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REPORT NO. NADC - 76208-60

1 MAR 1977

LABORATORY TEST AND EVALUATION OF SECANT VECAS GA/M

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Warminster, Pennsylvania 18974
June 1976

FINAL REPORT
INTERAGENCY AGREEMENT
DOT-FA73-WAI-358

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

Prepared for
FEDERAL AVIATION ADMINISTRATION
Department of Transportation
Washington, D.C. 20591

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1. REPORT NUMBER NADC-76208-60	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* LABORATORY TEST AND EVALUATION OF SECANT VECAS GA/M		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Michael Raditz		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Navigation Laboratory (Code 60) Naval Air Development Center Warminster, Pa. 18974		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 6000N DOT-FA73-WAI-358 N.I.F. KZ701
11. CONTROLLING OFFICE NAME AND ADDRESS Federal Aviation Administration (Code ARD-241) Department of Transportation Washington, D. C. 20591		12. REPORT DATE 1 March 1977 13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

VECAS GA/M
Collision Avoidance System
SECANT
Warnings and Advisories

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The VECAS GA/M is the member of the SECANT family of collision avoidance systems, designed for larger civilian aircraft and certain military aircraft. Laboratory tests showed it provided the necessary warnings and advisories in a timely and effective manner. It performed collision avoidance as proposed and specified and flight tests would probably yield good results. The short round time and multiple trackers are a significant improvement.

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SUMMARY

INTRODUCTION

SECANT (Separation Control of Aircraft by Nonsynchronous Techniques is one potential solution to the problem of mid-air collisions. This is a family of cooperative equipments designed for various types of aircraft. The VECAS GA/M (Vertical Escape Collision Avoidance System - General Aviation / Military) is the SECANT family member designed for the larger general aviation aircraft and certain military aircraft.

The NAVAIRDEVCEN (Naval Air Development Center) initiated the evaluation of portions of the SECANT techniques in July 1970. Preliminary flight testing demonstrated the potential of these techniques. Results of these tests are reported in reference a. In May 1972 the FAA (Federal Aviation Administration), the Navy, and the NAVAL AIR DEVELOPMENT CENTER, entered into an agreement for the purchase and subsequent laboratory and flight testing of the SECANT VECAS equipment, full size version. Flight testing showed the VECAS had the ability to communicate accurately and with sufficient distance to provide timely and correct advisories and maneuver commands in simulated high traffic density and in a manner consistent with the requirements of ANTC 117. The results of these tests are reported in reference b. In May 1974, the agreement was modified to include the purchase and testing of VECAS GA/M units. Reference c is the contract for the purchase of VECAS GA/M equipments from RCA. Laboratory tests were performed, although flight testing was not conducted. (Reference d.) This is a report on the factory acceptance tests and NAVAIRDEVCEN bench tests. The work reported herein was sponsored by the Department of Transportation.

SUMMARY OF RESULTS

In general, the VECAS GA/M provided the necessary warnings and advisories in a timely and effective manner and was completely compatible with the airline type "full" VECAS.

The power output and receiver sensitivity were as specified (+42 dbm peak pulse power, -81 dbm receiver sensitivity below the 10,000-foot altitude, and -87 dbm above the 10,000-foot altitude). The power output is 3db greater and the sensitivities are 3db less than the old full VECAS (as reported in reference b). Tests at -42 dbm indicate good operation and adherence to the specification for dynamic range. The accuracy of the range and range rate measurements met or exceeded design goals and was equivalent to the "half-track" of the old full VECAS equipment, i.e., a range rate error of 22 knots, one sigma, with zero mean, and a range error of less than 0.01 nmi.

The alarm display consistency was usually greater than 99 percent under various conditions of small signal levels of targets and amounts of interfering traffic signals larger than the standard fruit level (19,500 probes/second and 211,000 replies/second).

The round time was fixed at 3.9 seconds. The multiple trackers demonstrated successful operation.

The standard fruit levels generated no false alarms.

Analysis shows the problem of replying to own interrogations appears to have been solved.

The adjacent channel rejection has been improved.

Co-range targets were satisfactorily tracked to within a separation of 0.1 nmi (550 feet, 168 meters).

CONCLUSIONS

The VECAS GA/M does perform the collision avoidance function as proposed and specified.

Laboratory tests of power output and receiver sensitivity indicate that if flight tests were made, the communication range would be the same as for the old experimental VECAS equipments (reference a) where for 1200-knot encounters there would be sufficient communication range for Tau Two (as defined in ANTC 117 which is reference e).

Range rate accuracies from VECAS GA/M to VECAS GA/M should be somewhat less accurate than those measured in the laboratory with a target simulator. Flight tests are required for this measurement.

The laboratory tests indicate the round reliability (and thus the communications reliability in flight) should be satisfactory in the maximum aircraft density predicted by RCA simulations of the Los Angeles basin in 1982 (appendix A and reference a.)

The shortened round time obtained by using multiple trackers was a significent improvement. It means that the loss of communication or a range rate error at the Tau Two threshold would cause the display to be late a maximum of 3.9 seconds. The multiple trackers prevent co-range targets and multipath tracks from extending the round time.

The round-to-round threat memory was also a significent improvement, as it would prevent most CAS display dropouts during flight. This combined with the tracking of co-altitude and adjacent to co-altitude zones by both antennas during each round should result in a very good CAS display reliability during flight.

RECOMMENDATIONS

It is recommended:

That all SECANT family members incorporate the improvements demonstrated in the VECAS GA/M. These include the fixed round time, the multiple trackers, and the SAW (Surface Acoustic Wave) filters.

That any future SECANT hardware be allowed to use the new code format. This change could double the accuracy of the range and range rate measurements.

That consideration be given to returning to the centriod tracker instead of the leading edge tracker. This would reduce the sensitivity of the range and range rate measurements to fruit.

That any future development of SECANT VECAS family members include the smallest possible unit for the slowest aircraft. This might be a six frequency system with a four nmi (7.412 kilometers) range.

That a determination be made as to whether identity is a necessary part of a collision avoidance system. The elimination of identity from the SECANT message format could cut the fruit rate to one-fourth of its present value. This might permit command type systems for all aircraft and eliminate the need for PWI's (Proximity Warning Indicator) and remitters.

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BACKGROUND

The SECANT system is a family of compatible airborne equipments designed to provide protection against mid-air collisions and near misses. Several equipments are provided having various levels of capabilities. The full capability systems are called VECAS (Vertical Escape Collision Avoidance System) and VECAS GA/M (General Aviation/Military). Basic performance is identical for both of these. The VECAS GA/M is a lower cost equipment designed for aircraft smaller than transports, but large enough to require more than one antenna. Lower losses due to shorter antenna cable runs permit economies in transmitter and receiver design with resulting radiated power and sensitivity equal to VECAS. Also the VECAS GA/M contains economies in processing logic by having the capability to track, decode messages, and evaluate threats for fewer simultaneous targets than the 32 that VECAS can process.

During 1972, RCA developed and built three engineering experimental models of the VECAS to provide the complete operational capability defined in the airline industry document ANTC-117 (reference e.) Flight tests at NAVAIRDEVCEN showed the VECAS had the ability to communicate accurately and with sufficient distance to provide timely and correct advisories and maneuver commands in simulated high traffic density and in a manner consistent with the requirements of ANTC 117.

TECHNICAL DESCRIPTION SUMMARY

The VECAS GA/M flight test equipment is configured to be compatible with the existing three experimental VECAS equipments. This is accomplished by using the same data message format of the previous equipment rather than the new code format intended for production equipment. To insure reliable system operation, a majority of three voting logic has been incorporated. This results in a processing power which in the same noise or fruit signal environment is equivalent to the new code (see reference i). The penalty of the slightly increased logic complexity is offset by the ability to communicate with the existing experimental VECAS units.

The use of the new 393 ms basic track format in conjunction with a simple wire change in the VECAS will permit reception of the altitude portion of the message which is required for threat analysis, and the identity which is recorded for test data analysis. The identity and altitude bits are still transmitted to the VECAS equipment by the VECAS GA/M.

The package size for these first models of the VECAS GA/M is a 3/4 ATR short and contains the complete system. (See figure 1) The r-f assembly is a custom integrated package, and the processing logic is fabricated using existing low power consumption elements and MSI and LSI circuitry. (RCA expects that a production version of this equipment will be significantly reduced in size by the conversion to custom LSI circuits and the use of hybrid assembly technology.)

The output display interface is plug compatible with the VSI-CAS indicator used on the VECAS equipment; however, a simplified threat logic combines those appropriate signal lines to produce the fewer required displays. An alternate CAS only display of a simple arrow and "X" type can be used with the selected interface.

The VECAS GA/M requires only the two antenna radiators, the output display, the own ship's altitude from the digital altimeter, and primary power as interface signals.

Several technical improvements were made in the GA/M version which could be introduced in other SECANT family members. These include the use of SAW filters, full range correlator, parallel trackers, and fixed round time. There are eight SAW filters in the VECAS GA/M detector module which separate the individual SECANT signals for detection. They replace the bulky LC filters as used in the previous flight test equipments and contribute considerably to the size reduction, as well as being a technical improvement. Correlation time is reduced and the hardware is simplified through the use of a new full range correlator logic system. This system is capable of detecting all the targets in the full range of both fields in the same 25 milliseconds that was previously used for a 1.25-mile segment in one altitude zone. The VECAS GA/M has the capability to determine Tau (range divided by range rate), altitude, and identity, for up to 16 targets simultaneously during the track of each altitude zone. By utilizing the

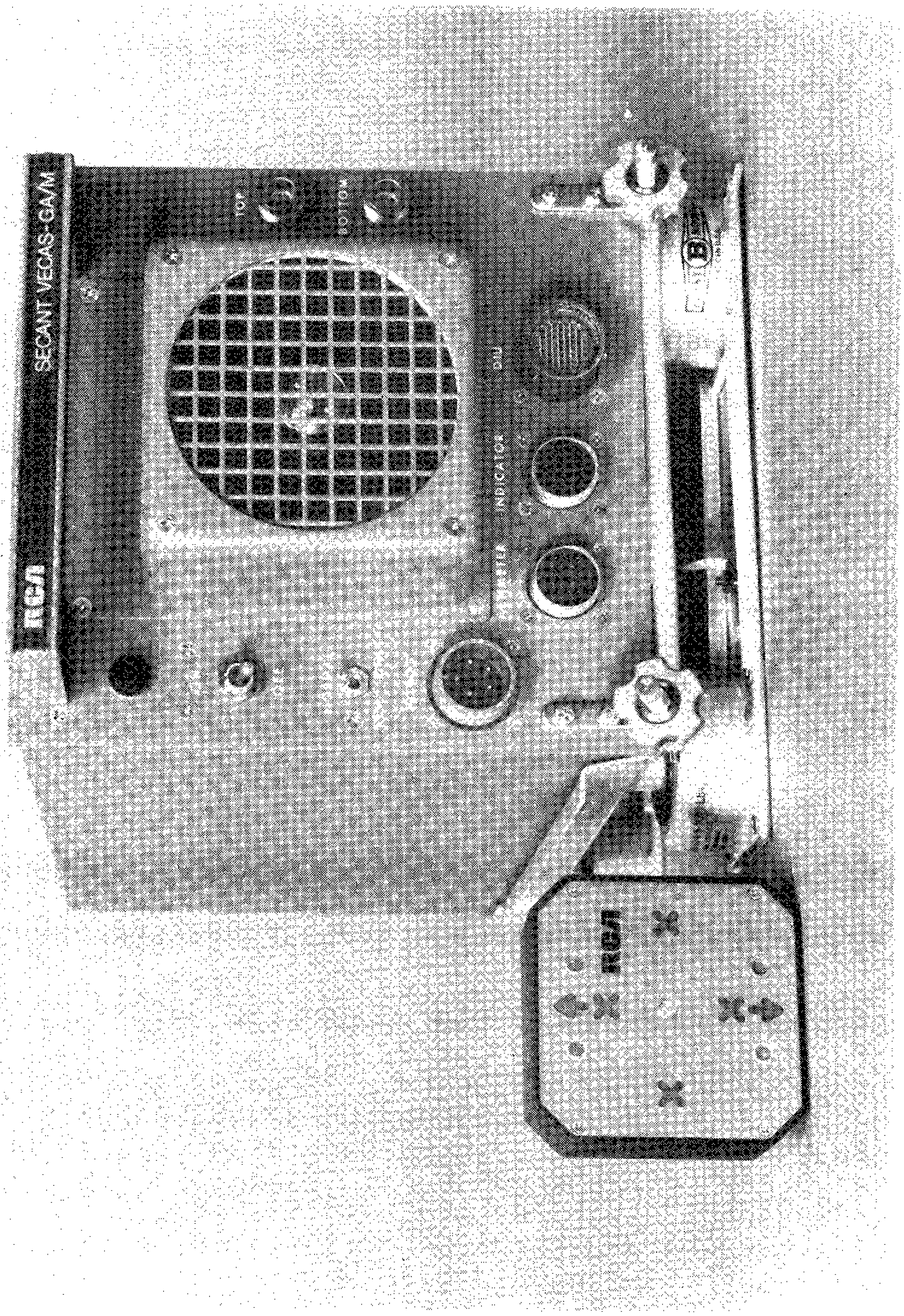

Figure 1. VECAS GA/M

information from the 16 targets closest in range in each altitude zone (160 targets possible), the round time is held fixed at 3.9 seconds. A technical description of the VECAS GA/M is in appendix A. Reference h is the SECANT System Description.

The following is a list of the significant parameters of the VECAS GA/M flight test equipment.

1. Two antennas, maximum cable loss 2 db

2. Altitude encoding used, 7 zones, below 10K ft (3000 meters), 500 ft. (152 meter) zones, above 10K ft., 1000 ft. (305 meter) zones, above 30K ft. (9,133 meter) common zone

2a. Level - own ± 3 zones, double probe own zone and adjacent zone
Climb/Descent - own zone - 2 zones +4 zones in direction of change, double probe own zone and adjacent zone

3. 13.0 nmi (24.1 kilometers) correlation, tracking range

4. Communication range 15 nmi (28 kilometers) (16 watts panel power probe/reply)

5. Fixed gain receiver, no AGC

6. Coherent Detector - amplitude linear

7. Top and bottom antennas in all altitude zones for correlation

7a. (a) "OR" correlators so no lost targets

(b) Use antenna of first one field target

(c) If both fields identical - use top for up zones and bottom for down zones

(d) Three co-altitude zones - separate tracks with each antenna

8. 2000 pps correlate, 1000 pps track, 50 pps idle

9. Threat logic processing

(a) Only one limit for climb or descent rates (1000 ft/min) (304.8 meters/minute)

(b) Tau 1 and Tau 2 detection

(c) Altitude unlimited

(d) Display, standard VSI/CAS or CAS "X", arrow

(e) Display information: Climb/descent limit indication NO TURN, LEVEL, CLIMB, DIVE (held through 2 rounds, update end of round)

10. VECAS GA/M provides full warning time for climb/descend rates up to 4000 ft./min (1,219.2 meters/min)

11. Size: 3/4 ATR short (7.6 x 12.6 x 7.5 inches) (19.304 x 32.004 x 19.05 centimeters)

12. Weight: 24 lb (10.9 kilograms)

LABORATORY TESTS

The general objective of this test program was to evaluate the performance of the VECAS GA/M and its potential to perform the collision avoidance function as part of the SECANT family of equipments. A series of flight tests were originally planned for the VECAS GA/M. The objectives of these flights are in appendix B. Laboratory tests were performed to determine how well the VECAS GA/M complied with the NAVAIRDEVCEN Specification (appendix C) and the RCA proposal.

NOTE

In this section the numbered items following each heading are extracted directly from the specification - which is shown in its entirety as appendix C.

OUTPUT POWER

Power Output: $\geq$42 dbm (2.1)

The r-f power output (peak pulse power) was measured for each VECAS GA/M at the time of acceptance and the results are shown in tables I, II, and III. The power output across the frequencies was nearly constant for each VECAS GA/M. In addition, the power output for these GA/M equipments was approximately 2 to 3 db greater than the power output of the old full vecas equipment during the 1973 flight tests.

TABLE I - OUTPUT POWER VECAS GA/M SERIAL NO. 1

Signal		Measurement
P	Top Low	43.2 dbm
Q	Top Low	43.2 dbm
P+	Top Low	43.2 dbm
P-	Top Low	43.2 dbm
Q-	Top Low	43.2 dbm
Q+	Top Low	43.2 dbm
P	Bot Low	43.2 dbm
Q	Bot Low	43.2 dbm
P+	Bot Low	43.3 dbm
P-	Bot Low	43.3 dbm
Q-	Bot Low	43.3 dbm
Q+	Bot Low	43.3 dbm
P	Top High	43.0 dbm
Q	Top High	43.1 dbm
P+	Top High	43.2 dbm
P-	Top High	43.2 dbm
Q-	Top High	43.2 dbm
Q+	Top High	43.1 dbm
P	Bot High	43.3 dbm
Q	Bot High	43.3 dbm
P+	Bot High	43.3 dbm
P-	Bot High	43.3 dbm
Q-	Bot High	43.3 dbm
Q+	Bot High	43.3 dbm

TABLE II - OUTPUT POWER VECAS GA/M SERIAL NO. 2

Signal		Measurement
P	Top Low	42.4 dbm
Q	Top Low	42.4 dbm
P+	Top Low	42.4 dbm
P-	Top Low	42.3 dbm
Q-	Top Low	42.3 dbm
Q+	Top Low	42.3 dbm
P	Bot Low	42.1 dbm
Q	Bot Low	42.1 dbm
P+	Bot Low	42.2 dbm
P-	Bot Low	42.3 dbm
Q-	Bot Low	42.4 dbm
Q+	Bot Low	42.5 dbm
P	Top High	41.7 dbm
Q	Top High	41.8 dbm
P+	Top High	42.2 dbm
P-	Top High	42.2 dbm
Q-	Top High	42.0 dbm
Q+	Top High	41.9 dbm
P	Bot High	42.9 dbm
Q	Bot High	42.9 dbm
P+	Bot High	42.6 dbm
P-	Bot High	42.6 dbm
Q-	Bot High	42.7 dbm
Q+	Bot High	42.8 dbm

TABLE III - OUTPUT POWER, VECAS GA/M SERIAL NO. 3

Signal		Measurement
P	Top Low	42.4 dbm
Q	Top Low	42.3 dbm
P+	Top Low	42.4 dbm
P-	Top Low	42.4 dbm
Q-	Top Low	42.3 dbm
Q+	Top Low	42.3 dbm
P	Bot Low	41.9 dbm
Q	Bot Low	42.0 dbm
P+	Bot Low	42.0 dbm
P-	Bot Low	42.0 dbm
Q-	Bot Low	42.1 dbm
Q+	Bot Low	42.1 dbm
P	Top High	42.0 dbm
Q	Top High	42.1 dbm
P+	Top High	42.2 dbm
P-	Top High	42.2 dbm
Q-	Top High	42.1 dbm
Q+	Top High	42.1 dbm
P	Bot High	42.25 dbm
Q	Bot High	42.25 dbm
P+	Bot High	42.1 dbm
P-	Bot High	42.2 dbm
Q-	Bot High	42.2 dbm
Q+	Bot High	42.2 dbm

RECEIVER SENSITIVITY

"Receiver Sensitivity: $\leq$-81 dBm below 10,000, $\leq$-87 dBm above 10,000 foot altitude for 95% probability of measuring correct (para. 2.4) altitude, range, range rate and identity with 50,000 probes per second per field above threshold, and 300,000 replies per second per field above threshold injected at the front end of the receiver. The 50,000/300,000 above threshold combination will be referred to throughout this document as SFL (Standard Fruit Level) and represents worst case conditions in the MITRE 1982 traffic model as established by RCA simulations." (2.2)

Specific test of receiver sensitivity were made for the low band on tape 32 and the high band on tape 31. Tests were made both with traffic and without traffic for comparison. For the low band, using VECAS GA/M No. 1, the traffic simulator was set to 10-7-11 (amplitude attenuator 10db, probe ratio at 7, and pulse rate at 11). This produces an amount of traffic higher than the SFL (Standard Fruit Level) of 19,000 probes/second and 211,000 replies per second. (The specification in appendix C was modified to these values established by RCA simulations of the Standard Traffic Model for the 1982 Los Angeles Basin. (See appendix A, reference a.) Below 10,000 feet, the specification calls for a receiver sensitivity of -81dbm "for 95 percent probability of measuring correct altitude, range, range rate and identity." Because the VECAS GA/M with the present data format does not use identity for any purpose, only the altitude data was taken into account for determining round reliability along with range and range rate. Figure 2 is a plot of the range rate one sigma values derived from table IV. With no traffic these values are less than 12 knots down to -84 dbm. With traffic greater than SFL, the range rate one sigma value is approximately 22 knots down to -81dbm. With no traffic, the altitude reliability is always 100 percent. With traffic greater than SFL, the altitude reliability is greater than 98 percent down to -81 dbm.

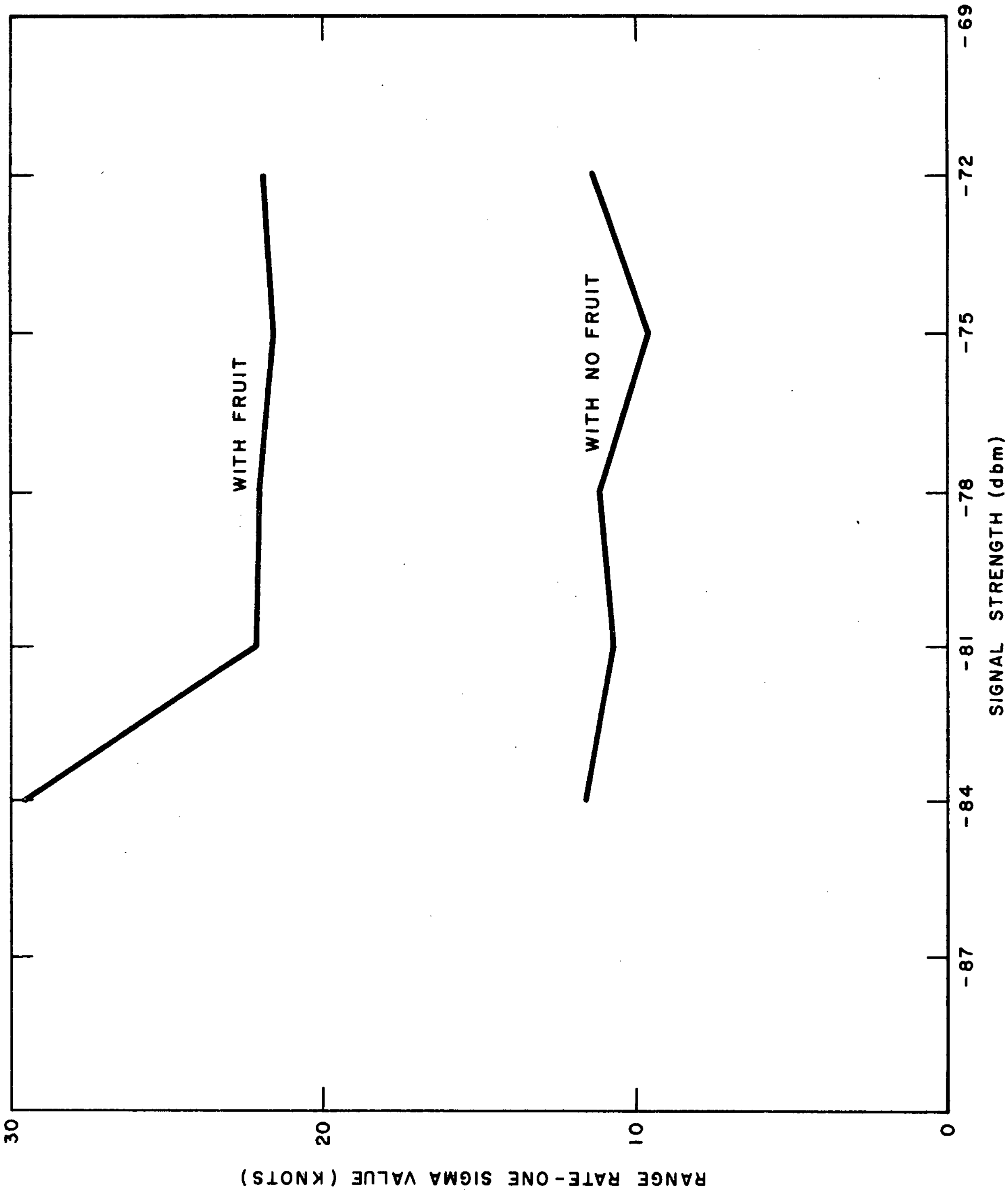

Figure 2. Receiver Sensitivity - Low Band - VECAS GA/M No. 1

TABLE IV - RECEIVER SENSITIVITY - LOW BAND VECAS GA/M NO. 1

Traffic Simulator	N	Probes/ Replies	Signal Strength (dbm)	Range Rate One Sigma (knots)	Range Rate Average (knots)	Altitude Reliability	Display Reliability
10-7-11	780	20/221	-84 dbm	29.64	-2.41	0.944	0.982
10-7-11	435	19/217	-81	22.22	0.41	0.982	1.000
10-7-11	434	20/226	-78	22.04	1.88	0.986	1.000
10-7-11	219	19/217	-75	21.56	0.20	0.991	1.000
10-7-11	485	18/204	-72	21.97	2.97	0.998	1.000
10-7-11	529	20/220	-42	20.51	0.68	0.996	1.000
-	157	*	-84	11.62	0.94	1.000	1.000
-	135	*	-81	10.73	-0.80	1.000	1.000
-	135	*	-78	11.38	0.96	1.000	1.000
-	68	*	-75	9.60	3.38	1.000	1.000
-	318	*	-72	11.44	1.70	1.000	1.000
-	117	*	-42	9.64	0.75	1.000	1.000

Notes:

1. N is the number of rounds included in the range rate statistics.

2. Probes/Replies are thousands per second; i.e., 20/221 is 20,000 probes per second and 221, 000 replies per second.

3. Traffic simulator refers to knob positions. For example: Attenuator=10, Probe Ratio = 7, and Pulse Rate = 11.

4. The Display Reliability is not a calculated value. It is taken from the printouts.

5. The data in this table is from tape no. 32 and tape no. 33.

6. The asterick (*) signifies that only the replies from the target are being counted. This is a small number.

For the high band using VECAS GA/M No. 1 and VECAS GA/M No. 2 the traffic simulator was set to 16-6-11. This produces an amount of traffic smaller than SFL. (SFL should only apply to the below 10,000-foot case where the traffic density is greater.) Above 10,000 feet, the specification calls for a receiver sensitivity of -87 dbm. Figure 3 is a plot of the range rate one sigma values derived from table V. With no fruit, these values are close to 20 knots. With fruit these values are between 25 and 30 knots. VECAS GA/M No. 2 appears to be slightly less accurate than VECAS GA/M No. 1. In all cases the altitude reliability is greater than 98 percent and the reliability of the pilots display is 100 percent.

Figures 4 and 5 are printouts showing a target at minimum signal level in the low band and in the high band.

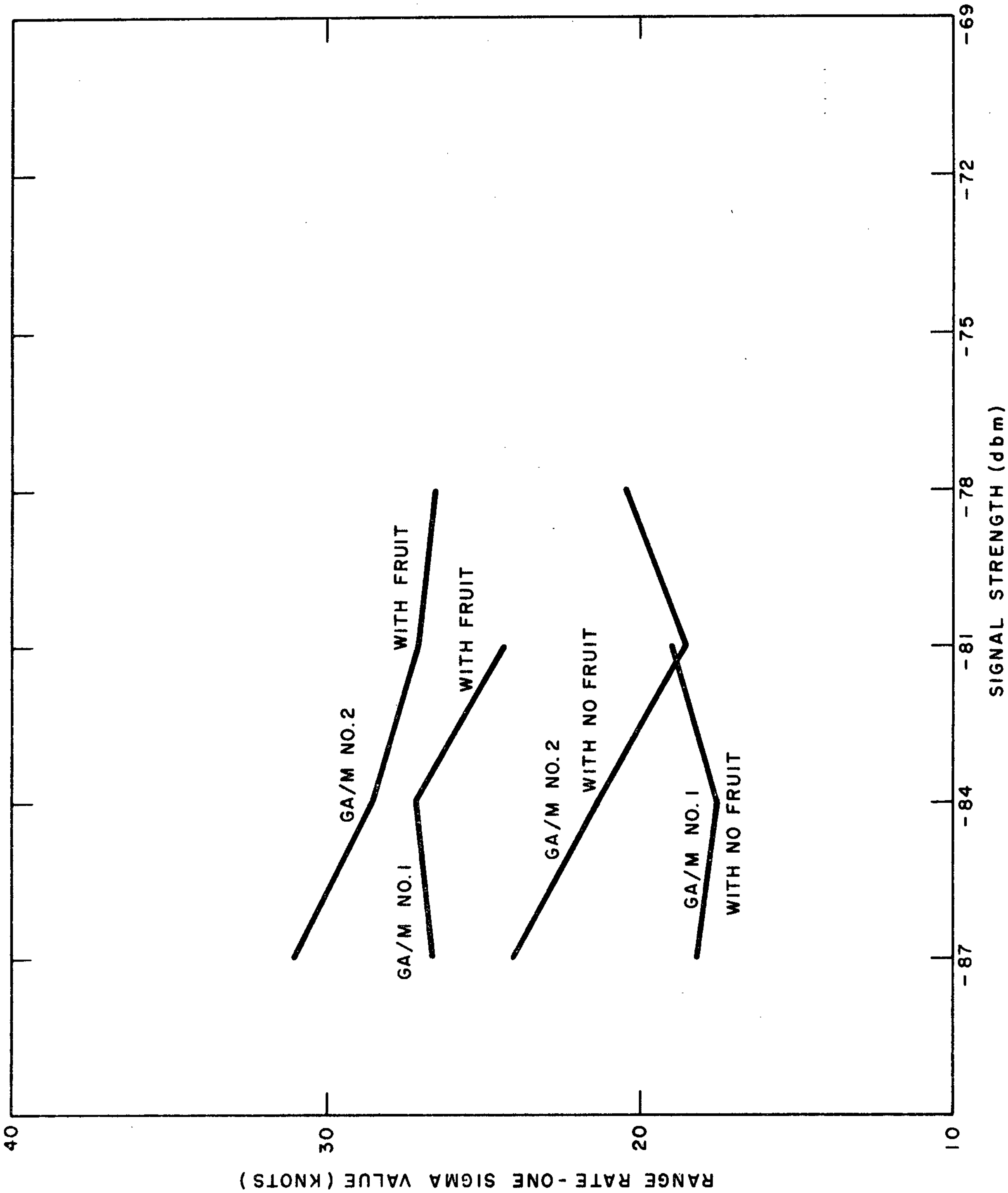

Figure 3. Receiver Sensitivity - High Band - VECAS GA/M No. 1 and No. 2

TABLE V - RECEIVER SENSITIVITY - HIGH BAND

Traffic Simulator	N	Probes/ Replies	Signal Strength	Range Rate one sigma (knots)	Range Rate Average (knots)	Altitude Reliability	Display Reliability
VECAS GA/M NO. 2							
16-6-11	1103	11/175	-87 dbm	31.04	0.58	0.983	1.000
16-6-11	867	11/177	-84	28.47	0.86	0.991	1.000
16-6-11	896	11/179	-81	27.08	3.18	0.998	1.000
16-6-11	1076	11/179	-78	26.51	4.18	0.997	1.000
-	111	*	-87	24.12	1.51	0.991	1.000
-	90	*	-84	21.38	0.96	1.000	1.000
-	135	*	-81	18.58	2.72	1.000	1.000
-	136	*	-78	20.50	-0.10	1.000	1.000
VECAS GA/M NO. 1							
16-6-11	707	5/193	-87	26.68	0.84	0.990	1.000
16-6-11	508	6/200	-84	27.18	1.87	0.994	1.000
16-6-11	599	7/205	-81	24.47	-0.13	0.995	1.000
16-6-11	1147	7/213	-42	25.18	0.98	0.995	1.000
-	180	*	-87	18.19	1.38	1.000	1.000
-	135	*	-84	17.86	-0.40	1.000	1.000
-	135	*	-81	18.68	3.52	1.000	1.000
-	67	*	-42	20.20	3.27	1.000	1.000

Notes:

1. The data in this table is from tape no. 31.
2. N is the number of rounds included in the range rate statistics.
3. Probes/Replies are thousands per second.
4. Traffic Simulator refers to knob positions.
5. The Display Reliability is not a calculated value. It is taken from the printouts.
6. The asterick (*) signifies that only the replies from the target are being counted. This is a small number.

TAPE NO. 32 N.A.D.C. LABORATORY TESTS OF

	TIME HR	MIN	SEC	DISPLAY			ALT	AZONE	ANT	RANGE
135	18	4	51.0	U1000			5.2	14.	TOP	1.07
136	18	4	54.5	U1000	EOR	I				
137	18	4	54.9	U1000			5.2	14.	TOP	1.07
138	18	4	58.5	U1000	EOR	I				
139	18	4	58.9	U1000			5.2	14.	TOP	1.07
140	18	5	2.4	U1000	EOR	I				
141	18	5	2.8	U1000			5.2	14.	TOP	1.08
142	18	5	6.3	U1000	EOR	I				
143	18	5	6.7	U1000			5.2	14.	TOP	1.07
144	18	5	10.3	U1000	EOR	I				
145	18	5	10.7	U1000			5.2	14.	TOP	1.07
146	18	5	14.2	U1000	EOR	I				
147	18	5	14.6	U1000			5.2	14.	TOP	1.07
148	18	5	18.1	U1000	EOR	I				
149	18	5	18.5	U1000			5.2	14.	TOP	1.07
150	18	5	22.1	U1000	EOR	I				
151	18	5	22.5	U1000			5.2	14.	TOP	1.07
152	18	5	26.0	U1000	EOR	I				
153	18	5	26.4	U1000			5.2	14.	TOP	1.07
154	18	5	29.9	U1000	EOR	I				
155	18	5	30.3	U1000			5.2	14.	TOP	1.07
156	18	5	33.9	U1000	EOR	I				
157	18	5	34.3	U1000			5.2	14.	TOP	1.07
158	18	5	37.8	U1000	EOR	I				
159	18	5	38.2	U1000			5.2	14.	TOP	1.07
160	18	5	41.7	U1000	EOR	I				
161	18	5	42.1	U1000			5.2	14.	TOP	1.07
162	18	5	45.7	U1000	EOR	I				
163	18	5	46.1	U1000			5.2	14.	TOP	1.08
164	18	5	49.6	U1000	EOR	I				
165	18	5	50.0	U1000			5.2	14.	TOP	1.07
166	18	5	53.5	U1000	EOR	I				
167	18	5	53.9	U1000			5.2	14.	TOP	1.07
168	18	5	57.5	U1000	EOR	I				
169	18	5	57.9	U1000			5.2	14.	TOP	1.07
170	18	6	1.4	U1000	EOR	I				
171	18	6	1.8	U1000			5.2	14.	TOP	1.07
172	18	6	5.3	U1000	EOR	I				
173	18	6	5.7	U1000			5.2	14.	TOP	1.07
174	18	6	9.3	U1000	EOR	I				
175	18	6	9.7	U1000			5.2	14.	TOP	1.07
176	18	6	13.2	U1000	EOR	I				
177	18	6	13.6	U1000			5.2	14.	TOP	1.07
178	18	6	17.1	U1000	EOR	I				
179	18	6	17.5	U1000			5.2	14.	TOP	1.07

BOTTOM FIELD SIGMA = .0 N = 0 SUM = 0. SUM SQUARES =
TOP FIELD SIGMA = 16.5 N = 23 SUM = 35. SUM SQUARES =
AP = 418.0 AR = 4895.0

Figure 4. Sample Printout - Low]

JRY TESTS OF VECAS GA/M DATE 5 26

RANGE	RATE	TAU	TALT	IDNT		PRB	RPY	
1.07	-3.	*284.0	6.0	01CG	B	17.	214.	TAU-TWO
1.07	18.	214.0	6.0	01CG	B	13.	230.	TAU-TWO
1.07	13.	296.3	6.0	01CG	B	19.	231.	TAU-TWO
1.08	0.	3888.0	6.0	01CG	B	12.	177.	TAU-TWO
1.07	-1.	*852.0	6.0	01CG	B	22.	222.	TAU-TWO
1.07	0.	3852.0	6.0	01CG	B	15.	144.	TAU-TWO
1.07	22.	175.1	6.0	01CG	B	25.	210.	TAU-TWO
1.07	-13.	-296.3	6.0	01CG	B	22.	117.	TAU-TWO
1.07	11.	350.2	6.0	01CG	B	11.	421.	TAU-TWO
1.07	-1.	*852.0	6.0	01CG	B	12.	198.	TAU-TWO
1.07	30.	128.4	6.0	01CG	B	29.	210.	TAU-TWO
1.07	2.	1926.0	6.0	01CG	B	20.	211.	TAU-TWO
1.07	-40.	-96.3	6.0	01CG	B	20.	194.	TAU-TWO
1.07	-3.	*284.0	6.0	01CG	B	16.	231.	TAU-TWO
1.08	23.	169.0	6.0	01CG	B	19.	228.	TAU-TWO
1.07	0.	3852.0	6.0	01CG	B	15.	189.	TAU-TWO
1.07	20.	192.6	6.0	01CG	B	18.	179.	TAU-TWO
1.07	-12.	-321.0	6.0	01CG	B	22.	198.	TAU-TWO
1.07	11.	350.2	6.0	01CG	B	18.	211.	TAU-TWO
1.07	-13.	-296.3	6.0	01CG	B	24.	221.	TAU-TWO
1.07	-30.	-128.4	6.0	01CG	B	17.	229.	TAU-TWO
1.07	2.	1926.0	6.0	01CG	B	14.	228.	TAU-TWO
1.07	-1.	*852.0	6.0	01CG	B	18.	202.	TAU-TWO

UARES = 0. BPRB = .0 BRPY = .0 KBK = 0
RES = 6059. TPRB = 18.2 TRPY = 212.8 KTK = 23

Printout - Low Band, Minimum Signal

2

TAPE NO. 31 N.A.D.C. LABORATORY TESTS OF

	TIME HR	MIN	SEC		DISPLAY	ALT	AZONE	ANT	RANGE
587	9	16	22.9	D1000		25.8	30.	BOT	1.05
588	9	16	25.2	D1000	EOR I				
589	9	16	26.8	D1000		25.8	30.	BOT	1.05
590	9	16	29.2	D1000	EOR I				
591	9	16	30.7	D1000		25.8	30.	BOT	1.05
592	9	16	33.1	D1000	EOR I				
593	9	16	34.7	D1000		25.8	30.	BOT	1.05
594	9	16	37.0	D1000	EOR I				
595	9	16	38.6	D1000		25.8	30.	BOT	1.05
596	9	16	41.0	D1000	EOR I				
597	9	16	42.5	D1000		25.8	30.	BOT	1.05
598	9	16	44.9	D1000	EOR I				
599	9	16	46.5	D1000		25.8	30.	BOT	1.05
600	9	16	48.8	D1000	EOR I				
601	9	16	50.4	D1000		25.8	30.	BOT	1.05
602	9	16	52.8	D1000	EOR I				
603	9	16	54.3	D1000		25.8	30.	BOT	1.05
604	9	16	56.7	D1000	EOR I				
605	9	16	58.3	D1000		25.8	30.	BOT	1.05
606	9	17	.6	D1000	EOR I				
607	9	17	2.2	D1000		25.8	30.	BOT	1.05
608	9	17	4.6	D1000	EOR I				
609	9	17	6.1	D1000		25.8	30.	BOT	1.05
610	9	17	8.5	D1000	EOR I				
611	9	17	10.1	D1000		25.8	30.	BOT	1.05
612	9	17	12.4	D1000	EOR I				
613	9	17	14.0	D1000		25.8	30.	BOT	1.05
614	9	17	16.4	D1000	EOR I				
615	9	17	17.9	D1000		25.8	30.	BOT	1.05
616	9	17	20.3	D1000	EOR I				
617	9	17	21.9	D1000		25.8	30.	BOT	1.05
618	9	17	24.2	D1000	EOR I				
619	9	17	25.8	D1000		25.8	30.	BOT	1.05
620	9	17	28.2	D1000	EOR I				
621	9	17	29.7	D1000		25.8	30.	BOT	1.05
622	9	17	32.1	D1000	EOR I				
623	9	17	33.7	D1000		25.8	30.	BOT	1.05
624	9	17	36.0	D1000	EOR I				
625	9	17	37.6	D1000		25.8	30.	BOT	1.05
626	9	17	40.0	D1000	EOR I				
627	9	17	41.5	D1000		25.8	30.	BOT	1.05
628	9	17	43.9	D1000	EOR I				
629	9	17	45.5	D1000		25.8	30.	BOT	1.05
630	9	17	47.8	D1000	EOR I				
631	9	17	49.4	D1000		25.8	30.	BOT	1.05

BOTTOM FIELD SIGMA = 21.3 N = 23 SUM = -59. SUM SQUARES =
TOP FIELD SIGMA = .0 N = 0 SUM = 0. SUM SQUARES =
AP = 138.0 AR = 4110.0

Figure 5. Sample Printout - High

ABCRATORY TESTS OF VECAS GA/M DATE 5 17

ANT	RANGE	RATE	TAU	TALT	IDNT		PRB	RPY	
BOT	~~1.05~~	-12.	-315.0	18.0	01CG	B	~~5.~~	220.	TAU-TWO
BOT	1.05	-8.	-472.5	18.0	01CG	B	5.	193.	TAU-TWO
BOT	1.05	38.	99.5	18.0	01CG	B	4.	219.	TAU-TWO
BOT	~~1.05~~	-22.	~~-171.8~~	18.0	01CG	B	~~5.~~	176.	TAU-TWO
BOT	1.05	2.	1890.0	18.0	01CG	B	10.	190.	TAU-TWO
BOT	1.05	-28.	-135.0	18.0	01CG	B	8.	162.	TAU-TWO
BOT	~~1.05~~	-10.	-378.0	18.0	01CG	B	7.	160.	TAU-TWO
BOT	1.05	0.	3780.0	18.0	01CG	B	5.	200.	TAU-TWO
BOT	1.05	20.	189.0	18.0	01CG	B	7.	173.	TAU-TWO
~~3OT~~	~~1.05~~	~~32.~~	~~118.1~~	~~18.0~~	~~01CG~~	~~B~~	~~7.~~	~~172.~~	~~TAU-TWO~~
3OT	1.05	31.	121.9	18.0	01CG	B	6.	196.	TAU-TWO
3OT	1.05	21.	180.0	18.0	01CG	B	8.	249.	TAU-TWO
~~3OT~~	~~1.05~~	~~0.~~	~~3780.0~~	~~18.0~~	~~01CG~~	~~B~~	~~8.~~	~~195.~~	~~TAU-TWO~~
3OT	1.05	-22.	-171.8	18.0	01CG	B	4.	16.	TAU-TWO
3OT	1.05	-42.	-90.0	18.0	01CG	B	6.	180.	TAU-TWO
~~3OT~~	~~1.05~~	~~-19.~~	~~-198.9~~	~~18.0~~	~~01CG~~	~~B~~	~~3.~~	~~213.~~	~~TAU-TWO~~
3OT	1.05	-23.	-164.3	18.0	01CG	B	7.	159.	TAU-TWO
3OT	1.05	22.	171.8	18.0	01CG	B	6.	217.	TAU-TWO
~~3OT~~	~~1.05~~	~~-10.~~	~~-378.0~~	~~18.0~~	~~01CG~~	~~B~~	~~3.~~	~~175.~~	~~TAU-TWO~~
3OT	1.05	0.	3780.0	18.0	01CG	B	7.	147.	TAU-TWO
3OT	1.05	-3.	*260.0	18.0	01CG	B	8.	167.	TAU-TWO
~~3OT~~	~~1.05~~	~~-23.~~	~~-164.3~~	~~18.0~~	~~01CG~~	~~B~~	~~5.~~	~~163.~~	~~TAU-TWO~~
3OT	1.05	-3.	*260.0	18.0	01CG	B	4.	168.	TAU-TWO

~~SUM SQUARES = 10119. BPRB = 6.0 BRPY = 178.7 KBK = 23~~

JM SQUARES = 0. TPRB = .0 TRPY = .0 KTK = 0

Sample Printout - High Band, Minimum Signal

2

RANGE AND RANGE RATE MEASUREMENTS

"Accuracy: The following accuracies shall be obtained with SFL injected with a VECAS-GA/M connected to the calibration generator at levels of -81 and -21 dBm below 10,000 feet and at -87 and -21 dBm above 10,000 feet:

Altitude: same as the input (digitized in 100-foot steps)

Range: mean < 300 feet (+0.5% of range), standard deviation < 300 feet

Range Rate: mean < 5 knots (+1% of range rate), standard deviation < 30 knots

Identity: same as that transmitted by the intruder" (2.4)

The error in the range measurements during these laboratory tests was always less than the resolution of the digital interface unit which was only 0.01nmi. Thus the range readout for a fixed target was always constant or in some cases alternating between two adjacent values.

The range rate measurements for a fixed target in the low band (below 10,000-foot altitude) are shown in table VI. The tests were made with different traffic simulator settings and the results are plotted in figure 6. The range rate one sigma value increased monotonically from 9 to 26 knots as the number of replies goes from 0 to 300,000 replies per second. The direct correlation between range rate accuracy and fruit is an effect of using a leading edge tracker instead of a centroid tracker (See note 13 under "discussion"). Figure 7 shows that the reliability of the altitude message decreases as the amount of fruit becomes greater than 200,000 replies per second.

Table VII shows the range rate accuracy for moving targets in the low band. Figures 8 and 9 are printouts showing moving targets. The specification calls for a range rate accuracy: mean less than 5 knots and standard deviation less than 30 knots, with the VECAS GA/M connected to the calibration generator. On tape number 23, VECAS GA/M no. 1 was connected to VECAS GA/M no. 2 through a 500-foot coaxial cable and variable attenuators. Data was recorded at VECAS GA/M no. 1. With no traffic inserted, the range rate one sigma value at minimum signal level (-87dbm) was 28.96 knots and at 3 db above minimum signal (-84dbm) was 26.71 knots. This would indicate a degradation in the high-band range rate one sigma value of approximately 7 knots (ignoring the variation in accuracy of each unit due to any difference in receiver sensitivity from VECAS GA/M to VECAS GA/M) for the case of VECAS GA/M to VECAS GA/M when compared to the values from Table V for VECAS GA/M with a Calibration Generator. It was not possible to make a meaningful test with a insertion of traffic in this case. Because the VECAS receiver is blocked during its own transmissions, including interrogations, the receiver sensitivity has a finite recover time. Because the target VECAS is so close in range, when its amplitude is set with reference to a target from the calibration generator,

TABLE VI - RANGE RATE ACCURACY - LOW BAND - VECAS GA/M No. 3

Traffic Simulator	N	Probes/ Replies	Range Rate One Sigma (knots)	Range Rate Average (knots)	Altitude Reliability	Display Reliability
-	201	-	9.36	0.93	1.000	1.000
10-7-11	860	17/188	21.14	1.75	0.981	1.000
9-7-11	1606	23/244	22.89	1.24	0.953	0.999
8-7-11	720	29/305	25.39	-0.93	0.918	0.994

Notes:

1. The data in this table is from Tape no. 30. (VECAS GA/M No. 3).
2. All targets are in the low band at minimum signal (-81 dbm).
3. N is the number of rounds included in the range rate statistics.
4. Probes/Replies are thousands per second.
5. Traffic Simulator refers to knob positions.

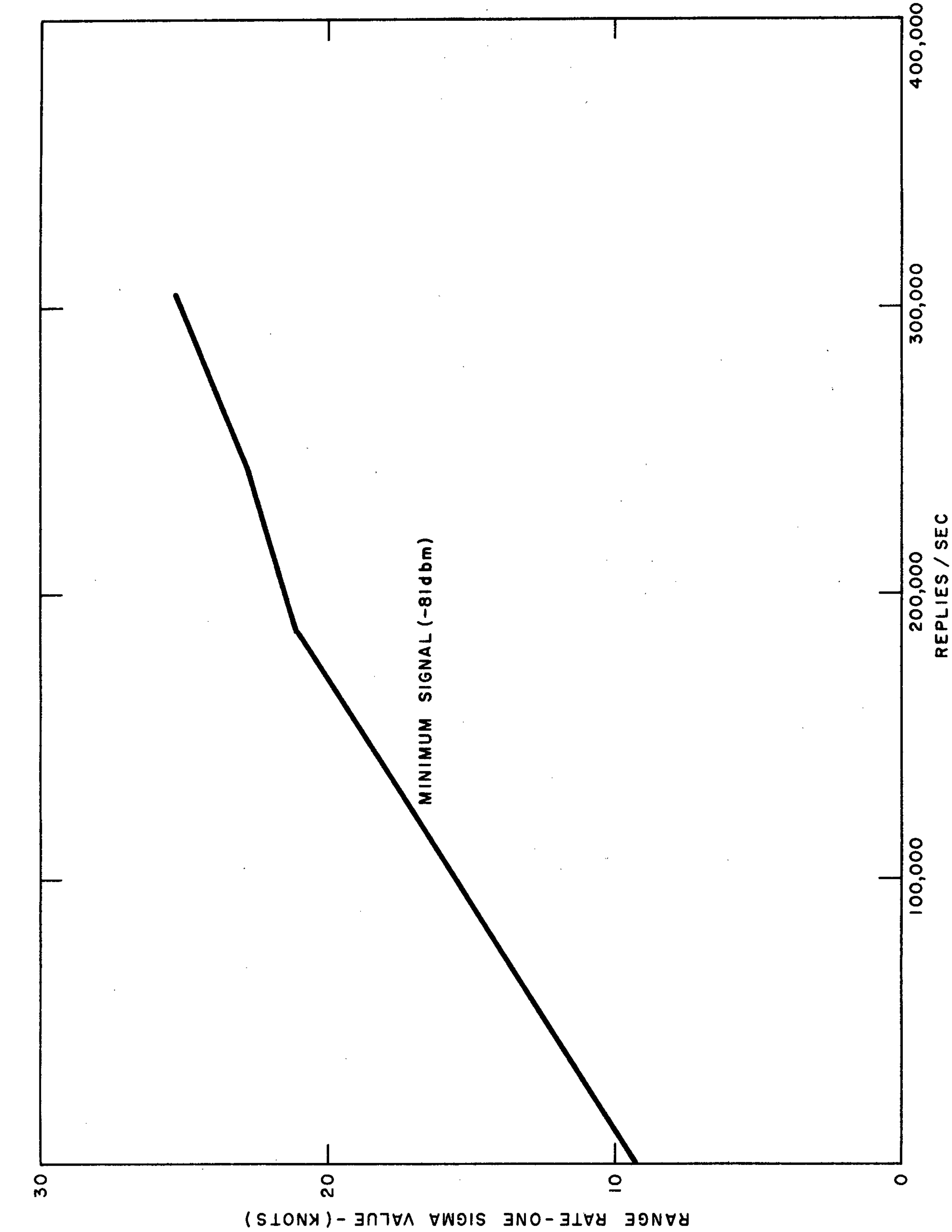

Figure 6. Range Rate Accuracy - Low Band - 81 dbm

TABLE VII - RANGE RATE ACCURACY FOR MOVING TARGETS AT MINIMUM SIGNAL LEVEL

Target Range Rate	Traffic Simulator Setting	N	Probes/ Replies	Range Rate One Sigma Value (knots)	Range Rate Average Value (knots)	Altitude Reliability
+ 100	-	89	*	14.58	98.11	1.000
+ 100	10-7-11	365	18/210	25.08	94.62	0.984
- 100	10-7-11	87	16/188	24.75	- 99.84	0.967
+ 200	-	111	*	12.08	199.85	1.000
+ 200	10-7-11	275	17/191	25.05	201.50	0.989
- 200	-	32	*	13.45	-199.66	1.000
- 200	10-7-11	40	16/190	20.95	-202.50	1.000
+ 500	-	100	*	12.82	501.67	1.000
+ 500	10-7-11	291	18/215	22.46	499.35	0.977
- 500	10-7-11	20	15/189	22.20	-501.55	0.909
+1000	-	16	*	12.80	1002.00	1.000
+1000	10-7-11	176	19/216	25.81	994.06	0.994
-1000	10-7-11	20	17/214	21.50	-1000.20	1.000
+1500	-	14	*	13.00	1502.50	1.000
+1500	10-7-11	54	17/202	25.43	1497.93	1.000
-1500	-	17	*	12.90	-1497.06	1.000
-1500	10-7-11	52	16/185	36.28	-1488.59	0.986

Notes:

1. The data in this table is from tape no. 32 and tape no. 33.
2. All targets are in the low band at -81 dbm.
3. N is the number of rounds included in the range rate statistics.
4. Probes/Replies are thousands per second.
5. Traffic Simulator refers to knob positions.
6. The asterick (*) signifies that only the replies from the target are being counted. This is a small number.

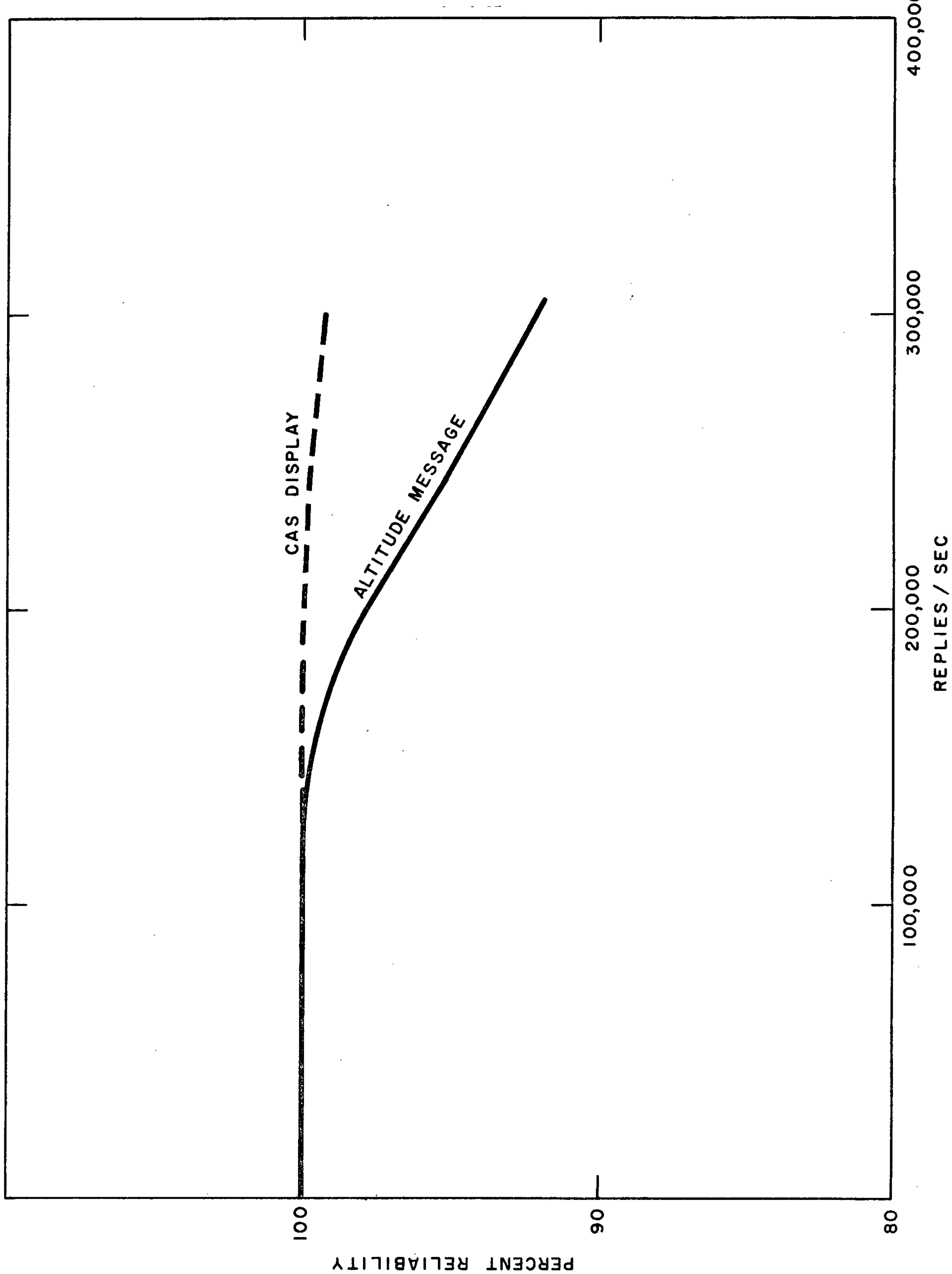

Figure 7. Data and Display Reliability (for Figure 6)

its real amplitude is somewhat greater due to the receiver desensitization in the close range case. The traffic is set up by observing the probe and reply counts on the digital interface front panel. These numbers depend upon the amplitude of the fruit when the receiver is at full sensitivity. Therefore, the amplitude of the traffic in the neighborhood of the real VECAS target is relatively smaller than the traffic numbers would indicate, and the exact relationship between the target and the fruit is unknown. A longer delay cable does not solve this problem because of the additional attenuation introduced, which makes the target amplitude too small for it to be tracked. The only way to accurately determine the range rate accuracy between two VECAS GA/M's with fruit injected is to fly the two equipments in separate aircraft over a test range.

TAPE NO. 33 N.A.D.C. LABORATORY TESTS OF VECA

TIME	HR	MIN	SEC	DISPLAY			ALT	AZONE	ANT	RANGE	RATE
1	13	50	52.1		EOR	I					
2	13	50	52.5				5.1	14.	TOP	11.47	493.
3	13	50	56.1		EOR	I					
4	13	50	56.5				5.1	14.	TOP	10.92	484
5	13	51	.0		EOR	I					
6	13	51	.4				5.1	14.	TOP	10.37	461.
7	13	51	3.9		EOR	I					
8	13	51	4.3				5.1	14.	TOP	9.82	521.
9	13	51	7.9		EOR	I					
10	13	51	8.3				5.1	14.	TOP	9.28	504.
11	13	51	11.8		EOR	I					
12	13	51	12.2				5.1	14.	TOP	8.73	501.
13	13	51	15.7		EOR	I					
14	13	51	16.1				5.1	14.	TOP	8.18	509.
15	13	51	19.7		EOR	I					
16	13	51	20.1				5.1	14.	TOP	7.64	513.
17	13	51	23.6		EOR	I					
18	13	51	24.0				5.1	14.	TOP	7.09	493.
19	13	51	27.5	U1000	EOR	I					
20	13	51	27.9	U1000			5.1	14.	TOP	6.54	492.
21	13	51	31.5	U1000	EOR	I					
22	13	51	31.9	U1000			5.1	14.	TOP	5.99	477.
23	13	51	35.4	U1000	EOR	I					
24	13	51	35.8	U1000			5.1	14.	TOP	5.44	468.
25	13	51	39.3	U1000	EOR	I					
26	13	51	39.7	U1000			5.1	14.	TOP	4.90	512.
27	13	51	43.3	U1000	EOR	I					
28	13	51	43.7	U1000			5.1	14.	TOP	4.35	516.
29	13	51	47.2	U1000	EOR	I					
30	13	51	47.6	U1000			5.1	14.	TOP	3.80	517.
31	13	51	51.1	U1000	EOR	I					
32	13	51	51.5	U1000			5.1	14.	TOP	3.25	479.
33	13	51	55.1	U1000	EOR	I					
34	13	51	55.5	U1000			5.1	14.	TOP	2.71	461.
35	13	51	59.0	U1000	EOR	I					
36	13	51	59.4	U1000			5.1	14.	TOP	2.16	502.
37	13	52	2.9	U1000	EOR	I					
38	13	52	3.3	U1000			5.1	14.	TOP	1.61	525.
39	13	52	6.9	U1000	EOR	I					
40	13	52	7.3	U1000			5.1	14.	TOP	1.07	529.
41	13	52	10.8	U1000	EOR	I					
42	13	52	11.2	U1000			5.1	14.	TOP	.52	538.
43	13	52	14.7	U1000	EOR	I					
44	13	52	18.7	U1000	EOR	I					
45	13	52	22.6		EOR	I					

BOTTOM FIELD SIGMA = .0 N = 0 SUM = 0. SUM SQUARES =
TOP FIELD SIGMA = 22.1 N = 21 SUM = 10495. SUM SQUARES = 5254763
AP = 382.0 AR = 4134.0

Figure 8. Moving Target 500 Knot

ORY TESTS OF VECAS SA/M DATE 6 9

RANGE	RATE	TAU	TALT	IDNT		PRB	RPY	
11.47	493.	83.8	6.0	01CG	B	15.	194.	
10.92	484.	81.2	6.0	01CG	B	16.	193.	
10.37	461.	81.0	6.0	01CG	B	20.	199.	
9.82	521.	67.9	6.0	01CG	B	17.	208.	
9.28	504.	66.3	6.0	01CC	B	18.	200.	
8.73	501.	62.7	6.0	01CG	B	15.	223.	
8.18	509.	57.9	6.0	01CG	B	24.	197.	
7.64	513.	53.6	6.0	01CG	B	12.	177.	
7.09	493.	51.8	6.0	01CG	B	23.	209.	TAU-TWO
6.54	492.	47.9	6.0	01CG	B	15.	213.	TAU-TWO
5.99	477.	45.2	6.0	01CG	B	19.	192.	TAU-TWO
5.44	468.	41.8	6.0	01CG	B	20.	197.	TAU-TWO
4.90	512.	34.5	6.0	01CG	B	17.	182.	TAU-TWO
4.35	516.	30.3	6.0	01CG	B	18.	213.	TAU-TWO
3.80	517.	26.5	6.0	01CG	B	21.	196.	TAU-ONE
3.25	479.	24.4	6.0	01CG	B	11.	179.	TAU-ONE
2.71	461.	21.2	6.0	01CG	B	21.	189.	TAU-ONE
2.16	502.	15.5	6.0	01CG	B	20.	180.	TAU-ONE
1.61	525.	11.0	6.0	01CG	B	15.	193.	TAU-ONE
1.07	529.	7.3	6.0	01CG	B	26.	195.	TAU-ONE
.52	538.	3.5	6.0	01CG	B	19.	205.	TAU-ONE

QUARES = 0. BPRB = .0 BRPY = .0 KBK = 0
ARES = 5254765. TPRB = 18.2 TRPY = 196.9 KTK = 21

oving Target 500 Knots (-81 dbm)

TAPE NO. 33 N.A.D.C. LABORATORY TESTS

	TIME HR	MIN	SEC	DISPLAY			ALT	AZONE	ANT	RANGE
1	15	10	9.2		EOR	I				
2	15	10	13.2		EOR	I				
3	15	10	13.6				5.1	14.	TOP	11.09
4	15	10	17.1	U1000	EOR	I				
5	15	10	17.5	U1000			5.1	14.	TOP	9.45
6	15	10	21.0	U1000	EOR	I				
7	15	10	21.4	U1000			5.1	14.	TOP	7.81
8	15	10	25.0	U1000	EOR	I				
9	15	10	25.4	U1000			5.1	14.	TOP	6.16
10	15	10	28.9	U1000	EOR	I				
11	15	10	29.3	U1000			5.1	14.	TOP	4.52
12	15	10	32.8	U1000	EOR	I				
13	15	10	33.2	U1000			5.1	14.	TOP	2.88
14	15	10	36.8	U1000	EOR	I				
15	15	10	37.2	U1000			5.1	14.	TOP	1.24
16	15	10	40.7	U1000	EOR	I				
17	15	10	44.6	U1000	EOR	I				
18	15	10	48.6		EOR	I				
19	15	10	52.5		EOR	I				
20	15	10	56.4		EOR	I				
21	15	10	56.8				5.1	14.	TOP	11.31
22	15	11	.4	U1000	EOR	I				
23	15	11	.8	U1000			5.1	14.	TOP	9.66
24	15	11	4.3	U1000	EOR	I				
25	15	11	4.7	U1000			5.1	14.	TOP	8.02
26	15	11	8.2	U1000	EOR	I				
27	15	11	8.6	U1000			5.1	14.	TOP	6.38
28	15	11	12.2	U1000	EOR	I				
29	15	11	12.6	U1000			5.1	14.	TOP	4.74
30	15	11	16.1	U1000	EOR	I				
31	15	11	16.5	U1000			5.1	14.	TOP	3.10
32	15	11	20.0	U1000	EOR	I				
33	15	11	20.4	U1000			5.1	14.	TOP	1.45
34	15	11	24.0	U1000	EOR	I				
35	15	11	27.9	U1000	EOR	I				
36	15	11	31.8		EOR	I				
37	15	11	35.8		EOR	I				
38	15	11	36.2				5.1	14.	TOP	11.57
39	15	11	39.7	U1000	EOR	I				
40	15	11	40.1	U1000			5.1	14.	TOP	9.93
41	15	11	43.6	U1000	EOR	I				
42	15	11	44.0	U1000			5.1	14.	TOP	8.29
43	15	11	47.6	U1000	EOR	I				
44	15	11	48.0	U1000			5.1	14.	TOP	6.65
45	15	11	51.5	U1000	EOR	I				

BOTTOM FIELD SIGMA = .0 N = 0 SUM = 0. SUM SQUARES =

TOP FIELD SIGMA = 20.7 N = 18 SUM = 26940. SUM SQUARES =

AP = 320.0 AR = 3748.0

Figure 9. Moving Target

RY TESTS OF VEGAS GA/M DATE 6 8

RANGE	RATE	TAU	TALT	IDNT		PRB	RPY	
11.09	1510.	26.4	6.0	01CG	B	22.	153.	TAU-TWO
9.45	1485.	22.9	6.0	01CG	B	19.	189.	TAU-ONE
7.81	1491.	18.9	6.0	01CG	B	24.	226.	TAU-ONE
6.16	1482.	15.0	6.0	01CG	B	15.	213.	TAU-ONE
4.52	1487.	10.9	6.0	01CG	B	24.	188.	TAU-ONE
2.88	1541.	6.7	6.0	01CG	B	12.	192.	TAU-ONE
1.24	1471.	3.0	6.0	01CG	B	17.	170.	TAU-ONE
11.31	1510.	27.0	6.0	01CG	B	14.	181.	TAU-TWO
9.66	1501.	23.2	6.0	01CG	B	18.	186.	TAU-ONE
8.02	1485.	19.4	6.0	01CG	B	18.	390.	TAU-ONE
6.38	1509.	15.2	6.0	21CG	B	12.	179.	TAU-ONE
4.74	1532.	11.1	6.0	01CG	B	10.	204.	TAU-ONE
3.10	1469.	7.6	6.0	01CG	B	18.	256.	TAU-ONE
1.45	1487.	3.5	6.0	01CG	B	17.	159.	TAU-ONE
11.57	1501.	27.7	6.0	01CG	B	16.	189.	TAU-TWO
9.93	1478.	24.2	6.0	01CG	B	19.	324.	TAU-ONE
8.29	1523.	19.6	6.0	01CG	B	27.	164.	TAU-ONE
6.65	1478.	15.2	6.0	01CG	B	18.	185.	TAU-ONE

JARES = 0. BPRB = .0 BRPY = .0 KBK = 0
RES = 40327480. TPRB = 17.8 TRPY = 208.2 KTK = 18

ving Target 1500 Knots (-81 dbm)

2

CO-RANGE TARGETS

> "Co-Range Targets: Under all the conditions of paragraphs 2.2, 2.3, and 2.4, two targets which are within 650 feet of each other shall be correctly tracked and processed through the threat logic regardless of the altitude separation between the targets." (2.16)

In all interrogator/transponder systems there exists the problem of co-range targets; i.e., the simultaneous reception of replies from two targets at the same slant range from the interrogator. In an air-to-air system these co-range replies can be generated by all transponders on a particular sphere centered at the interrogator. SECANT uses altitude encoding to sequentially illuminate 500-foot altitude zones below 10,000 feet and 1,000-foot altitude zones above 10,000 feet. Therefore, co-range replies can only be generated at the ring which is the intersection of the sphere and the altitude zone being illuminated. Replies from co-range targets in different altitude zones will not interfere with each other.

The VECAS GA/M uses a multiple target tracker. All control of the tracker is performed by the passage of a target bit through the control register (17bit). In the event that two targets in the same altitude zone are within 800 feet of the same range, their target bits would occupy the control register simultaneously. To avoid this possibility, the auxiliary control register is provided to handle co-range targets. This register is designed to track the trailing edge of the digital video pulse returned from the target (in SECANT the range measurement is made directly from the initiating pulse to the target video). Thus, both the leading edge and the trailing edge of the combined video from the two targets will be simultaneously tracked for range, range rate, and data.

The ability of the VECAS GA/M to track two co-range targets in the same altitude zone was tested during acceptance tests on tape no. 18. One target was provided by another VECAS GA/M in the screen room through 500 feet of coaxial cable. The second target was provided by a calibration generator which can vary its target range in increments of 50 feet. The two targets were set to equal amplitudes at a signal level 6 db above minimum usable signal. (Due to the near zero range with respect to the interrogator, the actual amplitude in the video in the interrogator is somewhat smaller). Tests were made both with and without fruit. (The fruit count in the neighborhood of the targets would be somewhat less than indicated.) Table VIII and figure 10 show the ability of the VECAS GA/M to separate and track data from two targets in the same altitude zone in a fruit environment to a range separation of approximately 600 feet and without fruit to a range separation of approximately 500 feet. Tau and data tracks can be made at smaller separations on one of the targets.

Additional Tests were made where the range of the target from the calibration generator was slowly moved through the range of the target from the other VECAS GA/M. Tests were made with no fruit, with 60,000 probes and 300,000 replies, with targets of equal amplitude, and with one target stronger than the other. The results show that with one target moving, when the two targets are at the same range, the data messages are inseparable and the CAS display will be extinguished. When the target is moving at 100 knots, the CAS display is lost for one round or less. At 50 knots, the CAS display is lost for an average of two rounds, and at 25 knots the CAS display is lost for between four and five rounds.

TABLE VIII. CO-RANGE TARGETS

Range Difference	Number of Rounds	Track Both Targets	Percent Success	Range Rate Sigma	Probes	Replies
492 feet	104	87	0.837	19.50	-	-
(150 meters)	153	31	0.203	28.26	60,000	261,000
542 feet	208	207	0.995	21.26	-	-
(165.2 meters)	91	87	0.906	23.32	55,000	245,000
592 feet	133	130	0.977	20.35	-	-
(180.4 meters)	153	145	0.948	26.44	66,000	283,000

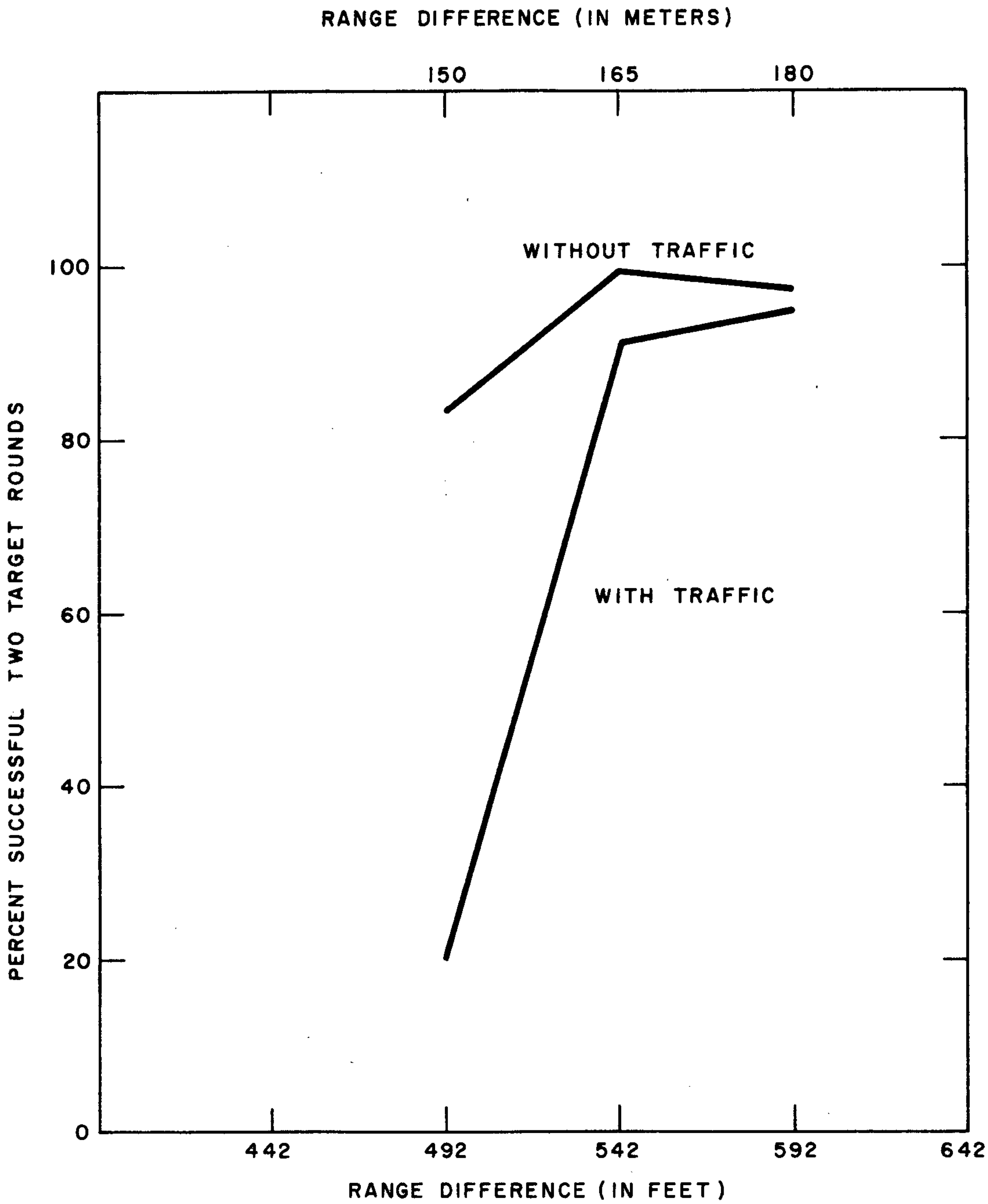

Figure 10. Co-Range Targets

FALSE ALARMS

"False Alarm Rate with SFL:

TAU 2 - $\leq$10 alarms per 10,000 hours
TAU 1 - $\leq$1 alarm per 10,000 hours" (2.7)

"False Alarm Rate with SFL and non-threatening targets and, false alarm rate with SFL and threatening targets (early or late alarms due to errors within the limits of paragraph 2.4 are not considered false alarms).

TAU 2 - $\leq$10 alarms per 10,000 hours
TAU 1 - $\leq$1 alarm per 10,000 hours" (2.8)

"False Alarm Rate Acceptance Test: The VECAS-GA/M shall be designed to meet the False Alarm rates described in paragraphs 2.7 and 2.8. Due to the extensive testing required to obtain valid data, only acceptance tests to establish standard statistical data over 10 hours will be performed. The false alarm rate for the ten (10) hour test shall be zero. If this number is exceeded a failure analysis and corrective action shall be implemented." (2.9)

The specification limits the number of false alarms allowable in 10,000 hours. To test this requirement two 5-hour tests were made. The first test (on tape 12) was made in the high band with no target. The traffic inserted was 27,000 probes and 326,000 replies in the bottom field, and 29,000 probes and 396,000 replies in the top field. There were no flase alarms. The second test (on tape 19) was also made in the high band. A single target was set at 2.55 nmi at minimum signal (-87dbm). The traffic inserted was 57,000 probes and 310,000 replies in the bottom field and 54,000 probes and 368,000 replies in the top field. There were no false alarms.

DYNAMIC RANGE

"Dynamic Range: The performance of paragraph 2.2 shall be met over a dynamic range of 60 db below 10,000 feet (-81 to -21 dbm) and over 66 db above 10,000 feet (-87 to -21 dbm)." (2.3)

The specification calls for full performance with signals as strong as -21 dbm both below and above 10,000 feet. The maximum signal that can be obtained from the calibration generator is -42 dbm. Tables IV and V show satisfactory performance at -42 dbm. The only effect is that the VECAS GA/M will attempt a co-range track approximately 1 percent of the time. (A signal level as strong as -42 dbm will only occur when two aircraft are at a very small separation in range.)

COMPATABILITY

Compatability with the old experimental VECAS was demonstrated during acceptance tests by connecting it to a VECAS GA/M through a 500-foot cable. Altitude and identity were exchanged between both units.

ROUND TIME

"Round Time: Cycle time to completely correlate and track targets in all seven altitude zones, process the threatening targets through the threat logic and update the CAS display: ≤ 4 seconds." (2.6)

Round time during all tests was fixed at 3.9 seconds.

MULTIPLE TRACKERS

The use of parallel trackers to track multiple targets in a single altitude zone was successfully demonstrated. Examples of multiple targets are in figures 11, 12, and 13.

TAPE NO. 32 N.A.D.C. LABORATORY TESTS

TIME HR	MIN	SEC	DISPLAY			ALT	AZONE	ANT	RANG
1 13	23	14.5	U1000	EOR	I				
2 13	23	14.9	U1000			5.2	14.	TOP	1.08
2 13	23	14.9	U1000			5.2	14.	TOP	5.24
2 13	23	14.9	U1000			5.2	14.	TOP	9.24
3 13	23	18.4	U1000	EOR	I				
4 13	23	18.8	U1000			5.2	14.	TOP	1.08
4 13	23	18.8	U1000			5.2	14.	TOP	5.24
4 13	23	18.8	U1000			5.2	14.	TOP	9.24
5 13	23	22.4	U1000	EOR	I				
6 13	23	22.8	U1000			5.2	14.	TOP	1.08
6 13	23	22.8	U1000			5.2	14.	TOP	5.24
6 13	23	22.8	U1000			5.2	14.	TOP	9.24
7 13	23	26.3	U1000	EOR	I				
8 13	23	26.7	U1000			5.2	14.	TOP	1.08
8 13	23	26.7	U1000			5.2	14.	TOP	5.24
8 13	23	26.7	U1000			5.2	14.	TOP	9.24
9 13	23	30.2	U1000	EOR	I				
10 13	23	30.6	U1000			5.2	14.	TOP	1.08
10 13	23	30.6	U1000			5.2	14.	TOP	5.24
10 13	23	30.6	U1000			5.2	14.	TOP	9.24
11 13	23	34.2	U1000	EOR	I				
12 13	23	34.6	U1000			5.2	14.	TOP	1.08
12 13	23	34.6	U1000			5.2	14.	TOP	5.24
12 13	23	34.6	U1000			5.2	14.	TOP	9.24
13 13	23	38.1	U1000	EOR	I				
14 13	23	38.5	U1000			5.2	14.	TOP	1.08
14 13	23	38.5	U1000			5.2	14.	TOP	5.24
14 13	23	38.5	U1000			5.2	14.	TOP	9.25
15 13	23	42.0	U1000	EOR	I				
16 13	23	42.4	U1000			5.2	14.	TOP	1.08
16 13	23	42.4	U1000			5.2	14.	TOP	5.24
16 13	23	42.4	U1000			5.2	14.	TOP	9.24
17 13	23	46.0	U1000	EOR	I				
18 13	23	46.4	U1000			5.2	14.	TOP	1.08
18 13	23	46.4	U1000			5.2	14.	TOP	5.24
18 13	23	46.4	U1000			5.2	14.	TOP	9.24
19 13	23	49.9	U1000	EOR	I				
20 13	23	50.3	U1000			5.2	14.	TOP	1.08
20 13	23	50.3	U1000			5.2	14.	TOP	5.24
20 13	23	50.3	U1000			5.2	14.	TOP	9.24
21 13	23	53.8	U1000	EOR	I				
22 13	23	54.2	U1000			5.2	14.	TOP	1.08
22 13	23	54.2	U1000			5.2	14.	TOP	5.24
22 13	23	54.2	U1000			5.2	14.	TOP	9.24
23 13	23	57.8	U1000	EOR	I				

BOTTOM FIELD SIGMA = .0 N = 0 SUM = 0. SUM SQUARES =
TOP FIELD SIGMA = 21.6 N = 33 SUM = 177. SUM SQUARES =
AP = 612.0 AR = 8103.0

Figure 11. Sample Printout -

ORY TESTS OF VECAS GA/M DATE 5 27

RANGE	RATE	TAU	TALT	IDNT		PRB	RPY	
1.08	43.	90.4	6.0	01CG	B	15.	199.	TAU-TWO
5.24	19.	992.8	6.0	01CG	B	15.	199.	
9.24	9.	3696.0	6.0	01CG	B	15.	199.	
1.08	-10.	-388.8	6.0	01CG	B	15.	232.	TAU-TWO
5.24	28.	673.7	6.0	01CG	B	15.	232.	
9.24	18.	1848.0	6.0	01CG	B	15.	232.	
1.08	20.	194.4	6.0	01CG	B	19.	205.	TAU-TWO
5.24	39.	483.7	6.0	01CG	B	19.	205.	
9.24	-1.	*264.0	6.0	01CG	B	19.	205.	
1.08	11.	353.5	6.0	01CG	B	18.	226.	TAU-TWO
5.24	-29.	-650.5	6.0	01CG	B	18.	226.	
9.24	-11.	*024.0	6.0	01CG	B	18.	226.	
1.08	12.	324.0	6.0	01CG	B	16.	282.	TAU-TWO
5.24	-2.	*432.0	6.0	01CG	B	16.	282.	
9.24	-9.	*696.0	6.0	01CG	B	16.	282.	
1.08	18.	216.0	6.0	01CG	B	18.	239.	TAU-TWO
5.24	-48.	-471.6	6.0	01CG	B	18.	239.	
9.24	3.	*088.0	6.0	01CG	B	18.	239.	
1.08	-22.	-176.7	6.0	01CG	B	20.	232.	TAU-TWO
5.24	-2.	*432.0	6.0	01CG	B	20.	232.	
9.25	-2.	*650.0	6.0	01CG	B	20.	232.	
1.08	-13.	-299.1	6.0	01CG	B	20.	432.	TAU-TWO
5.24	-11.	*714.9	6.0	01CG	B	20.	432.	
9.24	19.	1750.7	6.0	01CG	B	20.	432.	
1.08	43.	90.4	6.0	01CG	B	26.	230.	TAU-TWO
5.24	41.	460.1	6.0	01CG	B	26.	230.	
9.24	-32.	*039.5	6.0	01CG	B	26.	230.	
1.08	-10.	-388.8	6.0	01CG	B	15.	200.	TAU-TWO
5.24	-11.	*714.9	6.0	01CG	B	15.	200.	
9.24	28.	1188.0	6.0	01CG	B	15.	200.	
1.08	0.	3888.0	6.0	01CG	B	22.	224.	TAU-TWO
5.24	22.	857.5	6.0	01CG	B	22.	224.	
9.24	9.	3696.0	6.0	01CG	B	22.	224.	

UARES = 0. BPRB = .0 BRPY = .0 KBK = 0
RES = 15933. TPRB = 18.5 TRPY = 245.5 KTK = 33

Printout - 3 targets (-81 dbm)

2

TAPE NO. 33 N.A.D.C. LABORATORY TESTS OF \

TIME HR	MIN	SEC	DISPLAY			ALT	AZONE	ANT	RANGE
1 15	25	39.4	U1000	EOR	I				
2 15	25	39.8	U1000			5.1	14.	TOP	.17
2 15	25	39.8	U1000			5.1	14.	TOP	2.82
2 15	25	39.8	U1000			5.1	14.	TOP	5.32
2 15	25	39.8	U1000			5.1	14.	TOP	7.83
2 15	25	39.8	U1000			5.1	14.	TOP	10.33
3 15	25	43.3	U1000	EOR	I				
4 15	25	43.7	U1000			5.1	14.	TOP	.17
4 15	25	43.7	U1000			5.1	14.	TOP	2.82
4 15	25	43.7	U1000			5.1	14.	TOP	5.32
4 15	25	43.7	U1000			5.1	14.	TOP	7.83
4 15	25	43.7	U1000			5.1	14.	TOP	10.33
5 15	25	47.2	U1000	EOR	I				
6 15	25	47.6	U1000			5.1	14.	TOP	.17
6 15	25	47.6	U1000			5.1	14.	TOP	2.82
6 15	25	47.6	U1000			5.1	14.	TOP	5.32
6 15	25	47.6	U1000			5.1	14.	TOP	7.83
6 15	25	47.6	U1000			5.1	14.	TOP	10.33
7 15	25	51.2	U1000	EOR	I				
8 15	25	51.6	U1000			5.0	14.	TOP	.17
8 15	25	51.6	U1000			5.0	14.	TOP	2.02
8 15	25	51.6	U1000			5.0	14.	TOP	5.32
8 15	25	51.6	U1000			5.0	14.	TOP	7.03
8 15	25	51.6	U1000			5.0	14.	TOP	10.33
9 15	25	55.1	U1000	EOR	I				
10 15	25	55.5	U1000			5.0	14.	TOP	.17
10 15	25	55.5	U1000			5.0	14.	TOP	2.02
10 15	25	55.5	U1000			5.0	14.	TOP	5.32
10 15	25	55.5	U1000			5.0	14.	TOP	7.02
10 15	25	55.5	U1000			5.0	14.	TOP	10.33
11 15	25	59.0	U1000	EOR	I				
12 15	25	59.4	U1000			5.1	14.	TOP	.17
12 15	25	59.4	U1000			5.1	14.	TOP	2.82
12 15	25	59.4	U1000			5.1	14.	TOP	5.32
12 15	25	59.4	U1000			5.1	14.	TOP	7.83
12 15	25	59.4	U1000			5.1	14.	TOP	10.33
13 15	26	3.0	U1000	EOR	I				
14 15	26	3.4	U1000			5.1	14.	TOP	.17
14 15	26	3.4	U1000			5.1	14.	TOP	2.82
14 15	26	3.4	U1000			5.1	14.	TOP	5.32
14 15	26	3.4	U1000			5.1	14.	TOP	7.83
14 15	26	3.4	U1000			5.1	14.	TOP	10.33
15 15	26	6.9	U1000	EOR	I				
16 15	26	7.3	U1000			5.1	14.	TOP	.17
16 15	26	7.3	U1000			5.1	14.	TOP	2.82

BOTTOM FIELD SIGMA = .0 N = 0 SUM = 0. SUM SQUARES =

TOP FIELD SIGMA = 16.9 N = 35 SUM = 281. SUM SQUARES = 1

AP = 599.0 AR = 6790.0

Figure 12. Sample Printout - 5 t

RY TESTS OF VECAS GA/M DATE 6 9

RANGE	RATE	TAU	TALT	IDNT		PRB	RPY	
.17	-3.	-204.0	6.0	01CG	B	14.	172.	TAU-ONE
2.82	28.	352.6	6.0	01CG	B	14.	172.	
5.32	-3.	*384.0	6.0	01CG	B	14.	172.	
7.83	16.	1761.7	6.0	01CG	B	14.	172.	
10.33	38.	978.6	6.0	01CG	B	14.	172.	
.17	27.	22.7	6.0	01CG	B	16.	176.	TAU-ONE
2.82	8.	1269.0	6.0	01CG	B	16.	176.	
5.32	32.	598.5	6.0	01CG	B	16.	176.	
7.83	41.	687.5	6.0	01CG	B	16.	176.	
10.33	34.	1093.8	6.0	01CG	B	16.	176.	
.17	5.	122.4	6.0	01CG	B	18.	185.	TAU-ONE
2.82	-2.	*076.0	6.0	01CG	B	18.	185.	
5.32	25.	766.1	6.0	01CG	B	18.	185.	
7.83	-3.	*396.0	6.0	01CG	B	18.	185.	
10.33	-8.	*648.5	6.0	01CG	B	18.	185.	
.17	-14.	-43.7	6.0	01CG	B	16.	201.	TAU-ONE
2.02	12.	606.0	6.0	01CG	B	16.	201.	
5.32	-7.	*736.0	6.0	01CG	B	16.	201.	
7.03	26.	973.4	6.0	01CG	B	16.	201.	
10.33	-1.	*188.0	6.0	01CG	B	16.	201.	
.17	4.	153.0	6.0	01CG	B	11.	171.	TAU-ONE
2.02	25.	290.9	6.0	01CG	B	11.	171.	
5.32	-12.	*596.0	6.0	01CG	B	11.	171.	
7.02	20.	1263.6	6.0	01CG	B	11.	171.	
10.33	24.	1549.5	6.0	01CG	B	11.	171.	
.17	-17.	-36.0	6.0	01CG	B	16.	185.	TAU-ONE
2.82	10.	1015.2	6.0	01CG	B	16.	185.	
5.32	-3.	*384.0	6.0	01CG	B	16.	185.	
7.83	21.	1342.3	6.0	01CG	B	16.	185.	
10.33	-5.	*437.6	6.0	01CG	B	16.	185.	
.17	4.	153.0	6.0	01CG	B	20.	192.	TAU-ONE
2.82	-3.	*384.0	6.0	01CG	B	20.	192.	
5.32	-17.	*126.6	6.0	01CG	B	20.	192.	
7.83	-9.	*132.0	6.0	01CG	B	20.	192.	
10.33	-13.	*860.6	6.0	01CG	B	20.	192.	
.17	-23.	-26.6	59.4	00#(	BC	22.	190.	
2.82	1.	*152.0	6.0	01CG	B	22.	190.	

ARES = 0. BPRB = .0 BRPY = .0 KBK = 0
ES = 12139. TPRB = 16.2 TRPY = 183.5 KTK = 37

Printout - 5 targets (-81 dbm)

2

TAPE NO. 33 N.A.D.C. LABORATORY TESTS

	TIME HR	MIN	SEC	DISPLAY			ALT	AZONE	ANT	RANGE
24	15	20	32.6	U1000	EOR	I				
25	15	20	33.0	U1000			5.1	14.	TOP	.17
25	15	20	33.0	U1000			5.1	14.	TOP	1.31
25	15	20	33.0	U1000			5.1	14.	TOP	2.32
25	15	20	33.0	U1000			5.1	14.	TOP	3.32
25	15	20	33.0				5.1	14.	TOP	4.32
26	15	20	33.0	U1000			5.1	14.	TOP	7.32
26	15	20	33.0	U1000			5.1	14.	TOP	8.33
26	15	20	33.0	U1000			5.1	14.	TOP	9.33
26	15	20	33.0	U1000			5.1	14.	TOP	10.33
26	15	20	33.0	U1000			5.1	14.	TOP	11.33
26	15	20	33.0	U1000			5.1	14.	TOP	12.34
27	15	20	36.5	U1000	EOR	I				
28	15	20	36.9	U1000			5.1	14.	TOP	.17
28	15	20	36.9	U1000			5.1	14.	TOP	1.31
28	15	20	36.9	U1000			5.1	14.	TOP	2.32
28	15	20	36.9	U1000			5.1	14.	TOP	3.32
28	15	20	36.9				5.1	14.	TOP	4.32
29	15	20	36.9	U1000			5.1	14.	TOP	7.32
29	15	20	36.9	U1000			5.1	14.	TOP	8.33
29	15	20	36.9	U1000			5.1	14.	TOP	9.33
29	15	20	36.9	U1000			5.1	14.	TOP	10.33
29	15	20	36.9	U1000			5.1	14.	TOP	11.33
29	15	20	36.9	U1000			5.1	14.	TOP	12.33
30	15	20	40.5	U1000	EOR	I				
31	15	20	40.9	U1000			5.1	14.	TOP	.17
31	15	20	40.9	U1000			5.1	14.	TOP	1.31
31	15	20	40.9	U1000			5.1	14.	TOP	2.32
31	15	20	40.9	U1000			5.1	14.	TOP	3.32
31	15	20	40.9				5.1	14.	TOP	4.32
32	15	20	40.9	U1000			5.1	14.	TOP	7.32
32	15	20	40.9	U1000			5.1	14.	TOP	8.33
32	15	20	40.9	U1000			5.1	14.	TOP	9.33
32	15	20	40.9	U1000			5.1	14.	TOP	10.33
32	15	20	40.9	U1000			5.1	14.	TOP	11.33
32	15	20	40.9	U1000			5.1	14.	TOP	12.34
33	15	20	44.4	U1000	EOR	I				
34	15	20	44.8	U1000			5.1	14.	TOP	.17
34	15	20	44.8	U1000			5.1	14.	TOP	1.31
34	15	20	44.8	U1000			5.1	14.	TOP	2.32
34	15	20	44.8	U1000			5.1	14.	TOP	3.31
34	15	20	44.8				5.1	14.	TOP	4.32
35	15	20	44.8	U1000			5.1	14.	TOP	7.32
35	15	20	44.8	U1000			5.1	14.	TOP	8.33
35	15	20	44.8	U1000			5.1	14.	TOP	9.33

BOTTOM FIELD SIGMA = .0 N = 0 SUM = 0. SUM SQUARES =

TOP FIELD SIGMA = 24.5 N = 41 SUM = 95. SUM SQUARES =

AP = 697.0 AR = 7851.0

Figure 13. Sample Printout -

ADC-76208-60

RY TESTS OF VECAS GA/M DATE 6 9

RANGE	RATE	TAU	TALT	IDNT		PRB	RPY	
.17	-31.	-19.7	6.0	01CG	B	26.	202.	TAU-ONE
1.31	-13.	-362.8	6.0	01CG	B	26.	202.	TAU-TWO
2.32	30.	278.4	6.0	01CG	B	26.	202.	
3.32	18.	664.0	6.0	01CG	B	26.	202.	
4.32	6.	2592.0	6.0	01CG	B	26.	200.	
7.32	22.	1197.8	6.0	01CG	B	26.	202.	
8.33	54.	555.3	6.0	01CG	B	26.	202.	
9.33	11.	3053.5	6.0	01CG	B	26.	202.	
10.33	0.	*188.0	6.0	01CG	B	26.	202.	
11.33	22.	1854.0	6.0	01CG	B	26.	202.	
12.34	-8.	*553.0	6.0	01CG	B	26.	202.	
.17	-20.	-30.6	6.0	01CG	B	15.	211.	TAU-ONE
1.31	-17.	-277.4	6.0	01CG	B	15.	211.	TAU-TWO
2.32	-8.	*044.0	6.0	01CG	B	15.	211.	
3.32	-15.	-795.8	6.0	01CG	B	15.	211.	
4.32	3.	5184.0	6.0	01CG	B	15.	200.	
7.32	29.	908.7	6.0	01CG	B	15.	211.	
8.33	36.	833.0	6.0	01CG	B	15.	211.	
9.33	-21.	*599.4	6.0	01CG	B	15.	211.	
10.33	25.	1487.5	6.0	01CG	B	15.	211.	
11.33	-8.	*098.5	6.0	01CG	B	15.	211.	
12.33	5.	8877.6	6.0	01CG	B	15.	211.	
.17	1.	612.0	6.0	01CG	B	10.	184.	TAU-ONE
1.31	-21.	-224.6	6.0	01CG	B	10.	184.	TAU-TWO
2.32	-8.	*044.0	6.0	01CG	B	10.	184.	
3.32	25.	478.1	6.0	01CG	B	10.	184.	
4.32	8.	1944.0	6.0	01CG	B	10.	100.	
7.32	39.	675.7	6.0	01CG	B	10.	184.	
8.33	-12.	*499.0	6.0	01CG	B	10.	184.	
9.33	-9.	*732.0	6.0	01CG	B	10.	184.	
10.33	55.	676.1	6.0	01CG	B	10.	184.	
11.33	6.	6798.0	6.0	01CG	B	10.	184.	
12.34	6.	7404.0	6.0	01CG	B	10.	184.	
.17	10.	61.2	6.0	01CG	B	17.	183.	TAU-ONE
1.31	37.	127.5	6.0	01CG	B	17.	183.	TAU-TWO
2.32	-24.	-348.0	6.0	01CG	B	17.	183.	
3.31	5.	2383.2	6.0	01CG	B	17.	183.	
4.32	-26.	-598.2	6.0	01CG	B	17.	100.	
7.32	-36.	-732.0	6.0	01CG	B	17.	183.	
8.33	-34.	-882.0	6.0	01CG	B	17.	183.	
9.33	-47.	-714.6	6.0	01CG	B	17.	183.	

UARES = 0. BPRB = .0 BRPY = .0 KBK = 0

RES = 24183. TPRB = 17.0 TRPY = 191.5 KTK = 41

Printout - 11 targets (-81 dbm)

ADJACENT CHANNEL REJECTION

"Adjacent Channel Rejection: Shall be such that at any level over the dynamic range of paragraph 2.3, a video reply signal in the desired data channel shall result in a signal in the undesired data channel which is 70 percent or less than the threshold of the undesired data channel." (2.14)

A test for Adjacent Channel Rejection was made during acceptance. Over the maximum range of the calibration generator the signal in the adjacent channel did not exceed 70 percent of threshold.

REPLY TO OWN PROBES

"Reply to own probes accompanied by receipt of those replies due to signal reflection from ground, water or other structures: design of system logic shall be such that at any altitude over any reflecting surface, the replies will not be processed in the threat logic." (2.13)

It was impractical to connect a coaxial cable between the top and bottom antenna ports because the r-f attenuation in the cable for the required range would be too great. Therefore, the blanking signals were observed on the correlator transmit control board. Analysis shows that the RCA solution to the self-interrogation problem should work, although a flight would be required for absolute conformation.

ALARM DISPLAY CONSISTENCY

"Alarm Display Consistency: For all range rates from -70 to +1000 knots with SFL injected and over the dynamic range of paragraph 2.3, once the TAU 2 threshold has been crossed (assuming the commands are not obeyed) the correct TAU 2 and TAU 1 alarms will be displayed with a probability of 99% updated every 4 seconds from the range corresponding to the initial TAU 2 threshold crossing to 0.5 nmi opening." (2.5)

The specification requires operation over all range rates from -70 to +1000 knots. This includes a 99 percent CAS display reliability from the Tau Two threshold crossing to a 1/2-nmi opening. The VECAS GA/M could successfully track inbound targets at 1500 knots, which is the maximum range rate obtainable from the calibration generator. The inbound to outbound crossing is beyond the capability of the calibration generator, although outbound targets can also be tracked to 1500 knots.

DISCUSSION

The following items are intended as follow-up explainations of the Notes and Observations recorded concerning the 1972 Full VECAS equipment as reported in Report NADC-74207-60.

1. The round time has a signifieent effect on the warning time. In the VECAS GA/M, the round time, no longer a variable, is fixed at 3.9 seconds. The use of the larger correlator and multiple trackers made this possible.

2. The elimination of the test track prevented the loss of the first Tau Two advisory for at least one round time due to a false dismissal of a threat due to test track range rate inaccuracy. The elimination of the test track also contributed to the reduction in the round time.

3. The old full VECAS experienced a problem when an aircraft is within 1000 feet of the ground, i.e., the VECAS communicates with itself. This is because the interrogations from each antenna reflect off the ground and are received by the other antenna. The replies are returned via a similar path. This could cause an extension of the round time (in the old equipment) and more importantly, a false Tau One command. One solution to this problem involves comparing the identity of the target to the VECAS's own identity and discarding targets with the same identities. However, this solution will work only if the data message is decoded correctly. RCA has implemented a different solution to this problem. During correlation, when the VECAS GA/M is probing through one antenna, the probe receivers on the other antenna are blocked; therefore, the VECAS GA/M will not reply to its own interrogations. This solution should work, although it could only be demonstrated by flight tests.

4. The exact co-altitude situations can cause potential problems, as in the case where two aircraft on a collision course at the same altitude simultaneously or nearly simultaneously track each other inside the Tau One Boundary. The possibility exists that both aircraft will bias their altitude transmissions in the same direction. This could lead to the case of alternating bias directions and alternating commands, expecially in the case of fixed round times. However, the round times, although fixed, are short (3.9 seconds) and in a dynamic situation this problem should be resolvable. For those rare cases of co-altitude indeciveness, additional logic must be added to make sure biasing and thus commands are complementary and opposite.

5. The old full VECAS compared the identities of all targets tracked in a round, and if the identities are the same the target tracked last is assumed to be a multipath target and is discarded. This could cause the Tau One maneuver command to be one round late when the same target is tracked in both fields. The proposed solution to this problem was to use identity to discard targets in only one field. The VECAS GA/M does not use identity for any purpose. Because of parallel trackers and thus the fixed round time, the occurence of multipath targets does not extend round time. If

identity were to be used to eliminate multipath targets, it could be done in the same way as proposed before.

6. In the old full VECAS equipment, an imbalance could occur in the theoretical threat range at the high-band/low-band boundary. This was partially the fault of the original design before altitude encoding was incorporated. The new VECAS GA/M receiver configuration is designed around altitude encoding in that the probe receiver thresholds are determined by own altitude, and the reply receiver threshold is determined by the particular altitude being illuminated. Thus, when a VECAS GA/M at 9,500 feet interrogates a target at 10,500 feet, the targets probe receivers are at full high-band sensitivity (-87dbm) and the interrogator's reply receiver is also at full high-band sensitivity. Because the VECAS GA/M has a full range correlator of nearly 13 nmi for all targets, this boundary case situation would have the same communication link as if both interrogator and target were in the high band. For the opposite case where the interrogator is at 10,500 feet and the target is at 9,500 feet, the link sensitivity is the same as if both aircraft were in the low band, although the full length correlator is still being used. It still might be advisable to have a new full VECAS increase its probe power by 3 db and increase its receiver sensitivity by 3 db for the case of probing the low band when the interrogator aircraft is in the high band.

7. The main effect of multipath targets on the old full VECAS was to increase the round time. The VECAS GA/M has multiple trackers and a fixed round time which multipath targets cannot increase. Although occasional illumination of the wrong altitude zone might still take place, this additional effect cannot now increase round time.

8. The VECAS GA/M was designed to conform as much as possible with ANTC 117 (reference e). The co-altitude bands are $\pm$ 600 feet when below 10,000 feet and $\pm$ 800 feet when above 10,000 feet; however, the only non-co-altitude bands are less than 3300 feet above and below. The Tau threshold values are modified slightly in the prototype VECAS GA/M from 40 seconds to 39.96 seconds and from 25 seconds to 25.04 seconds. The range offsets of 1.8 and 0.25 nmi are retained alone with the Tau One minimum range of 0.5 nmi and the predicted co-altitude command.

9. The VECAS GA/M does incorporate a memory to remember the threat levels from the preceeding round of traffic. Because of this, a loss of communication in one round will not cause an advisory or command display to be extinguished. However, this does not delay the presentation of an advisory or command from a "pop-up" target because the change in threat level from a less threatening situation to a more threatening situation will be displayed at the end of the first round.

10. In the old full VECAS, very strong signals from a target aircraft spilled into the adjacent channel, which would look like the occurence of plus and minus replies simultaneously. This would lead to the assumption of co-range targets and could cause an extension of the round time. In the VECAS GA/M, adjacent channel crosstalk

does not cause co-range tracks. The only effect is the possible data degradation due to missing bits (simultaneous "one" and "zero").

A strong signal can cause adjacent channel crosstalk because some of the spectral content of the pulse type signal occurs in the other channel. When the pulse in the main channel has reached limiting, the maximum amount of signal from the pulse that can exist in the adjacent channel is now controlled. The threshold is adjusted so that the signal level in the channel adjacent to the main channel will not cross the threshold. This means that even with a perfect filter there is going to be some crosstalk because of the spectral content of the pulse, and this level cannot be reduced. If the filter on the adjacent channel has a wide enough skirt which covers part of the pulse spectrum in the main channel, then an additional amount of energy can appear in the adjacent channel. With the SAW filter, the theoretical limit is approached where the skirts problem is eliminated by controlling the SAW filter selectivity. Thus, the energy remaining in the adjacent channel is that caused by the pulse spectrum itself.

A strong signal could cause the assumption of co-range targets in another way. A strong signal occupies more time and could appear in several bins. Because the VECAS GA/M does not have a variable round time, the only effect of a strong signal level is to cause the utilization of a parallel tracker for the trailing edge track.

The following notes and observations are new items:

11. A problem developed during the laboratory tests was the occurence of very large range rate errors and poor data reliability. It was actually a lost track in the middle of a track. This was caused by the loss of data returns from the calibration generator. The blanking in the VECAS GA/M was improperly adjusted, so that the crosstalk noise was causing the transmitter to fire again and put out what was essentially another probe pair, not necessarily on the correct frequencies. The crosstalk was causing pulses to come out of all receivers, especially the probe receivers, and these were guaranteed to decode because they were at the same spacing as the probes which had been sent out. The timing was such that the VECAS GA/M had not switched the timing control from the probe mode, so that another set of probes (instead of replies) was transmitted on any possible probe frequency. The calibration generator would then receive another probe which might be a different frequency than the first probe. The calibration generator could then reply with the wrong frequency. The result would be that the VECAS GA/M would not get an answer on the target, therefore it would lose track and then perhaps track on fruit and move off the target with the result of a lost track. This is a consequence of the way the calibration generator is built. It is not designed to accept fruit, and this second probe is essentially probe fruit. The blanking was readjusted so that the transmitter crosstalk was prevented from effecting the logic.

12. The VECAS GA/M by design is 3 db less sensitive than the old full VECAS; however, the power output as measured is approximately 3 db stronger in the VECAS GA/M.

Therefore, the communication range between two VECAS GA/M's should be the same as the communication range between the experimental VECAS's as reported in reference a. The old experimental VECAS could correlate out to 15 nmi (28 kilometers). The VECAS GA/M is designed to correlate to less than 13 nmi (24.1 kilometers).

13. The centroid tracker was left out only on the basis of its slight extra cost. The goal was absolute simplification of the VECAS GA/M tracker. Any future equipment would have a centroid tracker. This would reduce the range rate one sigma value in high band down to the value at low band with an additional slight reduction in range rate error in the low band. The leading edge/trailing edge track would only be used for co-range targets. The centroid track is less sensitive to noise and fruit because it uses the centroid of the waveform where the leading edge tracker will use the leading edge of a small signal ahead of (in time) a normal signal.

14. Although the specification is not explicit, the SFL is understood to apply to the low-band case (below the 10,000-foot altitude). Since the quantity of aircraft within radio range in the high band is only approximately 4 percent of the total in the 1982 Los Angeles Basin Standard Traffic Model (appendix A of reference a) the resulting amount of fruit replies is also much less.

REFERENCES

a. FLIGHT TEST EVALUATION OF SECANT VECAS COLLISION AVOIDANCE SYSTEM, Report No. NADC-74207-60 of November 1974.

b. Contract N62269-75-C-0029 to RCA Corp for the purchase of VECAS GA/M and associated units.

c. TWIX FM FAA WASHDC TO COMMANDER NAVAL AIR DEVELOPMENT CENTER WARMINSTER PA R 151425Z OCT 75

d. FLIGHT TEST PLAN FOR SECANT VECAS GA/M, NADC Code 6071 of March 1975

e. ANTC Report No. 117, Revision Ten, of 27 Sept 1971, Airborne Collision Avoidance System, Air Transport Association of America.

f. Spectrum Signature Data for SECANT VECAS GA/M AIRBORNE COLLISION AVOIDANCE SYSTEM, RCA, Data Item A004 of Contract N62269-75-C-0029

g. Operating Instructions for SECANT EQUIPMENT, March 1975

h. SECANT SYSTEM DESCRIPTION, 4 December 1974, RCA Report Secant - Tech - 74 - 2

i. MESSAGE FORMAT AND CODING, March 5, 1974, Rev Dec 10, 1974, RCA SECANT TECH REPORT 74-1

j. SECANT VECAS GA/M FLIGHT TEST AND EVALUATION EQUIPMENT, FINAL REPORT, NOVEMBER 1975, RCA Report No. TP2234

APPENDIX A

RCA DESCRIPTION OF THE VECAS GA/M

2.1 TECHNICAL DESCRIPTION SUMMARY

The VECAS-GA/M flight test equipment is configured to be compatible with the existing three experimental VECAS equipments. This is accomplished by using the same data message format of the previous equipment rather than the new code format intended for production equipment. To insure reliable system operation a majority of three voting logic has been incorporated. This results in a processing power which in the same noise or fruit signal environment is equivalent to the Hamming code. The penalty of the slightly increased logic complexity is offset by the ability to communicate with the existing experimental VECAS units.

The use of the new 393 ms basic track format in conjunction with a simple wire change in the VECAS will permit reception of the altitude portion of the message which is required for threat analysis, and the identity which is recorded for test data analysis. The identity and altitude bits is still transmitted to the VECAS equipment by VECAS-GA/M.

The package size for these first models of the VECAS-GA/M is a 3/4 ATR short and contains the complete system. The RF assembly is a custom integrated package, and the processing logic is fabricated using existing low power consumption elements and MSI, and LSI circuitry.

The output display interface is plug compatible with the VSI-CAS indicator used on the VECAS equipment; however, a simplified threat logic combines those appropriate signal lines to produce the fewer required displays. An alternate CAS only display of a simple arrow and "X" type can be used with the selected interface.

The VECAS-GA/M requires only the two antenna radiators, the output display, the own ship's altitude from the digital altimeter, and primary power as interface signals.

The following is a list of the significant parameters of the VECAS-GA/M flight test equipment.

1) Two antennas, maximum cable loss 2 db

2) Altitude encoding used, 7 zones, below 10K ft, 500 ft. zones, above 10 K ft., 1000 ft. zones, above 30K ft. common zone

2A) Level - own $\pm$3, double probe own and adjacent
Climb/Descend - own -2 +4 in direction of change, double probe own and adjacent

3) 13.0 nautical mile correlation, tracking range

4) Communication range 15 nautical miles (16 watts panel power probe/reply)

5) Fixed gain receiver, no AGC

6) Coherent Detector - amplitude linear

7) Top and bottom antennas in all altitude zones for correlation

7A) a) "OR" correlators so no lost targets

b) Use antenna of first one field target

c) If both fields identical - use top for up zones and bottom for down zones

d) Three co-altitude zones - separate tracks with each antenna

8) 2000 pps correlate, 1000 pps track, 50 pps idle

9) Threat logic processing

a) Only one limit for climb or descent rates (1000 ft/min)

b) Tau 1 and Tau 2 detection

c) Altitude unlimited

d) Display, standard VSI/CAS or CAS "X", arrow

e) Display information: Climb/descent limit indication NO TURN, LEVEL, CLIMB, DIVE (held through 2 rounds, update end of round)

10) VECAS GA/M provides full warning time for climb/descend rates up to 4000 ft./min

11) Size: 3/4 ATR short

12) Weight: 20 lb. max

2.2 SIMPLIFIED TECHNICAL DESCRIPTION

2.2.1 Correlator

The capabilities of the VECAS-GA/M equipment are accomplished with processing hardware by the application of several newly developed techniques. Correlation time is reduced and the hardware is simplified through the use of a new full range correlator logic system which is capable of detecting all the targets in any desired range length in a time period equal to the sampling period times the number of desired correlation probes. This permits the full range of both fields to be correlated in the same 25 ms that was previously used for a 1.25 mile segment in one altitude zone.

The correlation technique previously used in the SECANT equipments required an individual up down counter for each of the range bins. The resultant circuit complexity caused a limitation in the number of bins that could be implemented in the system, and therefore, the total range was examined sequentially as a series of sectors. The sector scanning approach correspondingly required an overlap as targets were detected and resulted in extending the system round time.

The full range correlator technique is shown in simplified block diagram form in Figure 1. The incoming signals are detected and are clocked into an arithmetic logic circuit as the least significant bit. All other bits for that input of the parallel adder are zero. The second input set of the adder are supplied from the outputs of several serial shift registers whose inputs are the output of the adder. The number of shift registers required is dependent on the desired number of correlation counts to be considered. The example shown uses six registers to count to ±25. Since shift registers are not constrained by pin limitation of most LSI circuits, relatively long counts are readily available. This permits sufficient storage elements or bins for the entire system range. The outputs of the shift registers are monitored by a digital comparator to detect the desired correlation threshold. When this is equal or exceeded a target has been detected and is handed off to the range tracker. This technique, also will significantly aid the transfer of the correlator design to custom LSI form.

2.2.2 Multiple Target Tracker

A most important concept of all the SECANT trackers is the fact that the range measurement is made directly from the initiating pulse to the target video. The tracker servo system only provides a moving time gate which acts to filter out undesired pulses and, therefore, does not introduce any servo error into the range, range rate, or Tau computation.

The multiple target tracker is based on the principal that a bit in a long shift register can represent a target and its range, if the range is expressed in units which correspond to the bit time of the shift register clock.

The VECAS GA/M tracker employs a 1560 bit shift register clocked at 9.71252 MHz, which is given 1560 clock pulses following each probe transmission. After the final clock pulse the register is static until the next probe transmission. The clock frequency has been selected to make each bit position in the register equal to 50.65 ft. of range. With 1560 bit positions in the register this makes the maximum range of the tracker 13 nautical miles.

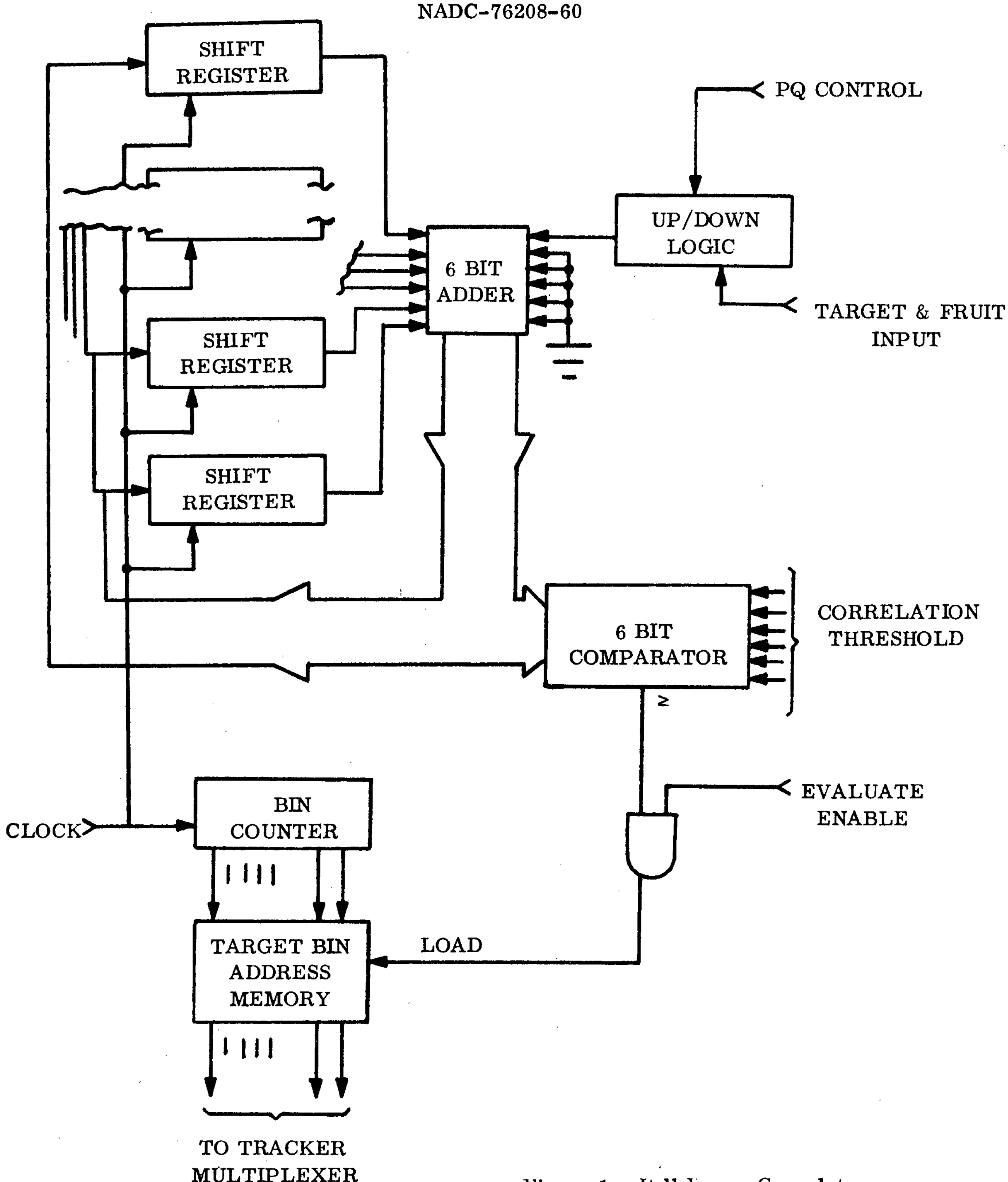

Figure 1. Full Range Correlator

To perform the function of tracking, the position of a target bit in the register must follow any changes in range of the target during the track period. This is accomplished by advancing or retarding the target bit location in the register while tracking.

Figure 2 is a block diagram of the tracker which will assist in explaining how it operates. Notice that the 1560 bit shift register is comprised of 2 parts: a 1544 bit section which is strictly serial; and a 17 bit section where access to the target bit is available.

During correlate the shift register is cleared to the all zeros state. Following correlation there is a 1 ms interval called correlator hand off where the tracker shift register and the correlator shift registers are rotated in synchronism. At this time a target bit is entered into the tracker control register for each target which the correlator found. The time at which each bit is transferred is a function of the range at which the correlator found the target. The nearest target is entered first and the farthest target last. The target bits are circulated through the entire shift register once each probe time during the acquisition and track periods.

All control of the tracker is performed by the passage of a target bit through the control register as follows. When the bit appears at tap 1 of the register, two flip-flops called LETG (Leading Edge Track Gate) and EG (Early Gate) are set. When the bit appears at Tap 5 EG is reset. At tap 6 a flip-flop called DG (Data Gate) is set and at tap 11 LETG is reset. DG is reset by the target bit at tap 14. The target bit exits the control register and enters the main shift register by way of tap 15, 16, or 17 depending on decisions made in the servo logic. LETG defines the time when the digital video line is sampled. The sampled digital video leading edge is compared against EG, tap 5 of the control register and DG and the results of the comparison used to select the exit tap for the target bit.

If the leading edge of the video occurs during EG the target bit is late, and exit tap 15 is selected. This means that the next appearance of this particular track bit (following the next probe) will be advanced 1 bit time which is the equivalent of moving it 50 feet nearer in range.

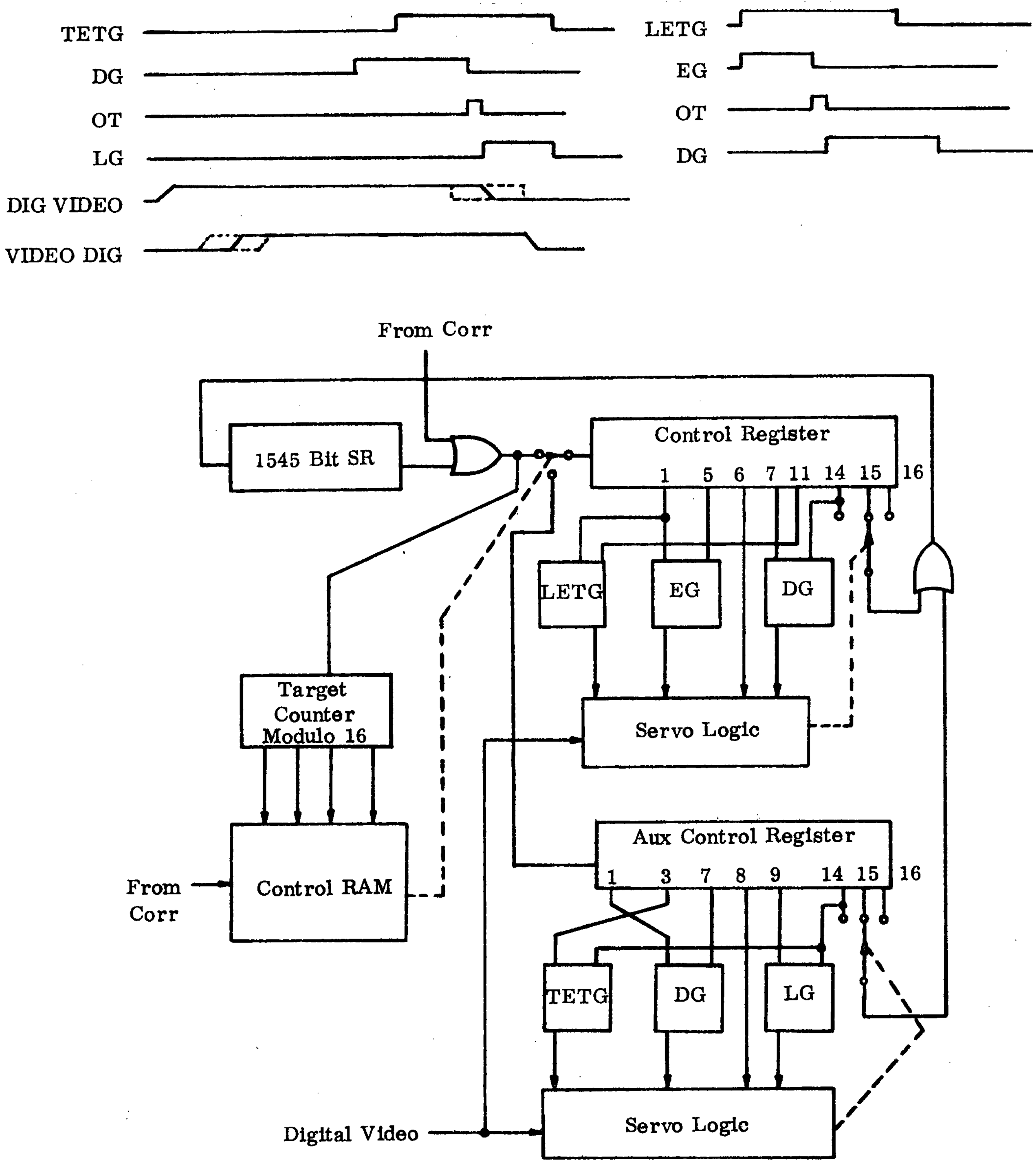

FIGURE 2. SECANT VECAS GA/M MULTIPLE TRACKER

If the leading edge of the video occurs while the target bit is at tap 6 the tracker is on target and exit tap 16 is selected. The relationship of this target bit and the video will be unchanged on the next appearance.

If the leading edge of the video occurs during DG the target bit is early, and exit tap 17 is selected. The next appearance of this target bit will be delayed 1 bit time which is the equivalent of moving it 50 ft. further in range.

The process described is repeated for every target bit each probe time. Because each target bit sequentially activates the same logic the tracker may be used for many targets. The only limitation is that 2 target bits may not occupy the control register at the same time. In the event that 2 targets are within 800 ft. of the same range their target bits would occupy the control register simultaneously.

To avoid this possibility the auxiliary control register is provided to handle co-range targets. This register is similar to the control register described above except it is designed to track the trailing edge of the digital video pulse returned from the target and is used only for targets that are designated as co-range by the correlator. To remember which targets are co-range the target counter and Control RAM are used. During correlator handoff a bit is written in the RAM for each target designated as co-range. The RAM output is used during track to determine whether a target bit goes to the regular control register or to the aux control register.

Operation of the aux control register is the same as described for the regular register except that the trailing edge of the video pulse is used. The timing diagrams opposite each control register in Figure 1 illustrate and clarify the operation.

The Multiple Target Tracker also consists of a Multiple Tau Detector. This circuit determines which target possesses a tau less than some critical value. This is accomplished by counting each bit position in the shift register and sampling that count each time the video pulse appears within the track gate. This count represents the range of the target quantized in 50 ft. increments. This range is then processed by an arithmetic unit to implement an algorithm associated with the detection of a critical tau. The range sampling and corresponding processing occurs once each probe interval of the track period. At the end of the track, the final result of the arithmetic processing for each target is sampled to determine which targets have a critical tau. The arithmetic unit consists of a 20 bit RAM, a 13 bit adder, and a 20 bit subtracter. The number of different targets the Multiple Tau Detector is able to process is equal to the number of RAM address locations. By using three 64 x 9 bit RAMS, 16 targets can be processed.

2.2.3 Track Cycle and Round Time

The experimental SECANT VECAS used range, range rate, and the reception of data for the threat analysis and required the operation of an individual tracker for each aircraft target for 0.4 seconds each round time. Therefore, the cost effective trade-off between the number of trackers and the round time in dense traffic was the subject of many analyses. Using the FAA-MITRE Standard Traffic Model for LAX 1982 and selecting the dense part of snapshot 3, it may be observed that there are 61 aircraft within 7.9 nautical miles of a spot with altitudes between 500 feet and 4000 feet. Although many of these are in takeoff or landing phase at smaller airports, it is used as a worst case model. In only two altitude zones would this equipment not track all of the aircraft in that altitude zone. These two aircraft would be tracked in the first round that they are included in the first 16 aircraft.

A round time analysis using a sixteen track capability is shown in Figure 3.

A second dense region more typical of regions with less active small airports is shown in Figure 4.

The VECAS-GA/M equipment with its unique multitarget tracker provides a optimized solution to the problem since it can handle each of the examples with a round time of 3.93 seconds.

2.2.4 VECAS-GA/M Multiple Data Receiver

Since VECAS-GA/M has the capability to determine Tau for up to 16 targets simultaneously during a track, system balance requires that altitude information for each of these targets be available at the end of the track. The multiple Data Receiver accumulates this data for each of the 16 targets for which the multi Tau detector is computing Tau.

SNAPSHOT #3 14.5 NM 329°
DENSE REGION (VAN NUYS REGION)

LAYER	NUMBER OF AIRCRAFT IN 7.9 NM	MULTI TARGET TRACKER 16 AIRCRAFT
1	0	
2	3	
3	4	
4	1	
5	2	.393
6	6	.393
7 adjacent	10	.786
8 own	2	.786
9 adjacent	6	.786
10	4	.393
11	4	.393
12	4	
13	2	
14	2	
15	1	
16	0	
17	0	
18	4	
19	0	
20	1	
		3.933 sec.

FIGURE 3.
ROUND TIME - STANDARD MODEL

SNAPSHOT #3 21.0 NM 145°
10 ALTITUDE LAYERS

500' LAYER	AIRCRAFT IN 7.9 NM	TRACKERS OR TARGET CAPABILITY 16
1	6	
2	5	.393
3	9	.393
4 adjacent	17	.786
5 own	20	.786
6 adjacent	4	.786
7	3	.393
8	3	.393
9	2	
10	2	
11	0	
12	0	
13	0	
14	0	
15	2	
16	1	
17	1	
18	1	
19	1	
20	0	

Round time with 1 or more aircraft in each altitude layer — 3.933 sec.

NOTE: Two altitude layers have more than 16 aircraft and those beyond #16 are not tracked this round.

FIGURE 4.

ROUND TIME - STANDARD MODEL

The multiple Data Receiver contains six 1024 bit MOS RAM chips. The 4 bit RAM address counter in the Multi Tau Detector and the six bit probe counter addresses the RAM. During the track period, each time the Tau Detector computes a partial factor of the Tau for one of 16 targets, the data bit from that target is entered into the RAM. The Data Bits are entered into the RAM as 2 parallel bits coded as follows:

REC DATA BIT		
ONE	0	1
ZERO	1	0
MISSING BIT	1	1

The track probe sequence is programmed so that three copies of a 57 bit message are accumulated in the RAM during the track period.

At the end of the track period the RAM address counter and the probe counters are stepped to examine the Tau value for each target which is now residing in RAM and to read out the area of Data RAM containing the data for that target. The read out is arranged so that the three copies of the message can be examined in parallel at the output of the RAM. The contents of this RAM area are transferred through a majority logic block which combines the 6 parallel bits into a single corrected bit stream which is entered into a 57 x 1 shift register. This shift register has a header decode associated with it and once it is loaded the contents are rotated until the header is detected.

The altitude of this target can now be handed off to the threat logic together with an indication of Tau 1 or Tau 2.

2.2.5 Use of Tau 1 and Tau 2 in Collision Warning

The ANTC-117 threat logic has had more theoretical analysis, computer runs, and air tests than any other logic. It has had the benefit of analysis by equipment manufacturers, government technical representatives, and user groups including the airlines. Although there are several aspects of this logic that should be updated, it still remains the only logic that is known to be acceptable for the collision avoidance problem. High on the list of possible changes to this logic is operation in high density traffic areas.

If a completely new threat logic is proposed, it must undergo analysis by most of the same groups and cannot expect to be approved without a through inspection.

Recently, emphasis has centered upon the operation at the maximum aircraft density in location, altitude, date, time and flight conditions. The maximum chosen is a point about 10 miles southeast of LAX, at 6000' MSL, at 12:35 local time, under VFR conditions using the FAA-MITRE Standard Traffic Model for LAX-1982. The SECANT system will operate in this high density traffic.

The description of Tau 1 is that an aircraft is either co-altitude or predicted co-altitude, whose range is either less than 0.5 nm at any closing velocity or is at a condition less than 25 sec. from an offset point of 0.25 nm from your aircraft. The formula for this is $\frac{\text{Range} - 0.25 \text{ nm}}{\text{Range Rate}} \leq 25$ sec. This formula controls when the aircraft is beyond 0.5 nm range.

Values at typical closing rates are:

Closing Velocity Knots	Tau 1 Range
50	.60 nm
100	.94
200	1.64
330	2.5
500	3.7
1200	8.6
2400	16.9
3600	25.3

The description of Tau 2 is that an aircraft is either co-altitude or predicted co-altitude, whose condition is less than 40 sec. with a 1.8 nm offset. The formula is:

$$\frac{\text{Range } -1.8 \text{ nm}}{\text{Range Rate}} \leq 40 \text{ seconds}$$

Typical values are:

Closing Velocity Knots	Tau 2 Range
50	2.4 nm
100	2.9
200	4.0
330	5.5
500	7.4
1200	15.1
2400	28.5
3600	41.8

Tau 2 has an importance to this ANTC-117 threat logic that surpasses the usual one of pilot alerting. This caution signal by the instruction of limiting turns and excessive vertical speed, stabilizes the geometric problem so that it is possible to effectively obey any resulting Tau 1 command to climb, descend, or not climb/descend. Without Tau 2 the situation has not been stabilized and much less meaning can be attributed to the Tau 1 indication.

While it is premature to make a final judgement, it appears that a system lacking the caution mode is unacceptable to the system analyst and to the aircraft pilot. A system whose design is not capable of generating these cautionary signals would be unacceptable even though all of its other characteristics are satisfactory.

In VECAS-GA/M the compromise is to limit the number of the targets processed to the nearest 16 aircraft in each 500 ft. altitude zone while operating in a dense traffic situation, and to include a Tau 2 indication as the cautionary signal.

2.2.6 VECAS-GA Threat Logic

The threat logic receives tau signals and altitude from the data link and tracker. Data on targets exceeding a Tau threshold are handed off to the threat logic in the order of range.

The threat logic continuously receives own altitude data from the plane's altimeter, updating it every thirty milliseconds. This data is converted from its special grey code to binary for use in the arithmetic unit. This is done at a 250 kHz rate and is finished in 128 μsec (96 μsec is the minimum possible but hardware considerations make 128 μsec a better choice). The binary altitude is monitored for any change in value, and the time between changes is used to predict the planes altitude in 30 seconds. This process takes 1.032 millisecond. When the aircraft is changing altitude at a rate greater than 500 ft. minimum, the threat logic will be busy for a maximum of 1.032 milliseconds every time a change occurs (max of 1 per second). Most of the time it will be busy for 128 μseconds every 30 milliseconds. The rest of the time data can be accepted from the tracker and data link for input to the arithmetic unit. The altitude difference is calculated in parallel and presented to the threat logic temporary store which can hold two targets. This store is cleared at the end of every round time when its output is transferred to the permanent store.

A decision is made to see if each new target is a more serious threat than either target in the store and it replaces the least serious threat target already stored. In the case of two targets already stored one above and one below, the comparison is made, above against above, and below against below only. If both stored targets are above and the new one is below or vice versa then the new target always replaces the least serious threat in the store. The evaluation of the threat for seriousness is based on the altitude difference and tau. This logic functions the same as the present VECAS equipment.

This process is repeated for each target until each is evaluated. The final result is held in the temporary store until the end of round time and then transferred to the pilot's indicator.

Only two bands above and two bands below are used in the threat logic; they are co-altitude, above and below (600-800 ft.) and <3300 feet above and below. Planes that are not co-altitude and <3300 feet and a tau 1 or 2 give an advisory command that someone can become a threat if one'os own altitude is changed. A predicted co-altitude gives a command as in the present VECAS. The present VSI/CAS indicator can be used for the test by connecting its present inputs to the proper VECAS-GA/M outputs. A lower cost CAS only indicator is advisable for a final system.

2.2.7 General

The VECAS-GA/M flight test model signal processing logic has been fabricated using standard integrated circuit logic elements. The majority of the circuits use the very low power consumption COS/MOS devices with a small percentage of TTL devices where higher operating speeds are required. The logic is assembled on custom double sided etched circuit module boards, and is contained in a single module nest occupying approximately one half of the total package. It is expected that the production version of this equipment will be significantly reduced in size by the conversion to custom LSI circuits and the use of hybrid assembly technology.

The new multitarget processing logic which is greatly simplified from that used in the experimental VECAS equipment results in sufficiently low power consumption that the entire miniaturized power supply occupies less than 140 cubic inches or about one fourth of the system package. This highly efficient switching regulator supply configuration is provided in a 115v, 47 Hz to 400 Hz input line model.

The remaining one quarter of the package volume contains the custom communication assemblies. The transmitter/receiver RF and IF package which has the full twenty-four frequency capability of the VECAS equipment requires less than 70 cubic inches as does the channel selection filters and detector assembly.

The complete VECAS-GA/M flight test unit less the pilots indicator is contained in a standard 3/4 ATR SHORT equipment case which is 7.6 x 12.6 x 7.5 inches.

2.2.8 Special Remitter Function

Since it is desirable during the flight tests to conduct tests of an additional member of the SECANT family, the REMITTER, which would be the minimum equipment required to fly in a cooperative airborne CAS environment. The GA/M flight test model contains provision to switch off all probing and related functions. These are the transmitted probes, correlation, tracking, threat logic and pilot display. Only the probe detection including altitude decoding and transmitted replies will function. The unit in this REMITTER mode will respond to any probe directed to its altitude and reply using the SECANT format to give altitude and identity information to the tracking aircraft.

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APPENDIX B

SECANT VECAS GA/M FLIGHT TEST PROGRAM OBJECTIVES

1. Determine the communication range and communication reliability.

2. Test the repeatability of the communication range and communication reliability data.

3. Determine the ability of the VECAS GA/M to derive the altitude difference of a target and specifically to correctly place the target as above or below and co-altitude or non-co-altitude or non-threatening altitude.

4. Determine and compare the ability of the VECAS GA/M and full VECAS to communicate with each other and provide complementary and correct avoidance maneuver commands.

5. Determine and evaluate the accuracy of hazard recognition, generation of warning and advisory information, suitability of avoidance maneuvers for Tau and minimum range warnings, and avoidance maneuver excursion.

6. Determine the ability of the VECAS GA/M to measure range and range rate to other SECANT equipped aircraft.

7. Determine for two aircraft encounters, generation of warning or advisory signals with aircraft in turning maneuvers.

8. Determine, for two aircraft encounters, generation of warning or advisory signals with aircraft ascending or desending.

9. Determine, for three aircraft encounters, the accuracy of hazard recognition of each intruder, the generation of warning and advisory information using the three aircraft logic, the suitability of advisory and command information, the suitability of avoidance maneuvers, and the avoidance maneuver excursion.

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APPENDIX C

SECTION 2.0

VECAS-GA/M SPECIFICATION

2.1 Power Output: ≥ 42 dBm

2.2 Receiver Sensitivity: ≤ -81 dBm below 10,000, ≤ -87 dBm above 10,000 foot altitude for 95% probability of measuring correct (para 2.4) altitude, range, range rate and identity with 50,000 probes per second per field above threshold, and 300,000 replies per second per field above threshold injected at the front end of the receiver. The 50,000/300,000 above threshold combination will be referred to throughout this document as SFL (Standard Fruit Level) and represents worst case conditions in the MITRE 1982 traffic model as established by RCA simulations.

2.3 Dynamic Range: The performance of paragraph 2.2 shall be met over a dynamic range of 60 dB below 10,000 feet (-81 to -21 dBm) and over 66 dB above 10,000 feet (-87 to -21 dBm).

2.4 Accuracy: The following accuracies shall be obtained with SFL injected with a VECAS-GA/M connected to the calibration generator at levels of -81 and -21 dBm below 10,000 feet and at -87 and -21 dBm above 10,000 feet:

Altitude:	same as the input (digitized in 100-foot steps)
Range:	mean < 300 feet (+0.5% of range), ~~standard deviation~~ < 300 feet
Range Rate:	mean < 5 knots (+1% of range rate), standard deviation < 30 knots
Identity:	same as that transmitted by the intruder

2.5 Alarm Display Consistency: For all range rates from -70 to +1000 knots with SFL injected and over the dynamic range of paragraph 2.3, once the TAU 2 threshold has been crossed (assuming the commands are not obeyed) the correct TAU 2 and TAU 1 alarms will be displayed with a probability of 99% updated every 4 seconds from the range corresponding to the initial TAU 2 threshold crossing to 0.5 nmi opening.

2.6 Round Time: Cycle time to completely correlate and track targets in all seven altitude zones, process the threatening targets through the threat logic and update the CAS display: ≤ 4 seconds.

2.7 False Alarm Rate with SFL:

TAU 2 - ≤ 10 alarms per 10,000 hours
TAU 1 - ≤ 1 alarm per 10,000 hours

2.8 False Alarm Rate with SFL and non-threatening targets and, false alarm rate with SFL and threatening targets (early or late alarms due to errors within the limits of paragraph 2.4 are not considered false alarms).

TAU 2 - ≤ 10 alarms per 10,000 hours
TAU 1 - ≤ 1 alarm per 10,000 hours

2.9 False Alarm Rate Acceptance Test: The VECAS-GA/M shall be designed to meet the False Alarm rates described in paragraphs 2.7 and 2.8. Due to the extensive testing required to obtain valid data, only acceptance tests to establish standard statistical data over 10 hours will be performed. The false alarm rate for the ten (10) hour test shall be zero. If this number is exceeded a failure analysis and corrective action shall be implemented.

2.10 Vibration: Reference 1.2, curve B (2g), figure 514.1 - two 15-minute cyclic scans of the frequency amplitude curve. Direction of the vibration through the vertical axis of the device; Device mounted on CFE rack with isolators. Devices shall operate properly during and after vibration.

2.11 Temperature: +32°F to +135°F - Devices shall operate without degradation over this ambient temperature range. Devices shall withstand cold soak at 0°F for 12 hours and then operate properly within 5 minutes after application of power. Cooling will be provided by a fan which will draw air through openings in the rear across the IC boards, power supply, and the transmitter and two receivers through the front of the device.

2.12 Failure Rate: To be considered flight worthy for purposes of evaluation, the equipment shall have a minimum MTBF of 50 hours. Prior to delivery and acceptance tests, the contractor shall be responsible for debugging and operating the equipment a sufficient number of hours to eliminate the early failures. During acceptance tests by NAVAIRDEVCEN, the equipment shall not experience greater than two failures in 80 hours of testing. If this number is exceeded, failure analysis and corrective action shall be implemented before resumption of testing.

2.13 Reply to own probes accompanied by receipt of those replies due to signal reflection from ground, water or other structures: design of system logic shall be such that at any altitude over any reflecting surface, the replies will not be processed in the threat logic. This problem area is discussed in reference 1.3.

2.14 Adjacent Channel Rejection: Shall be such that at any level over the dynamic range of paragraph 2.3, a video reply signal in the desired data channel shall result in a signal in the undesired data channel which is 70 percent or less than the threshold of the undesired data channel.

2.15 Size: ≤ 3/4 short ATR
≤ 20 pounds

2.16 Co-Range Targets: Under all the conditions of paragraphs 2.2, 2.3, and 2.4, two targets which are within 650 feet of each other shall be correctly tracked and processed through the threat logic regardless of the altitude separation between the targets.

2.17 General: All of the foregoing specifications are in addition to those contained in reference 1.1, and shall govern if in conflict with reference 1.1.

ACTION

RECEIVED

1975 SEP 30

☑ ACTION	☐ COG ☐ INFO
	601
60	602
60A	603
60B	604
60-3	605
60-4	606
60-5	607
60-6	DF.......
60-7	MF.......
60-8	FU.......
60-9	

RTTUZYUW RUEOGBA1969 2731748-UUUU--RUEODQA.
ZNR UUUUU
R 301724Z SEP 75
FM FAA WASHDC
TO COMMANDER NAVAL AIR DEVELOPMENT CENTER WARMINSTER PA
PA
BT
UNCLAS
RE INTER-AGENCY AGREEMENT DOT-FA72WAI-302 AND TELECON
BETWEEN MESSRS. SHAMES AND HINDS, NADC AND BRENNAN,
FAA/ARD-212, SECANT VECAS GA/M ACCEPTANCE TEST
PROCEDURE REVISION I, PARAGRAPH 1.5.5 AND 2.12. IN LIEU
OR REQUIREMENTS OF ABOVE PARAGRAPHS, EQUIPMENT
ACCEPTABLE IF REQUIREMENT OF PARAGRAPH 2.12 MET WITH
FRUIT LEVEL OF 19,000 PROBES/SEC/FIELD AND 211,000 REPLIES/
SEC/FIELD ABOVE THRESHOLD. HONECK, ALG-311
BT
#1969

NNNN

ACTION

01 OCT 1975

TOR: 301822Z/MC/JW
ACT: 60

R 301724Z SEP 75