCAS equipped aircraft (aircraft 1) has a Mode S transponder that regularly transmits (once per second) a squitter signal that identifies the transmitting aircraft. TCAS equipped aircraft in the area will monitor the 1090-MHz frequency and when a valid identification squitter is received, the transmitting aircraft identification is added to a list of aircraft the TCAS equipped aircraft will interrogate. (This list of aircraft is called a roll call.)



Interrogation/Reply Between TCAS Systems
Figure 4

Aircraft 1 will also receive the Mode S squitter signals and compiles a roll call list of the Mode S transponder equipped aircraft (in the area). The TCAS II rt of aircraft 1 will also transmit interrogations to any transponder (ATCRBS) equipped aircraft in the area. In the example of figure 3, aircraft 3 will respond to an ATCRBS interrogation, but only aircraft 2 will be able to respond to a Mode S only All-Call interrogation.

Aircraft 1 will then interrogate each of the aircraft appearing on the roll call. The replies are received by the TCAS antennas. The TCAS directional antenna contains several receiving elements which provide the rt unit with phase information relating to the the actual bearing of the intruder aircraft. If the replying transponder is capable of altitude reporting, the altitude of the replying aircraft is also received and used by the TCAS equipment. The TCAS equipment computes the range of the intruding aircraft by using the round trip time between transmission of the interrogation and the reception of the reply. The range of the replying aircraft can be calculated, using the speed of the returning signal and the amount of time elapsed.

This computation is shown in the following equation.

$$\text{Distance} = \frac{\text{Elapsed time}}{12.359\ \mu\text{s per nmi}}$$

The altitude, altitude rate, range, and range rate are determined by tracking the replies to each interrogation. Then by computer analysis of the replies, the TCAS receiver-transmitter determines which aircraft represent potential collision threats and then provides the appropriate advisory (aural and visual) indication to the flight crew. If the TCAS receiver-transmitter determines that the flight path of an aircraft within the area will pass within 1200 feet, an advisory will be issued. Each threat aircraft within the area is processed individually to allow selection of the minimum safe resolution advisory and to provide coordination with other TCAS-equipped aircraft. If the threat aircraft is equipped with TCAS, a coordination procedure is generated via the air-to-air Mode S data link.

The resolution advisories displayed to the pilot are of two types; corrective advisories which instruct the pilot to deviate from the current flight path, and preventive advisories that advise the flight crew to avoid certain maneuvers to prevent collision. A traffic advisory informs a flight crew of a potential threat aircraft present within the surveillance area.

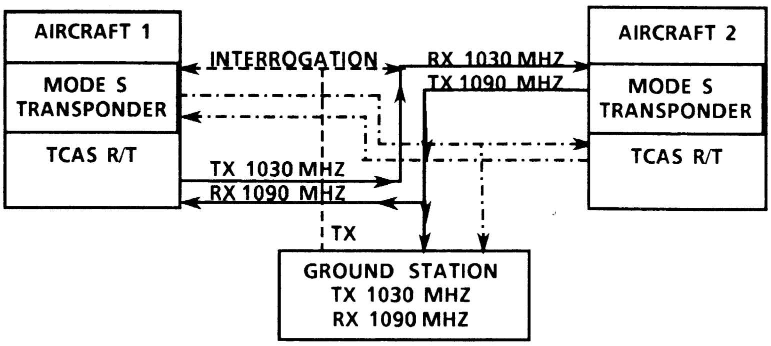
The flight crew will be notified visually on the display screen of the potential threat. If the traffic poses a threat, an aural annunciation of "TRAFFIC, TRAFFIC" will be made. If evasive action later becomes necessary, then the traffic advisory is followed by a resolution advisory, which will provide a corrective action that could include an aural annunciation of "CLIMB, CLIMB" or "DESCEND, DESCEND". The action required will also be displayed on the VSI (vertical speed indicator). When the threat clears, the display will show the now non-threatening target, and advise aurally "CLEAR OF TRAFFIC, CLEAR OF TRAFFIC".

The traffic advisories displayed to the pilot, on a crt display such as the weather radar display, will indicate the positions of the nearby aircraft and identify the level of the threat posed by the aircraft. The display of the potential threat aircraft will alert the flight crew and aid in the visual acquisition of the threat aircraft.

In addition, the TCAS equipment, through the transponders Mode S data link, will have the capability to provide to the ground station the resolution advisories displayed to the pilot. These resolution advisories may then be displayed to the air traffic controller. At the time of publication, this capability is not implemented in the system.

The ground based Mode S equipment may transmit sensitivity level commands to the TCAS equipment, in order to control the volume of the area around the aircraft that will reply to the interrogations. At the time of publication there are no ATC plans for ground control of the TCAS sensitivity level.

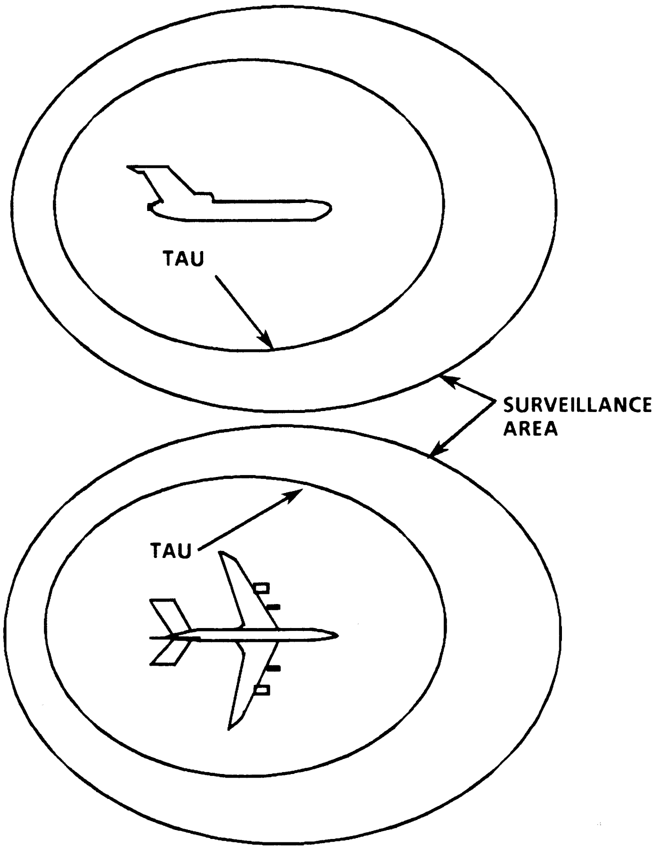
Figure 5 shows the transmit and receive frequencies for the TCAS receiver-transmitter and the Mode S transponder.



TCAS/Mode S Transponder Frequencies
Figure 5

PRINCIPLES OF TCAS

The Traffic Alert and Collision Avoidance System (TCAS) is a system designed to provide airborne separation assurance or collision avoidance. The system does this by maintaining a surveillance area about the aircraft, through the use of replies received from the other aircraft transponder. Refer to figure 6. The system maintains surveillance

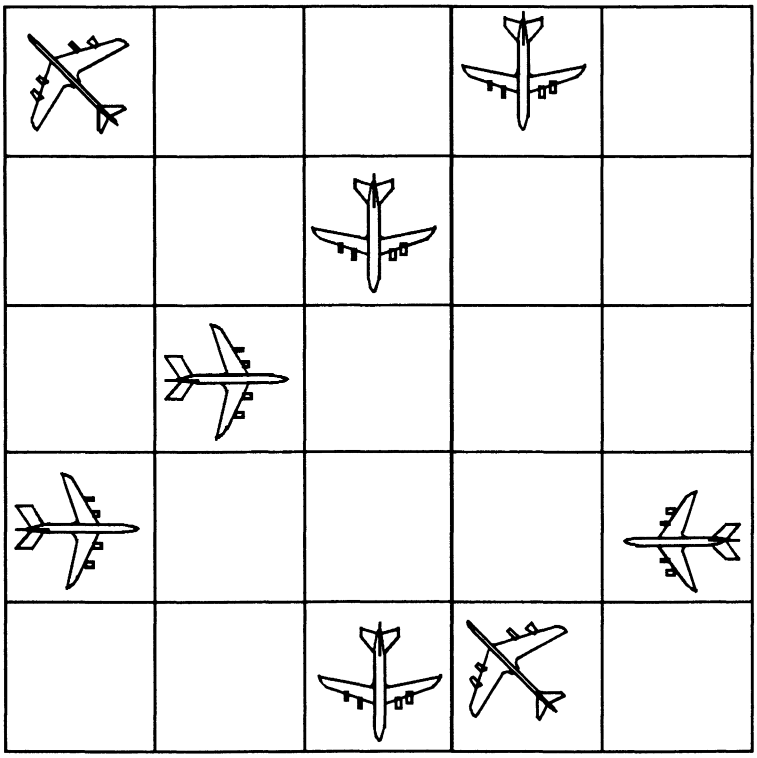


Surveillance area
Figure 6

within a sphere determined by the transmit power and receiver sensitivity of the TCAS rt. The area in which a threat is imminent depends on the speed and path of the aircraft and the threat aircraft. There is an area defined as tau within the surveillance area which represents the minimum time the flight crew needs to discern a collision threat and take evasive action. The TCAS Receiver-Transmitter determines the possibility of collision using algorithms, that define the speed, and possible path of the aircraft. An algorithm is a set of rules or equations for solving a problem. In this case, the problem is whether the path and speed of two aircraft (or many aircraft) will result in the aircraft passing within a predefined spacing of each other. If the answer to this problem is yes, the TCAS Receiver-Transmitter would issue an advisory to the flight crew.

The system is capable of providing resolution advisories to a pilot, allowing the pilot to avoid other aircraft equipped with an ATCRBS, or Mode S altitude reporting transponder, and TCAS. The system will handle aircraft densities of 0.3 transponder equipped aircraft per square nautical mile. Figure 7 shows an overhead view of a five square mile area with 8-transponder equipped aircraft. This is a density of 0.32 transponder equipped aircraft per square nautical mile.

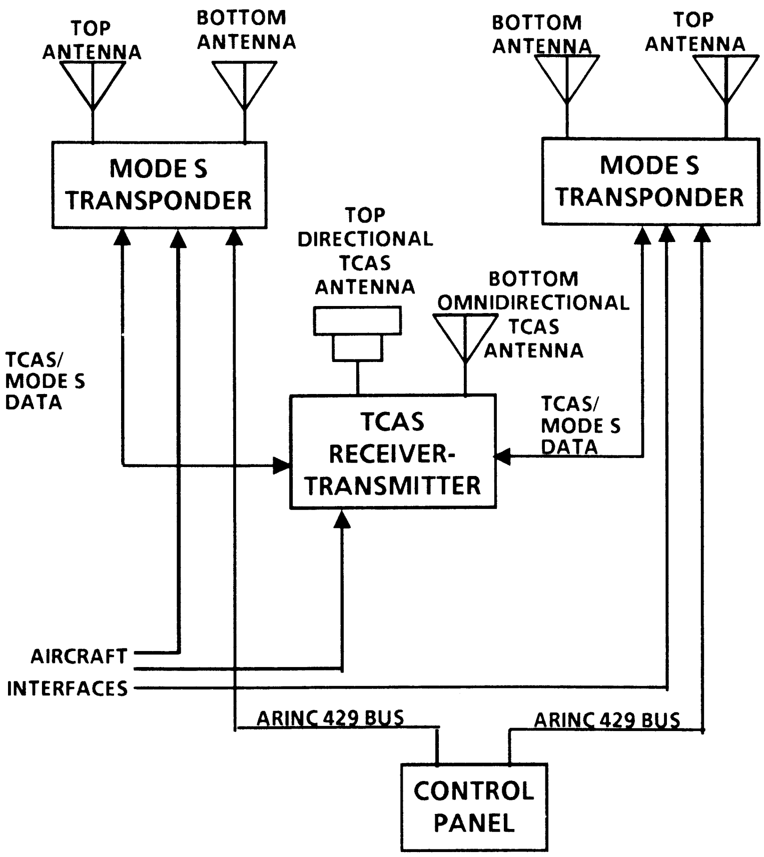
TCAS II consists of a TCAS receiver-transmitter, TCAS antennas, Mode S transponder, L-band antennas, a control panel, and displays. The TCAS II system provides vertical corrective or preventive advisories. The TCAS II provides bearing, range, and altitude information of aircraft within the surveillance area. Within the surveillance area, the system tracks and displays aircraft responding to the TCAS interrogations. The system will provide two different resolution advisories; corrective and preventive. The corrective advisory is a resolution advisory, advising the flight crew to alter the current flight path, in the vertical plane. A preventive advisory is a resolution advisory that advises the flight crew to avoid making certain



0.32 Transponder Equipped Aircraft /NM^2
Figure 7

maneuvers, in the vertical plane, to prevent a conflict from occurring. A traffic display informs the flight crew of an aircraft present within the surveillance area. The TCAS receiver-transmitter along with a Mode S transponder, appropriate displays, and control panel coordinates the collision avoidance and resolution advisories functions for the flight crew. Figure 8 shows a typical block diagram of the TCAS equipment and Mode S transponder.

The function of the system is to interrogate ATCRBS/Mode S transponders on other aircraft and to determine from the replies, the range, altitude, approximate bearing to the aircraft, and compute



Mode S/TCAS Block Diagram
Figure 8

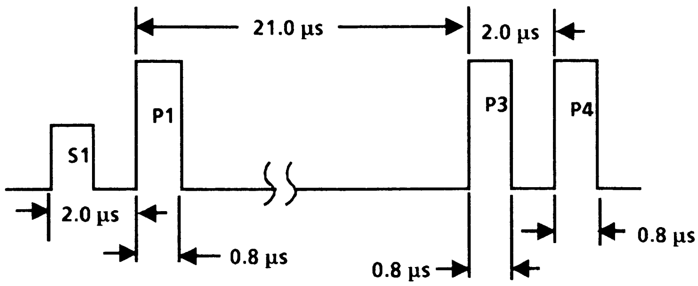
the collision hazard each aircraft represents. The TCAS receiver-transmitter determines whether any of the ATCRBS/Mode S transponder equipped aircraft constitute a collision threat, and coordinates its intentions with other TCAS equipped aircraft through the Mode S transponder.

Collision avoidance resolution advisories may be displayed to the flight crew on one or more dedicated displays, or other flight instruments. All TCAS data is provided to the display via 2-wire digital data per ARINC specification 429. Altitude data is provided to the TCAS unit through the Mode S transponder.

HOW TCAS RESOLVES ENCOUNTERS

The TCAS receiver-transmitter transmits interrogations at a frequency of 1030 MHz (± 0.01 MHz), to the transponder equipped aircraft in the vicinity to generate transponder replies that the signal processing circuits of the TCAS rt will decode to identify the threat aircraft. Once each second, the rt transmits an interrogation for all ATCRBS and Mode S transponder-equipped aircraft. This one second period is referred to as the surveillance update period for all traffic within range of the TCAS-equipped aircraft. The transmission interval is jittered to avoid chance synchronization with ground based transmitters or other Mode S equipped aircraft. The transmission time will be jittered between 0.95 and 1.05 seconds. It isn't necessary to intentionally jitter Mode S interrogations because of the inherently random nature of the Mode S interrogation process.

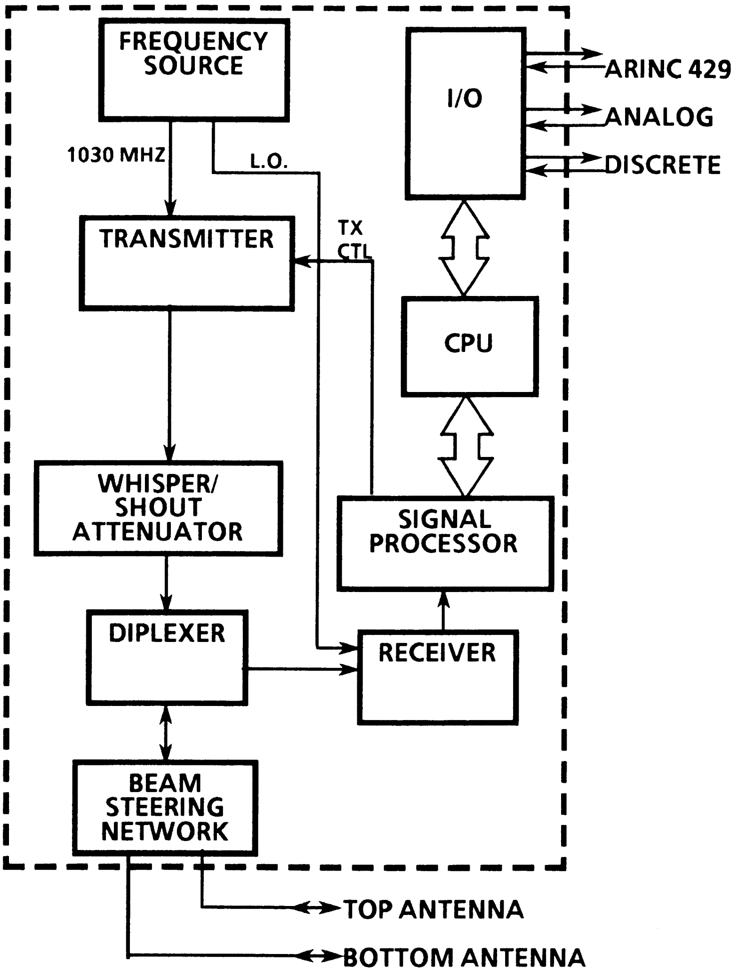
ATCRBS interrogations from TCAS equipment employs the Mode C only All-Call three pulse format. Refer to figure 9. Pulse S1 is of lower amplitude than pulse P1 and the two form a transponder suppression pair with a pulse separation of two microseconds. Only transponders that receive P1 above a noise level of about S1 pulse amplitude will respond to the TCAS II interrogation. The P1-P3 pulse spacing is the normal 21 microseconds for a mode C altitude reporting interrogation. Pulse P4 is part of the format in order to suppress airborne Mode S transponders, which also would provide Mode S replies if not suppressed. The four pulse format group of figure 9 are repeated at increasing power levels over an approximately 20-dB range to generate a whisper-shout sequence. When an aircraft transponder is interrogated by the whisper-shout sequence, the transponder will reply if the amplitude of S1 is below the noise level and P1 is received at a greater level than the transponder MTL (minimum trigger level).



Mode C Only All-Call
Figure 9

Refer to the simplified block diagram of figure 10. The block diagram shows the received signals entering the TCAS receiver-transmitter through a beam steering network and a diplexer. The received signal is then applied to the signal processing circuits that remove the altitude and aircraft identification information from the received signal. This information is then sent to the CPU for use in the threat algorithms stored in program memory. The TCAS system uses the replies of transponder equipped aircraft to determine the potential threat of the aircraft. The TCAS system is capable of determining range, bearing to intruder, and altitude of intruder if the intruder transponder is reporting altitude, from each reply.

The TCAS receiver-transmitter uses several replies from the intruder aircraft to determine the altitude rate, and range rate of the intruder aircraft. In other words, the TCAS receiver-transmitter uses the reported altitudes to determine how fast the intruder aircraft is climbing or descending and uses the elapsed time between transmission and replies to determine whether the aircraft is approaching or leaving the surveillance area. The TCAS receiver-



TCAS Receiver-Transmitter Block Diagram
Figure 10

transmitter also uses the changing bearing positions to determine a probable flight path for the intruder.

The TCAS receiver-transmitter contains the algorithms used for collision avoidance in TCAS II. These algorithms include tracking algorithms for intruder aircraft, threat detection algorithms, selection of resolution advisories algorithms, generating traffic advisory algorithms, and the algorithms for own aircraft altitude and sensitivity levels. The receiver-transmitter also handles the Mode S data link transmissions that are TCAS related. The Mode S data link capabilities are only required when two TCAS equipped aircraft approach each other, in order to coordinate the maneuvers of each aircraft.

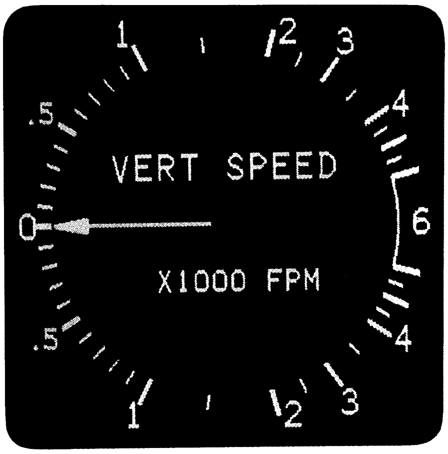
From the transponder replies of intruder aircraft, and if available the TCAS Mode S data link messages, the TCAS receiver-transmitter determines if the flight path and profile of the intruder aircraft will result in a conflict with its own aircrafts flight.

Based upon the TCAS own aircraft profile, the receiver-transmitter determines the appropriate resolution advisory. These advisories will be discussed in the next section.

HOW TCAS PRESENTS ADVISORIES

The resolution advisories from the TCAS II are presented to the flight crew in two forms, aurally and visually. For the purpose of this discussion the visual advisories will be presented on the aircrafts vertical speed indicator (VSI). The VSI provides two functions to the flight crew: (1) it is primarily a vertical speed indicator, and (2) displays the required vertical speeds associated with the resolution of a conflict. The VSI will display a resolution advisory vertical speed arc in red, green or both. Resolution advisories issued against all detected threats are combined for display to the pilot, so that the most demanding resolution advisory is displayed for each sense (up/down). Figure 11 shows a typical vertical speed indicator.

When the TCAS II system issues a resolution advisory, the aural form is annunciated first, and then the visual form is presented. For TCAS II there



Vertical Speed Indicator
Figure 11

are (at the time of publication) 12 different aural annunciation groups that represent the resolution advisory that the pilot will hear. Refer to figure 12 for a list of the annunciated aural resolution advisories.There are many aural annunciations that can be annunciated to the flight crew. For ease of discussion only three examples of aural resolution advisory annunciations will be discussed.

The first example is the aural annunciation listed as number two in figure 12. When TCAS II issues the resolution advisory of DESCEND, it also generates an aural annunciation of "DESCEND, DESCEND, DESCEND". Before the RA occurred, the VSI was displaying the vertical speed of the aircraft. After the RA is issued, vertical speed arcs will indicate to the flight crew which corrective action will resolve the conflict. For this discussion let us assume that the corrective action is to descend at a downward rate of 2500 feet per minute (refer to figure 13). For the descend RA, the VSI will display a vertical speed arc that will be red in color from +6000 to -2500 feet per minute, and green in color from -2500 to -3500 feet per minute. The red portion of the vertical speed arc indicates the vertical speeds the

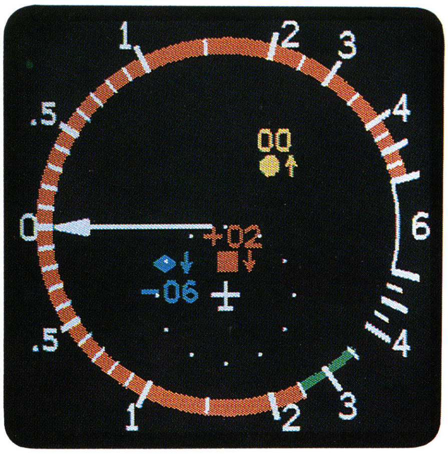
No.	ADVISORY
1	CLIMB, CLIMB, CLIMB
2	DESCEND, DESCEND, DESCEND
3	REDUCE DESCENT, REDUCE DESCENT
4	REDUCE CLIMB, REDUCE CLIMB
5	MONITOR VERTICAL SPEED, MONITOR VERTICAL SPEED
6	CLEAR OF CONFLICT
7	CLIMB, CROSSING CLIMB, CLIMB, CROSSING CLIMB
8	DESCEND, CROSSING DESCEND, DESCEND, CROSSING DESCEND
9	INCREASE CLIMB, INCREASE CLIMB
10	INCREASE DESCENT, INCREASE DESCENT
11	CLIMB-CLIMB NOW, CLIMB-CLIMB NOW
12	DESCEND-DESCEND NOW, DESCEND-DESCEND NOW

Aural Resolution Advisories
Figure 12

flight crew should avoid ("keep the aircraft out of"), and the green portion of the vertical speed arc indicates the vertical speeds the aircraft should attain ("fly-to"). Typically the descend RA will only last long enough to move the aircraft 200 to 300 feet vertically.

The second example is listed as number 6 in the list of figure 12, and occurs after the conflict has been resolved. When the RA (descend) is completed and the TCAS II has determined the threat no longer exists, the TCAS II will issue an aural annunciation of "CLEAR OF CONFLICT", and the red and green vertical speed arcs will be removed from the display.

The third aural annunciation is indicative of a preventive RA. This annunciation is listed as number 5 in the list of figure 12, and illustrated in figure 14. In this example, assume the aircraft is descending and that the intruder is below the aircraft. The TCAS II unit determines that if the TCAS II equipped aircraft maintains its vertical speed at the same or less than its present speed

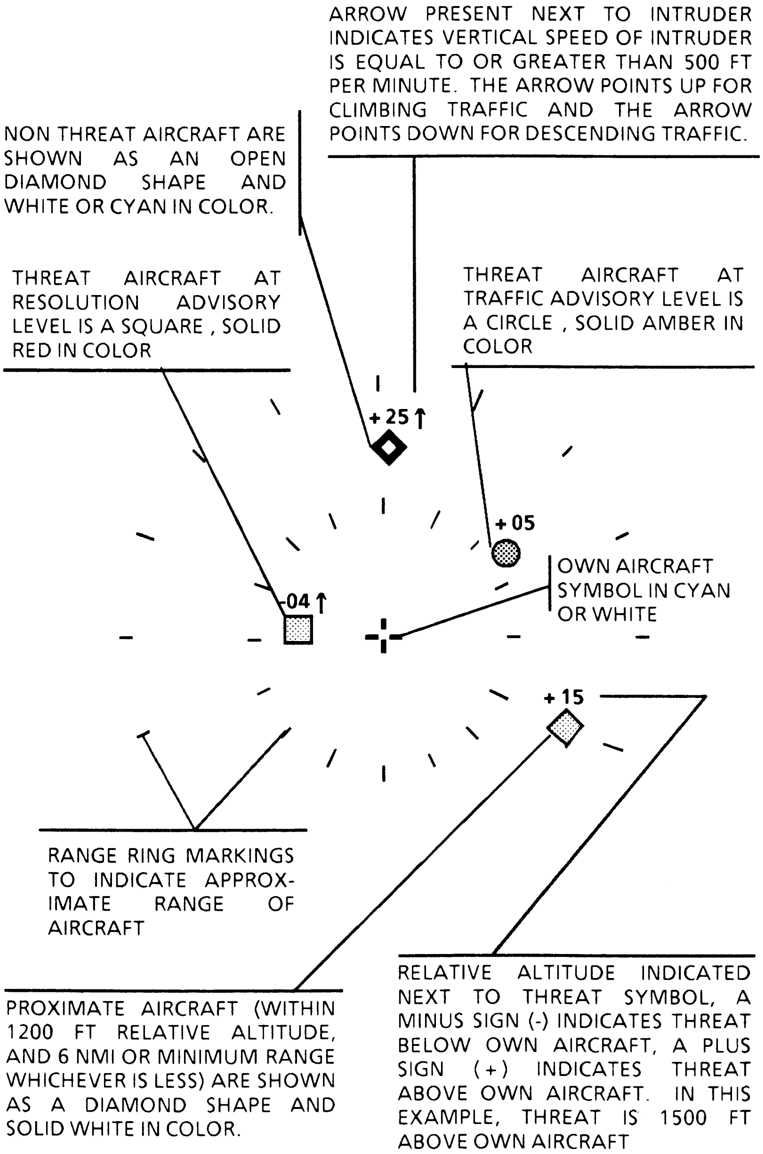


Resolution Advisory (Descend, Descend, Descend)
Figure 13

both aircraft will be safe. This would only occur if the right combination of vertical speeds of both the intruder and TCAS-equipped aircraft would provide the necessary safety margin. Note that under this circumstance, the TCAS II equipped aircraft takes no positive (corrective) action, as in the previous "DESCEND" example, but maintains its current vertical rate as a preventive RA.

There is another aural annunciation that is issued by TCAS II but does not appear in the list of figure 12. This annunciation occurs when TCAS II sends the first threat traffic symbol to the traffic display. "TRAFFIC, TRAFFIC" is annunciated to indicate the presence of intruder aircraft in the area about the aircraft. The traffic display will appear similar to the display shown in figure 15. The symbols associated with the traffic display are explained in the figure. The uniqueness of the traffic display is that the pilot can determine bearing, approximate range and altitude of the intruder by looking at the display.

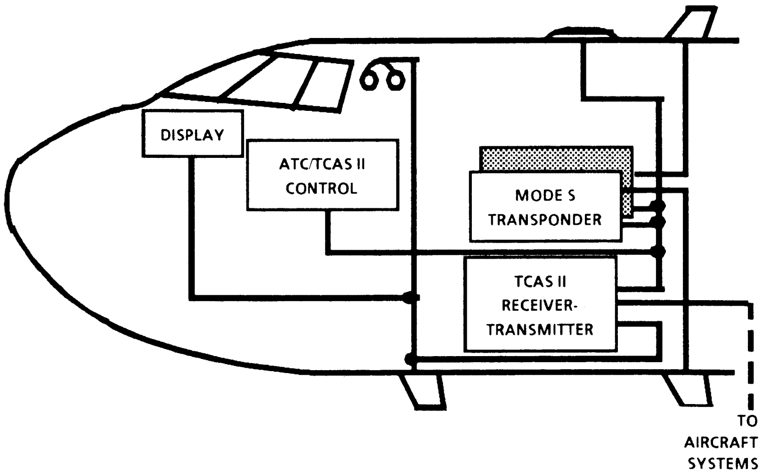
Resolution Advisory (Preventive)
Figure 14



TCAS Display On Weather Radar Indicator
Figure 15

TROUBLESHOOTING TCAS EQUIPMENT

Troubleshooting is a series of steps that will eventually isolate a problem to a specific component or circuit. Troubleshooting any equipment or system should consist of establishing a series of logical steps that will eventually isolate the trouble to a specific unit or component. The logical steps involved are much easier to determine when all the facts of a failure are available. Facts that a technician should seek are; when and where the fault occurred and under what circumstances. The circumstances one might be concerned with would include adverse weather conditions that might affect system performance, proximity to any electrical equipment that might interfere with system operation, the operating procedures performed just prior to the fault, and what occurred to annunciate the failure to the operator.



Many aircraft now contain a central maintenance system that coordinates the automatic testing of avionics equipment and centralizes the fault reporting of the equipment. Should any of the avionics equipment detect a failure during a self-test cycle, the fault is reported to the maintenance computer. The maintenance computer records each reported fault and maintains a history of the faults. The faults are recorded as a numbered code. If the technician has a list of the codes, referenced to the code meanings, the technician can decipher the reported faults to indicate a possible faulty circuit. If the fault is intermittent, that fact will also be recorded. If the TCAS equipment aboard an aircraft is part of a central maintenance system, the technician should first review the reported faults, before beginning troubleshooting. A review of the faults would provide a fault pattern that is useful in diagnosing equipment problems.

To isolate a fault within a unit, the technician can trace the signal through the circuit until it disappears. At the circuit point where the signal disappeared, the technician can examine the operation of the circuit components for faults.

Another method would be to divide the equipment into sections and work by halves. The fault is isolated by locating the trouble in one half of the unit or the other half, then dividing the troubled half of the unit in half to isolate the trouble further. The process is repeated until the fault is isolated to a component or set of components.

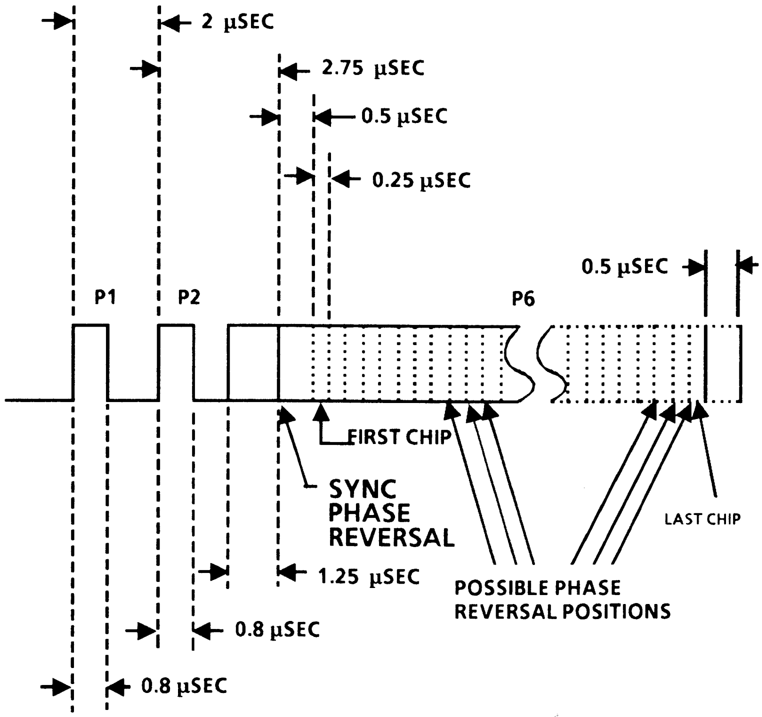
Units that continually are returned for repair, often suffer from a variety of minor faults. These faults would include corroded connectors, damaged wiring , or ineffective grounds. The units may also suffer from a poor installation where improper cooling is provided or poor system interconnections result in intermittent performance. It is a good idea to keep track of troublesome units and occasionally check the installation for faults.

While these troubleshooting hints do not cover all possible problems, they do indicate the information and troubleshooting clues that should be looked for. More specific troubleshooting aids are discussed in the maintenance manual applicable to each particular piece of equipment.

QUESTIONS AND ANSWERS

Q. What is sync phase reversal?

A. Sync phase reversal is the method used in transmitting messages via the transponder data link. It is a position in the Mode S interrogation word that synchronizes the decoding of the interrogation. Figure 16 shows the Mode S interrogation word and the sync phase reversal position.



Mode S Interrogation DPSK Signal
Figure 16

Q. What happens when multiple intruders are detected?

A. The collision avoidance system logic (CAS logic) is designed to consider all intruders when evaluating which resolution advisory (RA) it will issue. The CAS logic will choose an RA based on what coarse of action will provide the maximum separation at the closest point of approach (CPA).

Q. What are the defining characteristic and performance documents of TCAS II?

A. The minimum operating performance standards for TCAS airborne equipment is defined in RTCA document DO-185. The equipment specifications for traffic alert and collision avoidance systems are defined in ARINC specification 735.

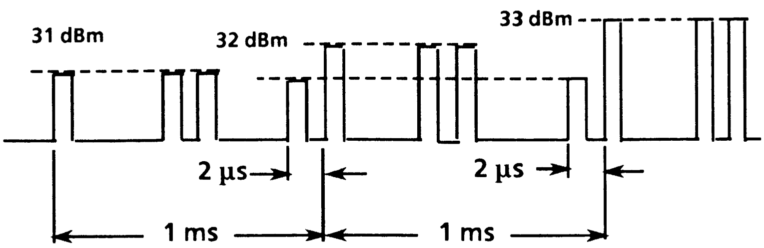
Q. What is the range of TCAS?

A. The surveillance area covered by TCAS is nominally an egg-shaped volume with maximum forward distance at about 30 nmi. The system maintains surveillance within a sphere determined by the transmit power and receiver sensitivity of the TCAS receiver-transmitter.

Q. What is whisper-shout?

A. Whisper-shout is a method to minimize ATCRBS synchronous interference and aid the operation of TCAS in high traffic density airspace. Basically, whisper-shout refers to the power levels of each interrogation and the associated suppression pulse of each interrogation. Refer to figure 17.

The four pulse group is repeated at increasing power levels over an approximate 20-dB range to generate a whisper-shout sequence. When an aircraft transponder is interrogated by the



Whisper - Shout Transmitter Sequence
Figure 17

whisper-shout sequence, the transponder will reply if the S1 pulse is below the noise level and P1 is received at a greater level that the transponder MTL.

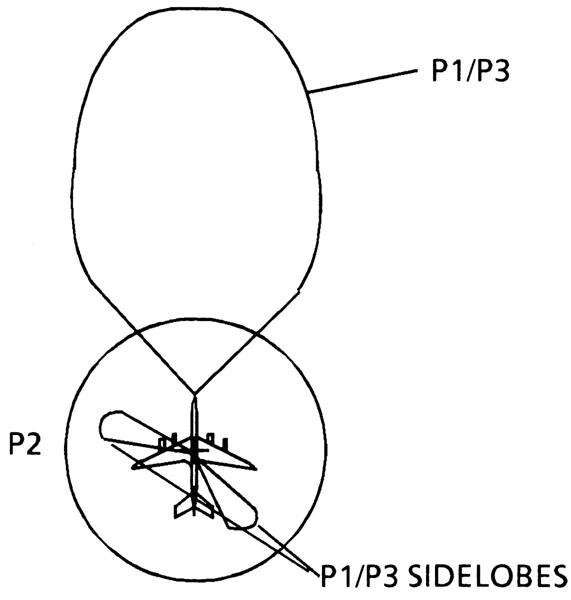
The first pulse of an interrogation serves as the second pulse of suppression. Each aircraft within an airspace will have a different effective sensitivity level due to variations in receivers, cable losses and antenna shielding. Using a system of increasing power in interrogations and accompanying suppression pulses, each aircraft within the airspace will most likely respond to two interrogations before it is turned off by the higher power suppression pulse accompanying the next higher power interrogation. By this method, the synchronous interference is reduced and also the severity of multipath effects on the interrogation link.

Q. What is DABS?

A. DABS is an abbreviation for discrete address beacon system. It was a precursor to the TCAS system, but differed in that it depended upon a ground based interrogation system. It would reduce interference by discretely addressing particular aircraft when interrogating transponder equipped aircraft.

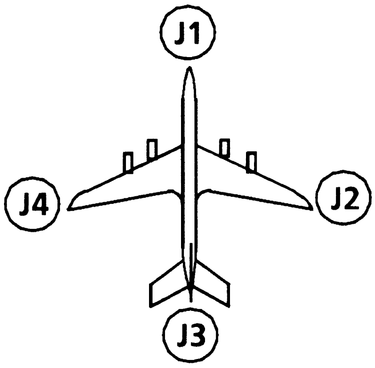
Q. How is bearing determined?

A. Figure 18 displays the TCAS transmit pattern for the area directly ahead of the aircraft (front quadrant). The TCAS II rt transmits interrogation signals to other aircraft in a manner similar to a ground based ATC station. The ground based ATC station uses a narrow beam, mechanically rotated antenna, while the TCAS II system uses a wider, electrically directed beam. The directionality is accomplished by inserting a different electrical phase delay into each of the rf signals applied to the elements of the antenna. Figure 19 shows the phase delay for the four possible directions and an omnidirectional pattern.



TCAS Transmit Pattern
Figure 18

After interrogating, the TCAS II system then waits to receive a reply ("listens") from the direction the transmission was sent. The phase difference in the received signals between the two pairs of antenna elements is used to determine the replying intruder bearing. The antenna elements used in determining the phase difference are determined by the interrogation direction. For example, if the intruder is approaching in the front quadrant, then the TCAS II rt calculates the phase difference between elements 1 and 2 and also 1 and 4. The relationship between the two phase differences then corresponds to the intruder bearing.

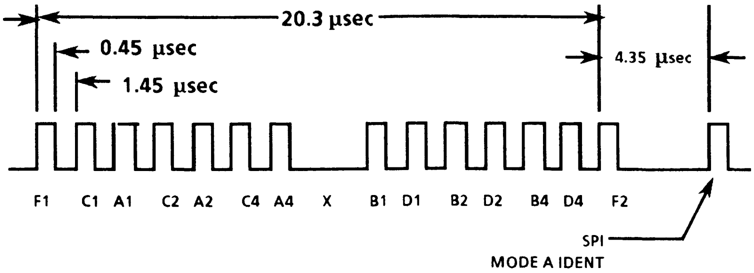


BEAM DIRECTION	J1	J2	J3	J4
↑	-90°	0°	-270°	0°
→	-90°	-180°	-90°	0°
←	-90°	0°	-90°	-180°
↓	-90°	-180°	-270°	-180°
OMNI	-90°	-90°	-90°	-90°

Phasing of Four Feed Signals
Figure 19

Q. How is altitude encoded in replies?

A. Mode C replies from ATCRBS transponders encode the aircraft altitude in a gray code format that is also known as the Gilham code. The Gilham code is an 11 pulse format, that uses the presence of pulses to indicate increments in the altitude. Refer to figure 20 for a diagram of the Mode C transponder reply. In order to display negative altitude values down to -1000 feet, the 0 value starts at -1000 feet, instead of 0 feet. Refer to the table of figure 21 for examples of Gilham encoded altitudes.



Mode C Reply Pulses
Figure 20

ALTITUDE	C4	C2	C1	B4	B2	B1	A4	A2	A1	D4	D2
-1000	0	1	0	0	0	0	0	0	0	0	0
0	0	1	0	1	1	0	0	0	0	0	0
100	0	1	1	1	1	0	0	0	0	0	0
500	0	1	0	0	1	0	0	0	0	0	0
1000	0	1	0	0	1	1	0	0	0	0	0
10000	0	1	0	1	0	1	1	1	0	0	0
50000	0	1	0	1	0	1	0	1	0	1	0
126700	1	0	0	0	0	0	0	0	0	0	1

Sample Gilham Coded Altitudes
Figure 21

Mode S replies send the altitude information in the AC fields of formats 0, 4, 16, and 20. The 13-bit AC field expresses the encoded altitude in the sequence of C1, A1, C2, A2, C4, A4, M, B1, D1, B2, D2, B4, and D4. The M bit allows for the possible future use of encoding altitude in metric units. Zero is transmitted in each of the 13 bits if the altitude information is not available.

Q. What is Tau?

A. Tau can be defined as the minimum time the flight crew needs to discern a collision threat and take evasive action. It represents the performance envelope (Speed and path of aircraft) divided by the closure rate of an intruder aircraft.

Q. How does the Mode S transponder coordinate with the TCAS equipment?

A. The Mode S transponder functions as the communication link between two TCAS equipped aircraft, to coordinate avoidance maneuvers.

All coordination between the Mode S transponder and the on-board TCAS is conducted via the TCAS coordination high-speed ARINC 429 bus. A total of eight different words are sent to the TCAS from the transponder, and three different words are sent from the TCAS to the transponder. In the exchange of information between TCAS and the transponder, some of the words are defined as periodic and the others as non-periodic. The non-periodic words must be acknowledged by the receiving unit. Periodic words do not require acknowledgement, but the word rate is monitored and if any periodic words are not received within the required interval, the bus will be considered failed. Examples of the TCAS coordination words are presented in appendix E.

The transponder communicates with TCAS equipped aircraft by responding (downlink formats 0 or 16) to short or long air-to-air surveillance messages (uplink formats 0 or 16) transmitted from the other TCAS equipped aircraft. The transponder replies consists of information normally available to the transponder or information via the TCAS bus.

APPENDIX A
MODE S INTERROGATION/REPLY FORMATS USED BY TCAS

Appendix A shows the Mode S interrogation and reply formats. Refer to figures 22, 23, 24, and 25.

UF (Uplink Format)								
0	0 0000	— 3 —	RL: 1	--- 4 ---	AQ: 1	--- 18 ---	AP: 24	
4	0 0100	PC: 3	RR: 5	DI: 3	SD: 16	AP: 24		
5	0 0101	PC: 3	RR: 5	DI: 3	SD: 16	AP: 24		
16	1 0000	— 3 —	RL: 1	-- 4 --	AQ: 1	-- 18 --	MU: 56	AP: 24
20	1 0100	PC: 3	RR: 5	DI: 3	SD: 16	MA: 56	AP: 24	
21	1 0101	PC: 3	RR: 5	DI: 3	SD: 16	MA: 56	AP: 24	

NOTES: 1. XX: M DESIGNATES A FIELD "XX" CONTAINING M BITS.

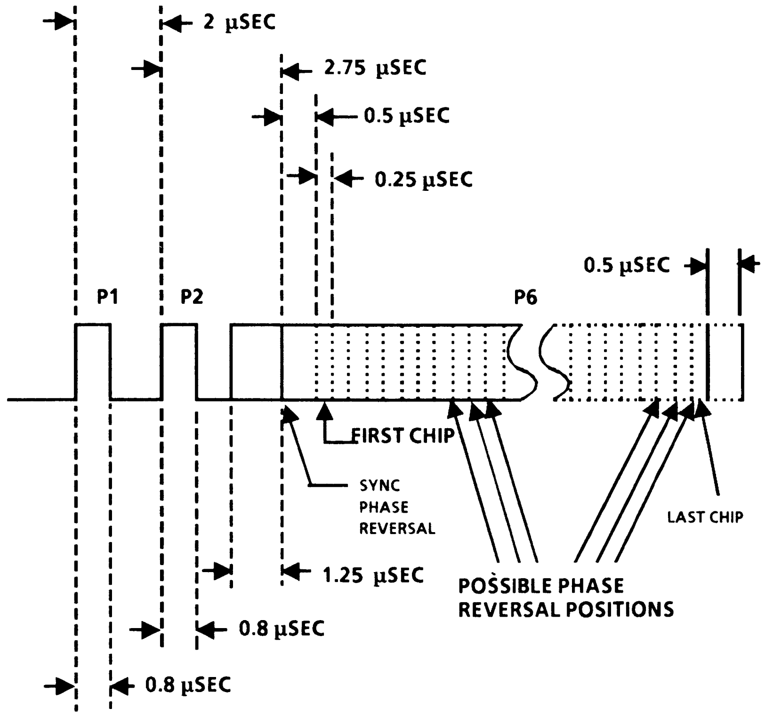
2. --N-- DENOTES FREE CODING SPACE WITH N AVAILABLE BITS.

3. FOR UPLINK FORMATS (UF), 0 THROUGH 23 THE FORMAT NUMBER CORRESPONDS TO THE BINARY CODE IN THE FIRST FIVE BITS OF THE INTERROGATION. FORMAT NUMBER 24 IS ARBITRARILY DEFINED AS THE FORMAT BEGINNING "11" IN THE FIRST TWO BIT POSITIONS, WHILE THE FOLLOWING THREE BITS VARY WITH THE INTERROGATION CONTENT.

FIELD DESIGNATORS

AP = ADDRESS/PARITY
AQ = ACQUISITION SPECIAL
DI = DESIGNATOR, IDENTIFICATION
MU = MESSAGE, COMM U (LONG SPECIAL SURVEILLANCE)
MA = MESSAGE, COMM A
PC = PROTOCOL
RL = REPLY LENGTH
RR = REPLY REQUEST
SD = SPECIAL DESIGNATOR

Mode S Interrogation Formats
Figure 22



Mode S Interrogation DPSK Signal
Figure 23

DF (Downlink Format)

DF										
0	0 0000	VS: 1	– 2 –	SL:3	– 2 –	RI:4	– 2 –	AC: 13	AP: 24	
4	0 0100	FS: 3	DR: 5	UM: 6	AC: 13	AP: 24				
5	0 0101	FS: 3	DR: 5	UM: 6	ID: 13	AP: 24				
11	0 1011	CA: 3	AA: 24	PI: 24						
16	1 0000	VS: 1	– 2 –	SL:3	– 2 –	RI: 4	– 2 –	AC: 13	MV: 56	AP: 24
20	1 0100	FS: 3	DR: 5	UM: 6	AC: 13	MB: 56	AP: 24			
21	1 0101	FS: 3	DR: 5	UM: 6	ID: 16	MB: 56	AP: 24			

NOTES: 1. XX: M DESIGNATES A FIELD "XX" CONTAINING M BITS.

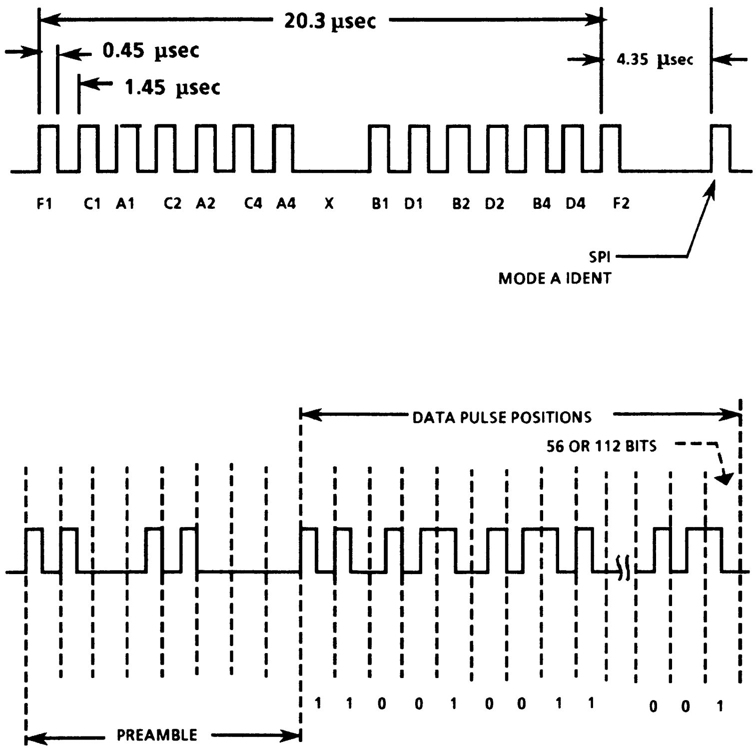
2. --N-- DENOTES FREE CODING SPACE WITH N AVAILABLE BITS.

3. FOR DOWNLINK FORMATS (DF), 0 THROUGH 23 THE FORMAT NUMBER CORRESPONDS TO THE BINARY CODE IN THE FIRST FIVE BITS OF THE INTERROGATION. FORMAT NUMBER 24 IS ARBITRARILY DEFINED AS THE FORMAT BEGINNING "11" IN THE FIRST TWO BIT POSITIONS, WHILE THE FOLLOWING THREE BITS VARY WITH THE REPLY CONTENT.

FIELD DESIGNATORS

AA = ADDRESS ANNOUNCED
AC = ALTITUDE CODE
AP = ADDRESS/PARITY
CA = CAPABILITY, TRANSPONDER
DR = DOWNLINK REQUEST
FS = FLIGHT STATUS
ID = IDENTIFICATION (4096 CODE)
MB = MESSAGE, COMM B
MV = MESSAGE, COMM V
(LONG SPECIAL SURVEILLANCE)
PI = PARITY/INTERROGATOR IDENTITY
RI = REPLY INFORMATION AIR-TO-AIR
SL = SENSITIVITY LEVEL
UM = UTILITY MESSAGE
VS = VERTICAL STATUS

Mode S Reply Formats
Figure 24



NOTES:
1. MODE S "SHORT" (56 BIT REPLY) = 64 μSEC.
2. MODE S "LONG" (112 BIT REPLY) = 118 μSEC.
3. LOGIC 1 AND LOGIC 0 FOR DATA PULSE POSITIONS ARE SHOWN BELOW. (LOGIC 0 IS A POSITIVE GOING PULSE IN THE SECOND HALF OF THE PULSE POSITION AND LOGIC ONE IS A POSITIVE GOING PULSE IN THE FIRST HALF OF THE PULSE POSITION).

Transponder Replies
Figure 25

APPENDIX B
MODE S UPLINK FIELD DESCRIPTIONS

Appendix B is a list of the uplink Mode S messages and the field descriptions used in the messages.

1. AP Address/Parity Field Description

The 24-bit address/parity field contains the parity overlaid on the address, and appears at the end of all transmissions on both the uplink and downlink, except for format DF = 11.

2. AQ Acquisition Special Field Description

The 1-bit acquisition special field designates uplink format (UF) numbers 0 and 16 as acquisition transmissions and is repeated as received by the transponder in downlink format (DF) numbers 0 and 16 (in the RI field). The field is used to designate UF0 or UF16 interrogations as acquisition transmission. Zero equals non-acquisition interrogation and one equals acquisition interrogations

3. DI Designator, Identification Field Description

The 3-bit designator, identification uplink field identifies the coding contained in the SD field (special designator) in format numbers UF4, UF5, UF20, and UF21. The codes are: 0 = SD not used, 1 = SD contains multisite information, 2 through 6 = not assigned, 7 = SD contains extended data readout request.

4. MA Message, Comm A Field Description

The 56-bit MA message, Comm A field contains messages directed to the aircraft (UF20 and UF21). This field also contains the 8-bit Comm A definition subfield (ADS). Subfield ADS defines the content of the MA message field, of which it is a part.

5. MU Message, Long Special Surveillance

TCAS uses the MU field of a long special surveillance interrogation to transmit a TCAS resolution message for air-to-air resolution advisory coordination. The MU field is also used by TCAS to transmit a resolution advisory broadcast interrogation, once per second whenever RABI information is available and to transmit (at 10 second intervals) a TCAS broadcast message containing own transponder's address. Figures 26 through 28 show the structure for MU resolution and broadcast interrogation messages. The following subfields in MU are used for a TCAS resolution message.

POSITION	NUMBER OF BITS	SUBFIELD	REMARKS
33-36	4	UDS1	=3
37-40	4	UDS2	=0
41	1	LCK	-
42	1	MTB	-
43-44	2	CVC	-
45-46	2	VRC	-
47-49	3	CHC	-
50-52	3	HRC	-
53-55	3	-	NOT ASSIGNED
56-60	5	HSB	-
61-64	4	VSB	-
65-88	24	MID	-

MU Structure for a TCAS Resolution Advisory Lock Request and a TCAS Resolution Message
Figure 26

POSITION	NUMBER OF BITS	SUBFIELD	REMARKS
33-36	4	UDS1	= 3
37-40	4	UDS2	= 1
41- 54	14	ARA	-
55-58	4	RAC	-
59	1	CLI	-
60	1	MTB	-
61-62	2	-	NOT ASSIGNED
63-75	13	AID	-
76-88	13	CAC	-

MU Subfields for a Resolution Advisory Broadcast
Interrogation Message
Figure 27

POSITION	NUMBER OF BITS	SUBFIELD	REMARKS
33-36	4	UDS1	= 3
37-40	4	UDS2	= 2
41- 64	24	-	NOT ASSIGNED
65 - 88	24	MID	-

MU Subfields for a TCAS
Broadcast Interrogation Message
Figure 28

UDS U-Definition Subfield

This 8-bit subfield defines the data content and coding in the remainder of the MU field. For convenience in coding, UDS is expressed in two groups of 4 bits each (UDS1 bits 33 -36, UDS2 bits 37-40). TCAS resolution messages are identified by UDS1 = 3, and UDS2 = 0 (the combination UDS = 48).

MTB Multiple Threat Bit

This one bit (42) subfield indicates a multiple threat. Zero equals interrogating TCAS has no more than one threat, and one equals interrogating TCAS has more than one threat.

CVC Cancel Vertical Resolution Advisory Complement

This two-bit subfield (43, 44) is used by airborne TCAS equipment to cancel a vertical resolution advisory complement sent to an equipped threat aircraft. Zero equals no cancellation, one equals cancel, don't descend, two equals cancel, don't climb, and three equals not assigned.

VRC Vertical Resolution Advisory Complement

This 2-bit (45, 46) subfield is used by the airborne TCAS equipment to send a vertical resolution complement (don't climb or don't descend) to the equipped threat aircraft. Zero equals no vertical resolution advisory complement sent, one equals don't descend, two equals don't climb, and three is not assigned.

CHC Cancel Horizontal Resolution Advisory Complement

This three bit (47 - 49) subfield is used by TCAS with horizontal on-board resolution equipment to cancel a horizontal resolution advisory complement sent to an equipped threat aircraft. In TCAS resolution messages transmitted by TCAS without horizontal resolution capability, CHC is set to zero. The codes are: 0 = no cancellation, 1 = cancel don't turn left, = cancel don't turn right, and 3 through 7 = not assigned.

HRC Horizontal Resolution Advisory Complement

This three bit (50 - 52) subfield is used by TCAS with horizontal on-board resolution equipment to send a horizontal resolution maneuver complement (don't turn left, or don't turn right) to the equipped threat aircraft. In TCAS resolution messages transmitted by TCAS without horizontal resolution capability, HRC is set to zero. The codes are 0 = no horizontal resolution advisory complement sent, 1 = intruder TCAS sense is turn left, don't turn left, 2 = intruder TCAS sense is turn left, don't turn right, 3 and 4 = not assigned, 5 = intruder TCAS sense is turn right, don't turn left, 6 = intruder TCAS sense is turn right, don't turn right, and 7 = not assigned.

ESB Encoded Sense Bits

This four bit (61 through 64) subfield is a parity coding field used to protect the four vertical sense bits (43 thru 46). The originating TCAS logic will include bits 61 through 64 in all TCAS resolution messages sent (UF 16, LCK = 0). The receiving TCAS logic will examine bits 61 through 64 in TCAS resolution messages received. If bits 43 through 46 are not in agreement with bits 61 through 64 as indicated in the table of figure 29, the receiving TCAS logic will assume there is an error in the message and will not use the message contents.

6. PC Protocol Field Description

The 3-bit PC field contains the operating commands to the transponder. The codes are: 0 = no changes in transponder state, 1 = nonselective all-call lockout, 2 and 3 = not assigned, 4 = cancel B, 5 = cancel C, 6 = cancel D, and 7 = not assigned.

VERTICAL SENSE BITS				ENCODED SENSE BITS			
43	44	45	46	61	62	63	64
0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	0
0	0	1	0	0	1	1	1
0	0	1	1	1	0	0	1
0	1	0	0	1	0	1	1
0	1	0	1	0	1	0	1
0	1	1	0	1	1	0	0
0	1	1	1	0	0	1	0
1	0	0	0	1	1	0	1
1	0	0	1	0	0	1	1
1	0	1	0	1	0	1	0
1	0	1	1	0	1	0	0
1	1	0	0	0	1	1	0
1	1	0	1	1	0	0	0
1	1	1	0	0	0	0	1
1	1	1	1	1	1	1	1

Vertical Sense/Encoded Sense Bit Agreement
Figure 29

7. RL Reply Length field Description

The 1-bit RL field commands a reply (DF0) if the bit equals zero, and a reply in downlink format 16 if the bit equals one.

8. RR Reply Request Field Description

The 5-bit RR field (9 - 13) contains length and content of the reply information requested by the interrogator. Refer to the table of figure 30 for the RR field codes. If the first bit of the RR code is a logic level one, the last four bits, if transformed into decimal equivalents, designate the number of the requested source. The RR code that airborne TCAS responds to is RR = 19.

RR CODE	REPLY LENGTH	MB CONTENT
0-15	Short	------
16	Long	Air initiated Comm B
17	Long	Extended capability
18	Long	Flight ID
19-31	Long	Not assigned

RR Field Code
Figure 30

9. SD Special Designator Field Description

The 16-bit SD field (17 - 32) contains control codes affecting the link protocol. The content is specified by the DI field. A subfield, IIS, is contained within the SD field, specifying the interrogator identifier.

Airborne TCAS equipment will examine the contents of field SD for ground interrogator identification information encoded in the IIS subfield.

IIS Interrogator Identifier Subfield

This 4-bit subfield contains the self-identification code of the ground interrogator and is numerically identical to the II coded transmitted by the same interrogator in the Mode S only All-Call. A ground interrogator is assigned an IIS code which takes on a value of 0 through 15. IIS = 0 is not a valid identifier code for multisite purposes.

TMS Tactical Message Subfield

This 4-bit subfield contains coding for the linking of Comm A message segments. The codes are shown in the table of figure 31.

CODE	MESSAGE
0	No action
1	Unlinked priority
2	Unlinked, acknowledge
3	Unlinked, priority, acknowledge
4	Linked 1st segment, single ADS
5	Linked 1st segment, single ADS priority
6	Linked 1st segment, single ADS acknowledge
7	Linked 1st segment, single ADS priority acknowledge
8	Linked 1st segment, multiple ADS
9	Linked 1st segment, multiple ADS priority
10	Linked 1st segment, multiple ADS acknowledge
11	Linked 1st segment, multiple ADS priority, acknowledge
12	Second segment
13	Third segment
14	Final segment
15	Not assigned

Tactical Message Subfield Codes
Figure 31

APPENDIX C
MODE S REPLY FORMAT FIELD DESCRIPTIONS

Appendix C is a list Mode S reply format field and subfield descriptions.

1. AA Address, Announced Field Description

The 24-bit AA field contains the aircraft address (in the clear), and is used in the all-call reply (for TCAS surveillance initiation).

2. AC Altitude Code Field Description

The 13-bit AC field contains the altitude code. The encoded altitude is expressed in the sequence of C1, A1, C2, A2, C4, A4, M, B1, D1, B2, D2, B4, and D4. The M bit allows for the possible future use of encoding the altitude in metric units (M equals one if metric altitude is contained in the field). if M equals zero, bit 28 is designated the Q bit. Q equals zero indicates that the Mode S altitude is reported in 100 ft increments. Starting with bit 20 (if M and Q equals 0) the sequence of bits will be C1, A1, C2, A2, C4, A4 zero, B1, zero, B2, D2, B4, D4. If Q equals one, the altitude will be reported in 25 ft. increments. The 11 bit field (if M = 0, and Q = 1) is represented by bits 20 to 25, 27, and 29 to 32. These bits will represent a binary coded field whose least significant bit has a value of 25 feet. The binary value of the decimal number N will be used to report the pressure altitudes in the range 25 x N-1000 ± 12.5 feet. Zero is transmitted in each of the thirteen bits if the altitude information is not available.

3. AP Address/Parity Field Description

The 24-bit address/parity field contains the parity overlaid on the address, and appears at the end of all transmissions on both the uplink and downlink, except for format DF = 11.

4. CA Transponder Capability Field Description

The 3-bit CA field reports transponder capability. The codes are: 0 = No communications capability (surveillance only); 1 = Comm A and Comm B capability; 2 = Comm A, Comm B and uplink ELM capability; 3 = Comm A, Comm B, uplink ELM, and downlink ELM capability; and 4 through 7 are not assigned at the time of publication. If the transponder CA code is 1, 2, or 3, the data link capability report is used to indicate the specific data link capabilities of the overall airborne installation.

5. DR Downlink Request Field Description

The 5-bit DR field is used to request extraction of downlink messages from the transponder by the interrogator. The codes are: 0 = no downlink request; 1 = request to send Comm B message; 2 through 15 are not assigned, and 16 through 31 are used to request permission to send ELMs of n-segments (the code inserted in the DR field will correspond to 15 + n). Downlink ELMs are transmitted only after authorization by the interrogator. The segments are transmitted in Comm D replies. On receipt of the authorization, the transponder will send a segment once every 136 microseconds. After the interrogator receives all the segments, a closeout transmission is used to indicate to the transponder that all segments have been received and the DR field will be reset. The closeout transmission (PC = 6) is contained in a surveillance or Comm A interrogation.

6. FS Flight Status Field Description

The 3-bit FS field reports the flight status of the aircraft. The table of figure 32 provides a description of the code definitions.

CODE	ALERT	SPI	AIRBORNE/ ON THE GROUND
0	NO	NO	AIRBORNE
1	NO	NO	ON THE GROUND
2	YES	NO	AIRBORNE
3	YES	NO	ON THE GROUND
4	YES	YES	EITHER
5	NO	YES	EITHER
6,7			(Not assigned)

Flight Status Field Code Descriptions
Figure 32

7. ID Identification Field Description

The 13-bit ID field contains the 4096 identification code reporting the numbers selected by the pilot.

8. MB Message Comm B Field Description

The 56-bit MB field contains the message transmitted to the interrogator. The field contains an 8-bit subfield (BDS) defining the contents of the Comm B message. TCAS uses the MB field to transmit a resolution advisory report and an extended capability report to Mode S sensors. The subfields of the MB field are BDS (B-definition subfield), ARA (active resolution advisories) and RAC (resolution advisory complement).

BDS B-Definition Subfield

This 8-bit subfield indicates that a resolution advisory report is contained in MB when BDS1 = 3, and BDS2 = 0 (BDS = 48).

ARA Active Resolution Advisories Subfield

Each bit of this subfield is a dedicated bit, representing a specific resolution advisory. Refer to the table of figure 33 for the meanings of each bit. A bit set to 1 indicates that the associated resolution advisory is active.

BIT	RESOLUTION ADVISORY
41	Climb
42	Don't descend
43	Don't descend faster than 500 ft/min
44	Don't descend faster than 1000 ft/min
45	Don't descend faster than 2000 ft/min
46	Descend
47	Don't climb
48	Don't climb faster than 500 ft/min
49	Don't climb faster than 1000 ft/min
50	Don't climb faster than 2000 ft/min
51	Turn left
52	Turn right
53	Don't turn left
54	Don't turn right

Resolution Advisory Subfield Bit Definitions
Figure 33

RAC Resolution Advisory Complement Subfield

This 4-bit subfield indicates the currently active resolution advisory complements (if any) received from all other TCAS aircraft equipped with an on-board resolution capability. Each bit in the RAC subfield is a dedicated bit representing a specific resolution advisory complement. Refer to the table in figure 34. A bit set to one indicates the associated resolution advisory complement is active.

BIT	RESOLUTION ADVISORY COMPLEMENT
55	Don't descend
56	Don't climb
57	Don't turn left
58	Don't turn right

Resolution Advisory Complement Bit Definitions
Figure 34

Extended Capability Codes in MB

When the BDS2 subfield equals 0 then a BCS subfield is identified in bits 69 and 70 and is referred to as the extended capability codes. Bits 69 and 70 indicate on-board resolution advisory generation capability. The table of figure 35 indicates the capability for the bit values of 69 and 70.

BIT 69	BIT 70	CAPABILITY
0	0	No on-board resolution advisory generation capability
0	1	An on-board vertical-only resolution advisory generation capability exists.
1	0	An on-board vertical and horizontal resolution advisory generation capability exists.
1	1	Not assigned

Extended Capability Codes in MB
Figure 35

9. MV Message Comm V Field Description

The 56-bit MV field contains information used in the air-to-air exchanges between Mode S transponders. The field is used by airborne TCAS equipment to transmit air-to-air resolution advisory coordination information to requesting TCAS equipped aircraft. This field does not use Comm B protocol.

10. PI Parity/Interrogator Identity

The 24-bit PI field contains the parity overlaid on the interrogators identity code.

11. RI Reply Information Field Description

The 4-bit RI field reports the airspeed capability and type of reply to the interrogating aircraft. The table of figure 36 describes the coding of this field.

12. UM Utility message Field Description

The 6-bit UM field contains transponder status readouts.

13. VS Vertical Status Field Description

The 1-bit VS field indicates the aircraft is airborne (bit = zero) or that the aircraft is on the ground (bit = one).

CODE	REPLY INFORMATION
0 thru 7	Indicates that downlink is the reply to an air-to-air non-acquisition interrogation.
0	No on-board TCAS
1	Not assigned
2	On-board TCAS with resolution capability inhibited.
3	On-board TCAS with vertical only resolution capability.
4	On-board TCAS with vertical and horizontal resolution capability.
5 thru 7	Not assigned
8 thru 15	Indicates that downlink is an acquisition reply.
8	No maximum airspeed data available.
9	Airspeed is up to 75 knots.
10	Airspeed is between 75 and 150 knots.
11	Airspeed is between 150 and 300 knots.
12	Airspeed is between 300 and 600 knots.
13	Airspeed is between 600 and 1200 knots.
14	Airspeed is more than 1200 knots.
15	Not assigned.

Reply Information Code Description
Figure 36

APPENDIX D

ASCII Seven-Unit Code

Appendix D is a list of ASCII Seven Unit Code.

Bits				b_7 → b_6 → b_5 →	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
b_4 ↓	b_3 ↓	b_2 ↓	b_1 ↓	Column → Row ↓	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	'	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L		l	|
1	1	0	1	13	CR	GS	-	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	∧	n	~
1	1	1	1	15	SI	US	/	?	O	—	o	DEL

APPENDIX E
TCAS Coordination Words

Appendix E presents the TCAS coordination words used between the TCAS equipment and the Mode S transponder. Refer to figure 37.

TCAS WORD	BITS	BIT DESCRIPTION
XTWORD 1 (XPDER to TCAS) TCAS Coordination data 1 Nonperiodic	1 - 8	Label (Octal 271)
	9	MTB
	10, 11	CVC
	12, 13	VRC
	14 - 16	CHC
	17 - 19	HRC
	20 - 24	HSB
	25 - 28	VSB
	29	Pad
	30, 31	SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn)
	32	Parity
XTWORD 2 (XPDER to TCAS) TCAS Coordination data 2 Nonperiodic	1 - 8	Label (Octal 272)
	9	TCAS Broadcast Bit (0 = coordination message, 1 = received TCAS Broadcast)
	10 -25	MID BIT A (bits 1 - 16)
	26 - 29	Pad
	30, 31	SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn)
	32	Parity
XTWORD 3 (XPDER to TCAS) Mode S Ground uplink (SLC, IIS) Nonperiodic	1 - 8	Label (Octal 273)
	9 - 21	Pad
	22 - 25	SLC (Sensitivity Level Command)
	26 - 29	IIS
	30, 31	SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn)
	32	Parity
XTWORD 4 (XPDER to TCAS) Altitude Periodic (31 - 62 msec)	1 - 8	Label (Octal 203)
	9, 10	Pad
	11	Altitude resolution (0 = 1 ft, 1 = 100 ft)
	12 - 28	Altitude (binary 1 to 65536 ft)
	29	SIGN (0 = POS, 1 = NEG)
	30, 31	SSM (00 = failure, 01 = test, 10 = no computed data, 11 = failure warn)
	32	Parity

TCAS Coordination Words
Figure 37 (Sheet 1 of 3)

TCAS WORD	BITS	BIT DESCRIPTION
XTWORD 5 (XPDER to TCAS) TCAS Control data Periodic (0.1 to 0.2 second)	1 - 8 9 - 13 14 - 29 30, 31 32	Label (Octal 275) Pad Mode S address part 1 (bits 1 -16) SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn) Parity
XTWORD 6 (XPDER to TCAS) TCAS Control data Periodic (0.1 to 0.2 second)	1 - 8 9 10 11, 12 13 -20 21 - 24 25 - 29 30, 31 32	Label (Octal 276) Spare RI Echo Pad Mode S address part 2 (Bits 17 - 24) Max Airspeed Pad SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn) Parity
XTWORD 7 (XPDER to TCAS) Acknowledge-ment Nonperiodic	1 - 8 9 - 28 29 30, 31 32	Label (Octal 277) Pad ACK/NAK (0 = not acknowledge, 1 = acknowledge) SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn) Parity
XTWORD 8 (XPDER to TCAS) MID PART 2 Nonperiodic	1 - 8 9 - 16 17 - 29 30, 31 32	Label (Octal 274) MID BIT A (bits 17 - 24) Pad SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn) Parity
TXWORD 1 (TCAS to XPDER and Displays) TCAS output (ARA, RAC)	1 - 8 9 - 11 12 - 25 26 - 29 30, 31 32	Label (Octal 273) Pad ARA RAC SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn) Parity
TXWORD 2 (TCAS to XPDR) TCAS Output (SL, RI) Periodic (0.1 to 0.2 second)	1 - 8 9 - 22 23 - 25 26 - 29 30, 31 32	Label (Octal 274) Pad SL (Sensitivity Level) RI (Reply Information) SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn) Parity

TCAS Coordination Words
Figure 37 (Sheet 2)

TCAS WORD	BITS	BIT DESCRIPTION
TXWORD 3 (TCAS to XPDR) Acknowledge Nonperiodic	1 - 8	Label (Octal 275)
	9 - 28	Pad
	29	ACK/NAK (0 = not acknowledge, 1 = acknowledge)
	30, 31	SSM (00 = valid, 01 = test, 10 = no computed data, 11 = failure warn)
	32	Parity

TCAS Coordination Words
Figure 37 (Sheet 3)

This instruction guide has been prepared to provide a basic understanding of TCAS systems. We welcome your comments concerning the contents of this instruction guide. Although every effort has been made to keep it free from errors, some may occur. When reporting a specific problem, describe it briefly, and include the instruction guide part number (523-0775922), the figure number, and the page number.

Send your comments to:

Publications Department
Collins Air Transport Division
Rockwell International Corporation
Cedar Rapids, Iowa 52498

If more detailed information is desired, or information concerning a specific piece of equipment is required, contact the Collins Air Transport Training Department. The training department can provide structured training courses or video taped courses in a most economical manner.

Send your course requests to:

Training Department
Collins Air Transport Division
Rockwell International Corporation
Cedar Rapids, Iowa 52498

523-0775922-00111R 8-1-89 Printed in USA

Collins Air Transport Division
Rockwell International Corporation
Cedar Rapids, Iowa

Rockwell Avionics

Collins