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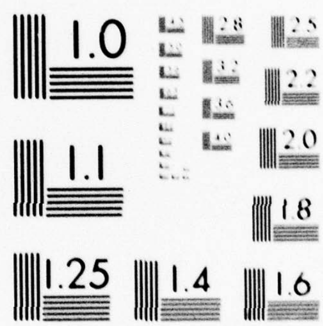

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Report No. FAA-RD-78-153

LEVEL II

OPERATIONAL EVALUATION OF AN OPTICAL INFRARED AIRBORNE PROXIMITY WARNING INDICATOR (APWI).

ERNEST LUCIER

December 1978

Final Report.

Apr 76 - Aug 77

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16. Abstract

This report summarizes the results of an operational evaluation conducted between April 1976 and August 1977 by general aviation pilots on an Airborne Proximity Warning Indicator (APWI). The APWI evaluated was a Rock Avionic Systems unit which was produced by the Scientific Prototype Manufacturing Company. The FAA conducted an operational evaluation of the Rock Avionic APWI using four systems installed in general aviation aircraft. The evaluation produced results consisting of questionnaires completed by the general aviation pilots who flew the system.

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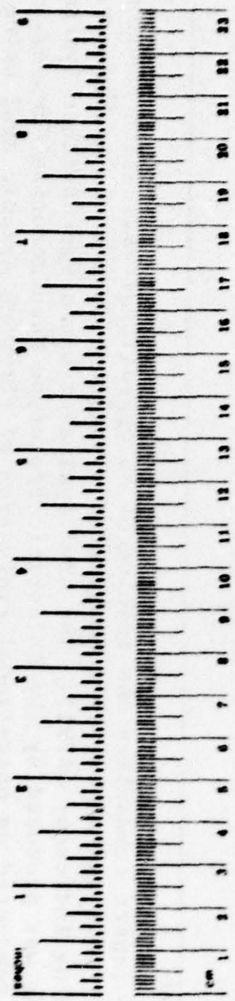
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

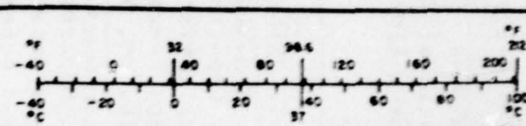
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

The purpose of the report is to summarize the results of an operational evaluation conducted between April 1976 and August 1977 by general aviation pilots on an Airborne Proximity Warning Indicator (APWI). The APWI evaluated was a Rock Avionic Systems unit which was produced by the Scientific Prototype Manufacturing Company. The Rock Avionic's APWI was commercially available at the time of the evaluation.

1.1 Background

The development of APWI systems has been in response to the problem of midair collisions and near midair collisions within various segments of the airspace. In the search for systems that could effectively eliminate or significantly reduce this threat, many systems were examined including both ground and airborne based solutions. These solutions included various electronic devices that ranged from detection and alert capabilities only (i.e., primarily warning indicators) through alert and locate capabilities, to the inclusion of maneuver commands to avoid a potential collision (i.e., Collision Avoidance Systems). Among this group of candidate solutions, a number filtered through as being worthy of further exploration. Proximity Warning Indicators (PWI's) were selected as one of those solutions.

In general, PWI systems can be either ground-based or airborne-based and are designed to alert pilots to the presence of other aircraft in the immediate area. Depending on the type of sensor and associated equipment, the pilot can be provided a simple proximity warning in the form of an alert only, or more complete information such as bearing, altitude and heading to aid the pilot in locating the proximate aircraft. Some PWI systems go further by filtering the sensor information so that the position information is provided only on aircraft that are potential collision threats rather than just in proximity. PWI's do not, however, provide maneuver information.

The Rock Avionic system is a completely airborne system using infrared (IR) technology to provide a proximity alert with the approximate bearing of the threat aircraft given in 60^{o} sectors.

The requirement for the evaluation of this APWI was generated by the National Transportation Safety Board (NTSB) in a letter to the FAA on October 16, 1974, recommending that the FAA "should conduct sufficient tests to determine the effectiveness of the supposedly improved system (Rock Avionic Systems)." The FAA's response to NTSB on November 22, 1974, indicated that "we (FAA) will now consider what additional test activity could validate the benefits of an IR PWI in the traffic patterns of uncontrolled airports."

In response to the NTSB recommendation, the FAA conducted an operational evaluation of the Rock Avionic APWI using four systems installed in general aviation aircraft. The evaluation period for each system lasted one year and produced results consisting of questionnaires completed by the general aviation pilots who flew the system.

1.2 Project Objectives

The principal objective of this project was to acquire operational data on the Rock APWI in a general aviation environment which would permit the user community to determine the usefulness and utility of the device for various traffic densities, in both controlled and uncontrolled airports. An equally important objective is to obtain an indication of user acceptance of this type of device.

The data collection effort included questions to qualitatively determine technical factors including range, accuracy, false alarm rate, missed alarm rate, alarm volume and detection characteristic.

1.3 System Description*

The Rock Avionic APWI system uses electro-optics to passively sense the near-infrared energy emmitted by aircraft strobe anti-collision lights. The strobe anti-collision light is of the type generally available and currently used on air carrier, military and some general aviation aircraft. The system consists of two solid state wing-tip sensors an optional tail sensor, a signal processor and a panel indicator. The elements of the system and their typical positioning in a general aviation aircraft are depicted in figure 1.

The operation of the signal processor is completely automatic and, therefore, can be located in an area remote from the cockpit. It is connected by cable to the other system elements, it receives input data from the wing tip (and, if installed, the optional tail sensors) and delivers appropriate control signals to the cockpit, flashing the sector lights on the panel indicator and activating a beeping alert tone.

The panel indicator is mounted in the cockpit control panel. It permits the pilot to monitor the display while also attending to other cockpit duties. Its circular dial is divided into six 60° sectors that coincide with the clock positions generally used to indicate direction of visual sightings. The two sectors to the right of 12 o'clock are defined as the 1 o'clock and 3 o'clock sectors, respectively; the two sectors to the left of 12 o'clock are defined as the 9 o'clock and 11 o'clock sectors, respectively. (The 5 o'clock and 7 o'clock sectors are reserved for the optional tail sensor that, when installed, will provide a system that completely encircles the aircraft). Each sector occupied by an intruder aircraft will flash.

*Reference "Operator's Instruction Manual, Aircraft Proximity Warning Indicator," Rock Avionic Systems, Inc.

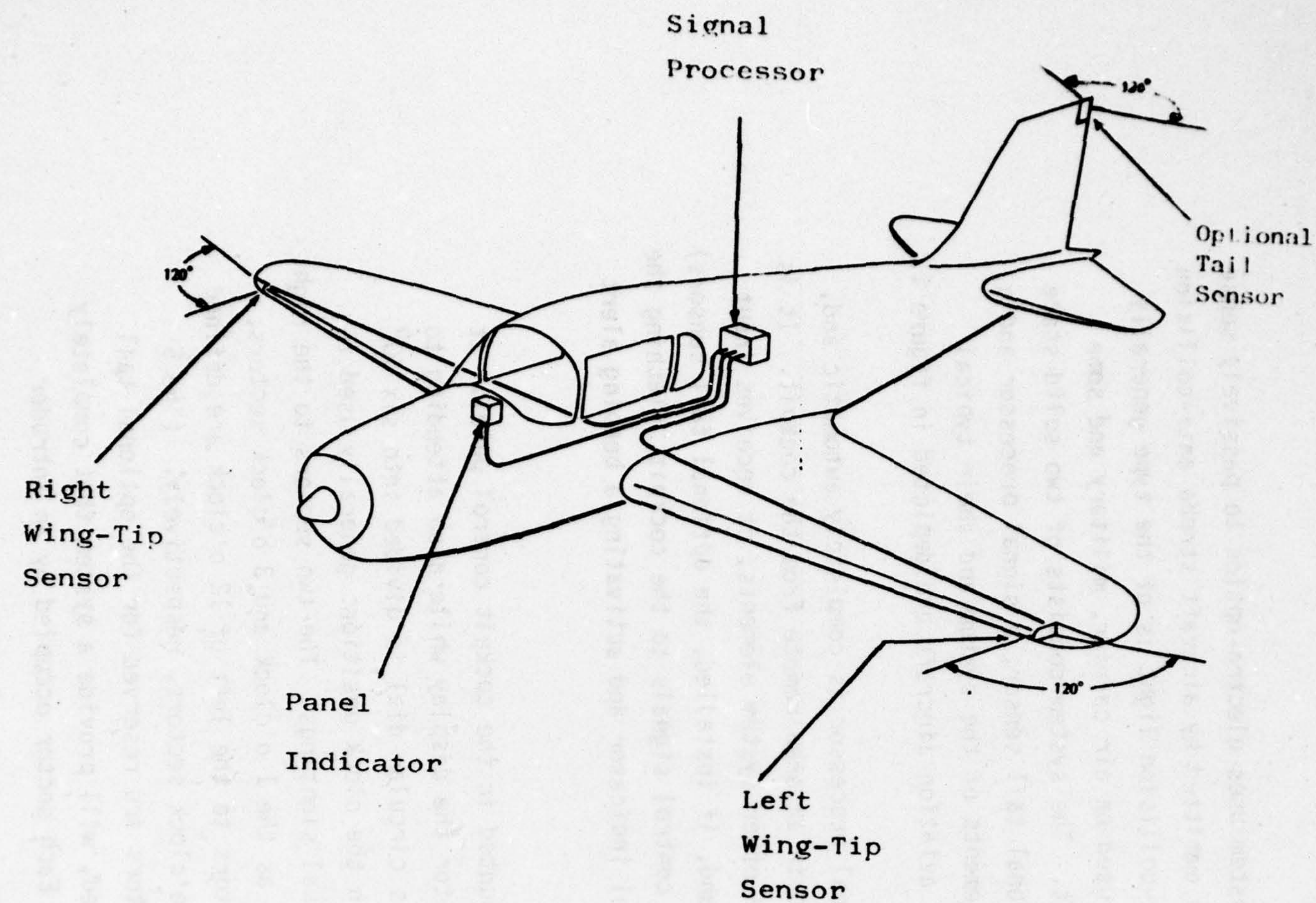


Figure 1: Location of APWI System Elements

As shown in figure 2, the panel indicator contains a single operating control, a toggle switch with three positions: an off (down) position, a self check/high sensitivity (center) position and a low sensitivity (up) position. The automatic self check feature is energized whenever the operating control is moved to the center, or high sensitivity, position. If the system is functioning properly all sectors will flash simultaneously six times and then automatically go into its high sensitivity mode of operation. An additional feature of the display is a photo sensor that automatically dims the intensity of the sector flashing as cockpit lighting conditions vary from day to night. In the low sensitivity position, system sensitivity is reduced and only strobe light infrared emissions up to approximately 1/2 mile distant will be processed. The low sensitivity indicator at the center of the display will glow red for as long as the switch remains in this position.

In the center of the indicator is a white two-inch circular dial which includes the six 60° sectors previously discussed. These comprise the four forward warning sectors and the two optional rearward warning sectors. When one or more of these sectors light and flash in synchronism with the beeper tone in the cockpit speaker, the presence of intruding aircraft flying parallel to, or across the flight path, is indicated. The aircraft may be visually acquired by looking in the direction indicated by the flashing sector.

The wing-tip (and optional tail) sensors are electro-optical and installed within the contours of each of the aircraft's wing tips. These sensors detect the infrared energy emitted by the high intensity strobe lights of other aircraft and respond with corresponding electrical output signals. These signals are applied, via an interconnecting cable, to the signal processor for analysis. Each sensor provides a 120 degree segment of horizontal coverage, with respect to the aircraft's nose, and an elevation (vertical) resolution of plus or minus 10° as illustrated in figure 3.

A summary of the pertinent technical data of the system is presented in table 1

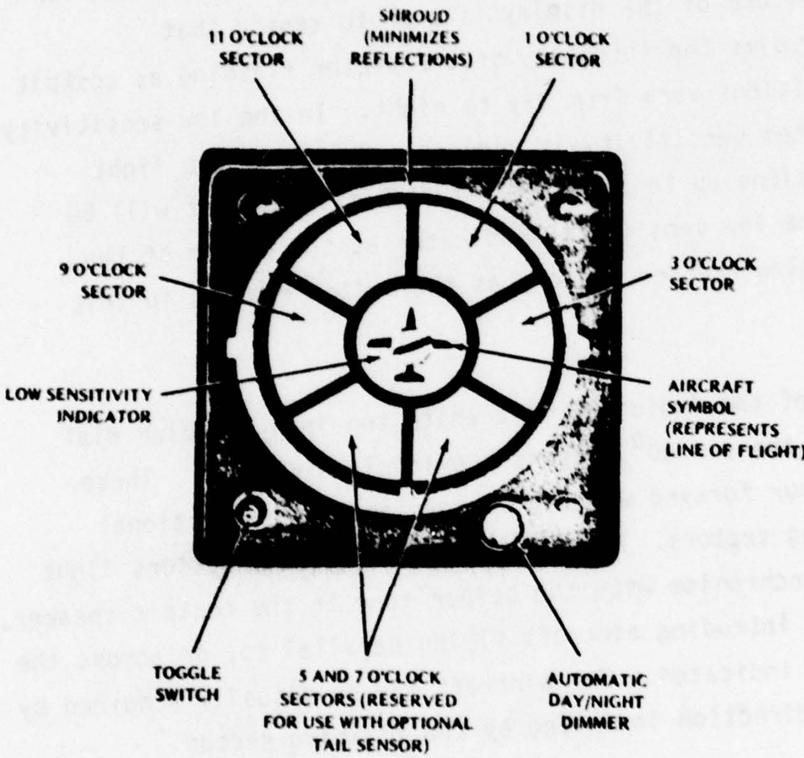
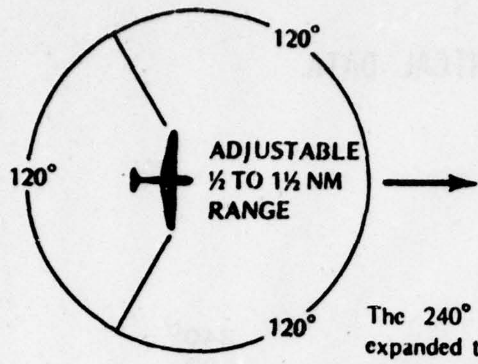


Figure 2: Panel Indicator

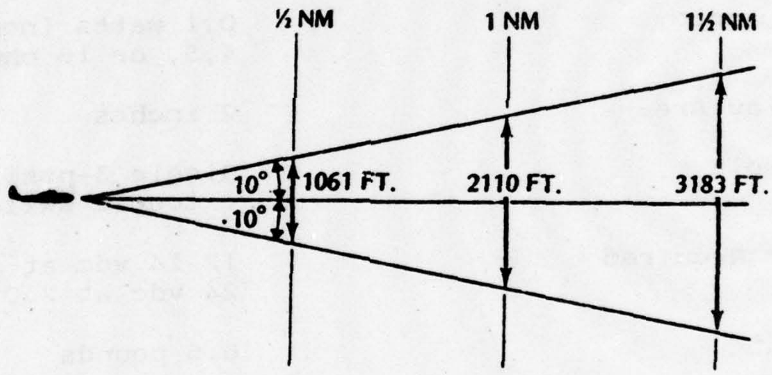
HORIZONTAL SCAN



The 240° forward coverage can be expanded to full circle protection with an optional Tail Sensor.

VERTICAL SCAN

Range adjusts from 1-1/2 miles for cruising to 1/2 mile for high density traffic.
Red light alerts pilot when low range is in use.



At 1-1/2 miles, the Rock Avionic APWI covers quarter-mile-high sectors above and below your airplane extending 120° on either side of the nose, or in a complete circle with an optional tail sensor. Nearby aircraft that will pass safely above or below your flight path are ignored.

Figure 3: APWI Horizontal and Vertical Coverage

TECHNICAL DATA

Area Coverage	
Horizontal*	240°
Resolution	60°
Elevation	$\pm 10^\circ$
Detection Range	1/2 to 1-1/2 miles (maximum)
Outputs	
Visual	Segmented 60° sectors
Audio	0.1 watts (nom.) into 4,8, or 16 ohms
Display Area	2 inches
Controls	Single 3-position toggle switch
Power Required	12-14 vdc at 1.5 amps. 24 vdc at 2.0 amps.
Weight	6.5 pounds
Dimensions	
Panel Indicator	2-9/16" x 2-9/16" x 1-5/8"
Sensors	2-7/8" x 4-3/4" x 2-13/16"
Signal Processor	6-3/4" x 7-11/16" x 4-15/16"

*360° horizontal coverage with optional tail sensor.

TABLE 1

1.4 Laboratory Tests

Laboratory tests were conducted by the Transportation System Center (TSC) on the Rock System. These tests investigated the beam pattern, noise susceptibility, multiple target capability and sensitivity. An earlier version of this system had demonstrated negative characteristics in these areas. These tests were to isolate any inherent characteristics in the equipment that would show up under operational testing. These tests showed that the Rock System had relatively good range uniformity over the field of view and that spurious alarms would not interfere with an operational flight test of this equipment. The results of the TSC laboratory tests are included in Appendix A for completeness.

2.0 OPERATIONAL FLIGHT TEST RESULTS

2.1 Data Acquisition Program

The objective of this evaluation program was to determine the usefulness, utility and user acceptance of the Rock APWI system for various traffic densities in both controlled and uncontrolled environments. The objective of the data acquisition flight program was to acquire operational data representative of conditions at and about typical general aviation airports, both controlled and uncontrolled.

This program was a minimal cost effort to obtain user response to the Rock Avionic Systems, APWI an optical-infrared aircraft strobe light detection device used as a proximity warning system. The program consisted of five separate small contracts, one with the manufacturer and four with the aircraft owners. The data acquisition effort consisted of questionnaires to be completed by the participating pilots after having used the system. These questionnaires (See Appendix B, Post Flight Questionnaires) were distributed at the beginning of the contract along with franked envelopes addressed to the responsible FAA project office. The pilots were to mail completed questionnaires after flying with the system. The information collected from these questionnaires is contained in Section 2.2.

The aircraft in which the equipments were installed are

a) a Cessna 172 owned by a private pilot and based at Freeway Airport, Maryland,

b) a Cessna 172 owned by a fixed base operator (FBO) based at Islip, New York

c) a Cessna 182 owned by an FBO at Gaithersburg, Maryland

d) a Piper 180 privately owned by five pilots and based at Hagerstown, Maryland.

The pilots participating in this program included general aviation and instructor pilots with private, commercial or airline transport certificates. About half of the pilots had their instrument rating and most flew over 200 hours per year. The majority of the operational flights were conducted under VFR conditions with about half of the flights operating from controlled airports. The Rock APWI system was assembled, tested and installed by the manufacturer, Scientific Prototype Mfg. Corp. of New York, New York. The manufacturer was contracted to install, maintain, repair, and remove the APWI Systems during the period encompassing the four contracts with the aircraft owners. The owners were contracted and briefed to use the equipment in a normal manner, evaluate the system and report their findings by filling out questionnaires provided by the FAA during the period of the contracts.

The manufacturer arranged for installation at Wiggins Airways Inc. of Norwood, Massachusetts and performed acceptance tests on the two Cessna 172's, the Cessna 182 and the Piper 180. All three Cessnas are highwing aircraft with the Piper 180 being a low wing aircraft.

In the beginning, three of the units worked satisfactorily with minimum maintenance. The fourth unit failed during the flight to the operating base of the owner and during the program continued to require excessive maintenance.

This was primarily due to the "own strobe" lockout feature. This particular aircraft has non-synchronous wing tip strobes and this configuration imposes severe limits on the system. The strobe lights could have been synchronized but this was deemed not advisable, since many aircraft have non-synchronous strobes.

The aircraft at Freeway airport was moved to Gaithersburg, Maryland during the course of the program. Check flights were made during this period with FAA personnel and the equipment appeared to be operating correctly. However, at the end of the contract period the equipment could not be made to work for a demonstration ride.

The aircraft at Islip resulted in the most pilot responses of the questionnaire because of the lease operation. However, during the course of this contract the aircraft was sold. Fortunately, the aircraft was leased back to the FBO and the test continued uninterrupted.

The FBO owned aircraft at Gaithersburg was sold to a private pilot early in the test period. The new owner assumed the obligations of the contract. However, this meant only one pilot would be flying this aircraft instead of numerous pilots in the leased operation. Due to the particular strobe light configuration on this aircraft considerable difficulty was experienced in obtaining satisfactory operation. The designer made several trips to Gaithersburg to maintain this unit. A ground check of the system was made three months after installation and the strobe lockout feature was inoperative. Investigation showed one of the lockout sensors was not working and a "light tube" on the second lockout unit was missing. The aircraft was flown to New York to permit the maintenance contractor to use shop test equipment to correct this lock out circuitry and replace the missing "light tube." The equipment was not repaired on that trip and necessitated a trip by the manufacturer to Gaithersburg. The equipment failed again and was, subsequently, removed per request of the owner.

The system on the aircraft at Hagerstown, Maryland worked satisfactorily during the course of the contract.

2.2 Results of Post Flight Questionnaire

The number of questionaires completed and their relationship to aircraft, number of pilots, and airports where they were based are presented in Table 2. Questionnaires supplied by the FAA were received from pilots of each of the aircraft indicating that user acceptance of the system is good when the system works properly. The subjective impressions of the pilots and their operational experiences were obtained from the completed questionnaires and are summarized in the following paragraphs:

1. A number of pilots expressed dissatisfaction with this particular piece of equipment because of its false alarms and unreliable operation. Some turned off the APWI because of the high frequency of alarms. These pilots all operated from a Long Island, New York airport and they felt that reflections off the water were a particular problem. One pilot didn't turn the system on because the aural warnings were reported to be excessive by other pilots.

2. A number of equipments experienced operational difficulty and required excessive service. One pilot requested the equipment be removed from his airplane because it did not work. Others expressed a desire for increased reliability in this equipment.

3. One pilot did discover an application that was not part of the design. During a final approach, in IFR conditions, the APWI warning was activated by the flashing strobes at the airport before the pilot could see them. The lighted sector correctly indicated the pilot was left of the final approach course.

These results did not appear to reflect all of the information available from this program. The design of this questionnaire and the lack of more substantive comments on the completed questionnaires did not permit meeting the program objectives. To gather more information a second questionnaire, a Post Experiment Questionnaire (Appendix C) was created.

TABLE 2: NUMBER OF AIRCRAFT QUESTIONNAIRES

AIRCRAFT	AIRPORT	AIRPORT TYPE/ DENSITY OF TRAFFIC	No. OF QUESTIONNAIRES COMPLETED		COMMENTS
			POST FLIGHT	POST EXPERIMENT	
Cessna 172	Freeway Airport, Maryland Subsequently moved to Montgomery County Airport Gaithersburg, Maryland	Non Tower/ Medium Density GA	2	1	Privately Owned Aircraft
Cessna 172	Long Island Mac Arthur Airport Islip, New York	Tower/High Density GA	11	4	Leased Aircraft Through FBO
Cessna 182	Montgomery County Airport Gaithersburg, Maryland	Non/Tower Medium Density GA	2	no usable data	Originally Leased but sold to a private owner and removal was requested by the owner because of Excessive Maintenance Requirements.
Piper 180	Hagerstown Regional Airport Hagerstown, Maryland	Tower/ Low Denisty GA	4	4	Privately owned Aircraft by five Pilots

The questionnaire was hand carried to all of the available pilots that had participated in the program. The data collected from the Post Experiment Questionnaire is contained in Section 2.3.

2.3 Results of the Post-Experiment Questionnaire

Table 2 in Section 2.2 contains information on the numbers of questionaires completed and their relationship to the aircraft and airports where they were based. The subjective impressions of the pilots and their operational experiences as obtained from the completed Post-Experiment Questionnaires are summarized in the following paragraphs:

1. One pilot said the APWI was too sensitive because the warnings occured in the airport pattern. His APWI was alarming from the strobe lights of aircraft on the ground. As a consequence he turned the APWI off in the pattern.

2. As a group, the pilots found the APWI to be more useful at visibilities less than 10 miles (i.e., relatively good VFR condition.)

3. One pilot shut the APWI off because "the alarm went off all of the time."

4. Alerts occurred for which the pilots did not observe any aircraft.

5. The system interfered with flying because of the false alarms and the difficulty in interpreting the slowly flashing display. The difficulty in interpreting the flashing display occured when a pilot made a quick glance at the flashing display and found the display in the off part of its alarm cycle (1 second on and 1 second off) with the sector not visable to the pilot.

When the beeping tone is sounded, it would draw the pilot's attention to the display; however, by the time the pilot turned his attention to the display the light had gone off. The pilot made the suggestion of alternating the sound and light alarms.

6. One pilot expressed the opinion that a pilot should have all the help possible, especially in the proximity of larger airports.

7. Operation was better on top of overcast.

8. Most pilots thought the APWI would be most useful in cruise flight.

9. Some pilots expressed the opinion that decreasing the vertical look angle (currently $\pm 10^{o}$ from the horizontal plane) would decrease false alarms in the pattern from aircraft on the ground.

10. None of the pilots reported any changes in their flying procedures as a result of the APWI.

11. Most pilots agreed with the indicated APWI sixty degree sector when a visually acquired aircraft was identified with the alarm.

12. Most of the pilots that used the APWI turned the equipment on for more than 75 percent of their flying.

13. The APWI did alert the pilots to other aircraft of which they were not aware. Two pilots felt that the equipment had prevented them from having a midair collision.

14. All of the pilots believe that they have less than five near misses per year.

15. About half of the pilots would like to have this equipment in all aircraft they fly. The pilots who did not want the equipment expressed dissatisfaction with the reliability and the false alarms.

16. The pilots suggested that a complete PWI service should provide the following information on proximate aircraft:

   . Range

   . Altitude

   . Course (Heading)

   . Bearing

   Range rate (i.e., rate of closing) and velocity were also indicated but not as strongly.

17. Less than half of the pilots had maneuvered on the basis of a warning and when they did a horizontal maneuver was preferred.

18. Most of the pilots felt they needed a warning at greater than ten seconds and a range greater than one mile to avoid another aircraft.

19. Recommendations for improving the system included:

   . decrease the vertical coverage

   . decrease false alarms

   . increase reliability

   Only one pilot had flown another APWI system; but, no comparative comments were made.

3.0 Summary and Conclusion

The operational flight tests produced significant qualitative results in the form of the subjective judgements of general aviation pilots. The majority of the operational data collected can be summarized as follows:

1. The Rock Avionics PWI did serve to alert the pilots to the presence of aircraft of which they were not aware; however,

   a) the high alarm rate detracted from the utility of the Rock System around airports with a high level of activity, and

   b) the false alarm rate was found objectionable by a significant number of pilots in both high and low density airspace.

2. After considering the limitation associated with and benefits to be derived from the Rock Avionic APWI, approximately one half of the pilots responding to the questionnaire indicated that they would like to have the equipment in all aircraft they fly. The pilots responding also indicated that the utility of the Rock Avionic system would be significantly increased by increasing the equipment reliability and decreasing the false alarm rate.

APPENDIX A

LABORATORY TEST OF ROCK

AVIONICS APWI

(Section 3 From Airborne Proxmity Warning Instrument Laboratory Test, Report No. FAA-RD-77-5 January 1977.)

3. PERFORMANCE OF TEST

Tests were conducted on the Rock System in four areas: Beam Pattern; Noise Susceptibility; Multiple Target Capability; and Sensitivity. The test setup is shown in Figure 1; the results are shown in Figure 2.

The Rock Avionics designers accomplished this breakthrough by the application to a commercial product of a principle described in the literature as "channel-optics" and hitherto used only in specialized laboratory devices. The advantage of this approach is that while it provides the signal enhancing properties of large aperture, it is non-imaging and thus is capable of sensing signals while exposed to direct sunlight.

Physically, the sensor consists of a plastic precision cast cylinder lens, which operates in the refractive mode in elevation and in the reflective mode in azimuth, by virtue of an external coating on the four sides. The back portion of the solid lens contains the silicon diode, which forms the active part of the sensor. The sensor assembly also contains the preamplifier, which determines the system's bandwidth and provides the signals to the logic, noise control and threshold circuits.

The signal processing unit contains a novel application of computer technology to the task of signal discrimination. It is not described here because of its proprietary nature, but was tested for proper functioning.

3.1 PATTERN

The most extensive test performed concerned the sensor pattern of the system. An optical bench was set up, as shown in Figure 1. The light from an anticollision strobe was collimated so that a 3 inch diameter beam was formed. A sensor head was mounted on a double rotary head, permitting its orientation with respect to the beam through arcs of ±65° and ±6°. The test flash was directed through the center of a reflective screen, which was illuminated

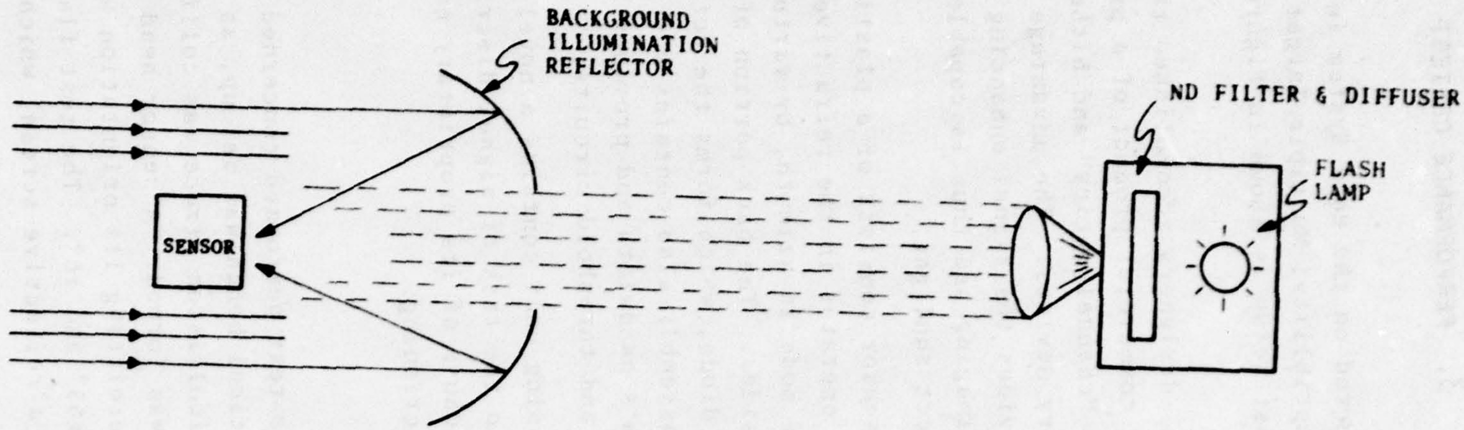


Figure 1. Basic Test Setup

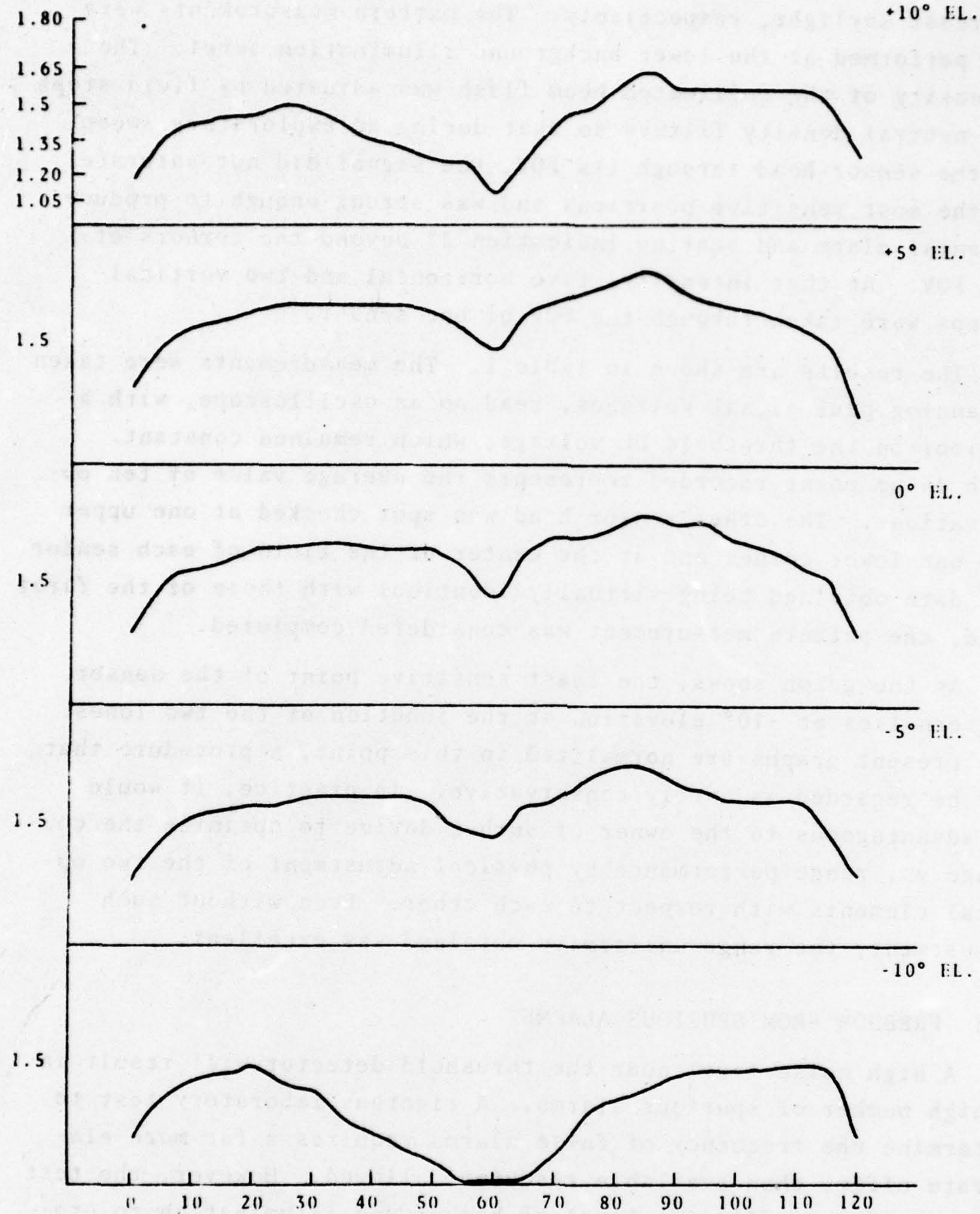


Figure 2. RANGE Variation vs Azimuth (Normalized)

alternately with a 100 watt desk lamp, and a 500 watt projection lamp, providing illumination levels comparable to light dusk and overcast daylight, respectively. The pattern measurements were all performed at the lower background illumination level. The intensity of the collimated beam flash was adjusted by field stops and neutral density filters so that during an exploratory sweep of the sensor head through its FOV, the signal did not saturate in the most sensitive positions and was strong enough to produce an aural alarm and bearing indication 2° beyond the corners of the FOV. At that intensity, five horizontal and two vertical sweeps were taken through the FOV of one sensor.

The results are shown in Table 1. The measurements were taken as analog peak signal voltages, read on an oscilloscope, with a monitor on the threshold DC voltage, which remained constant. Each datum point recorded represents the average value of ten observations. The other sensor head was spot checked at one upper and one lower corner and at the center of the field of each sensor. The data obtained being virtually identical with those of the first head, the pattern measurement was considered completed.

As the graph shows, the least sensitive point of the sensor pattern lies at -10° elevation at the junction of the two lobes. The present graphs are normalized to this point, a procedure that may be regarded as overly conservative. In practice, it would be advantageous to the owner of such a device to optimize the coverage vs. range performance by physical adjustment of the two optical elements with respect to each other. Even without such adjustment, the range uniformity obtained was excellent.

3.2 FREEDOM FROM SPURIOUS ALARMS

A high noise level near the threshold detector will result in a high number of spurious alarms. A rigorous laboratory test to determine the frequency of false alarms requires a far more elaborate effort than available resources allowed. However, the test did provide a sufficient level of background illumination to provide reasonable assurance that under normal sky-illumination (1000 ft. lamberts) the spurious alarm rate should be low. During the

TABLE 1. DIRECTION SENSITIVITY BEARING ANGLE VERSUS MILLIVOLTS

Azimuth Angle	+10°	+5°	±0°	-5°	-10°
0	24	30	30	28	24
5	32	39	39	36	32
10	35	42	42	40	35
15	36	44	44	42	37
20	37	46	46	43	38
25	38	48	48	44	36
30	37	48	49	45	34
35	34	48	49	45	28
40	32	48	48	45	26
45	30	48	47	45	23
50	29	46	47	43	21
55	28	42	42	41	16
060	22	38	36	36	15
65	29	46	46	43	19
70	35	49	50	45	22
75	38	52	50	50	29
80	43	53	52	52	32
85	45	55	54	52	34
90	42	52	52	48	36
95	42	50	52	46	37
100	42	47	48	44	37
105	42	46	47	44	38
110	42	43	45	44	39
115	38	39	40	42	37
120	24	25	28	28	24

test, false alarms did not occur. The peak noise level, whenever observed, never exceeded 35-50 millivolt (at a threshold level of one volt). We must note, however, that background illumination is not the only source of noise. It can be stated that, on the basis of the remarkably noise free behavior under normal test conditions, and the corroborating statements of the manufacturer about the behavior of the instrument in a flight environment, that the chances for a successful flight test are not likely to be diminished by a high incidence of false alarms.

3.3 MULTIPLE TARGET CAPABILITY

While the unit was exposed to a series of flashes from an angle of about 10°, a second, non-synchronous flash source was energized, from an angle of about 110°. Both sectors indicated targets as required. Movement of the second source through the 100° arc toward the first source resulted in a double aural alarm, again as specified. This test demonstrated the required multiple target capability and should prove quite satisfactory in flight tests, as reported by the manufacturer.

3.4 ESTIMATE OF SENSITIVITY

The laboratory test of the Rock Avionics APWI did not permit a precise sensitivity test because the spectral transmission of the Infra red filter that forms part of the unit's optical system is unknown. In any event, the range of the device is a statistical measure depending on the illumination level and must be determined in a flight environment since the threshold voltage is a function of the total electronic noise level. The general performance of the device in the laboratory lends significant weight to the credibility of the manufacturer, who represents the instrument as attaining an operational range of 1.5 miles.

APPENDIX B

APWI Post Flight Questionnaire

N________ Date:

APWI POST FLIGHT QUESTIONNAIRE

1. Pilot Certificate: Student Private Commercial

   Airline Transport Military Pilot

2. Instrument Rating? (check, if yes)

3. Type of Flight Plan: VFR IFR

4. Flight Route and Altitude ____

   ____

5. Flight Duration ____

6. General Weather Description ____

   ____

7. Number of APWI Warnings:

   Lo Range; None; Few-Qty________; Many-Qty_______;

   Hi Range; None; Few-Qty________; Many-Qty_______;

8. Number of These Aircraft Actually Seen:

   Lo Range: None; Few-Qty________; Many-Qty_______;

   Hi Range: None; Few-Qty________; Many-Qty_______;

9. Were There Occasions When Alarmed for No Apparent Reason?

   Never Occasionally-Qty _______; Frequently-Qty_______;

10. When Alarmed and You Visually Detected, Did You Generally Agree with the APWI Sector:

    Yes; No;

11. Number of Multiple Aircraft Detections (more than one sector lighted)

    Lo Range: None; Few-Qty________; Many-Qty_______;

    Hi Range: None; Few-Qty________; Many-Qty_______;

12. General Operational Comments ____

    ____

Appendix C

APWI Post Experiment Questionnaire

APWI POST EXPERIMENT QUESTIONNAIRE

1. NAME

2. PLANE TYPE

3. PILOT CERTIFICATE:

   ☐ STUDENT

   ☐ PRIVATE

   ☐ COMMERCIAL

   ☐ AIRLINE TRANSPORT

   ☐ MILITARY PILOT

4. APPROXIMATELY HOW MANY HOURS DO YOU FLY PER YEAR?

   ☐ Less than 100

   ☐ 100 to 200

   ☐ Greater than 200

5. INSTRUMENT RATING

   ☐ Yes

   ☐ No

6. APWI USED WITH FLIGHT PLANS

   ☐ VFR

   ☐ IFR

   ☐ Other ______________________

7. USUAL AREA OF OPERATION?

   ☐ Uncontrolled airport

   ☐ Controlled airport

   ☐ Approach

   ☐ En route

8. DID YOU FIND THE APWI TO BE MORE USEFUL IN SPECIFIC LEVELS OF VISIBILITY?

☐ NO

☐ YES

☐ Greater than 10 miles

☐ Between 5 and 10 miles

☐ Less than 5 miles

9. LIGHT CONDITIONS

☐ Dawn

☐ Day

☐ Dusk

☐ Night

10. WEATHER

☐ Overcast

☐ Haze

☐ Clear

11. ALARMS

☐ No

☐ Yes

☐ Aircraft seen before (always, sometimes, never)

☐ Aircraft seen after (always, sometimes, never)

☐ Aircraft not seen (always, sometimes, never)

12. WHEN ALARMED AND AIRCRAFT VISUALLY ACQUIRED, DID YOU USUALLY AGREE WITH THE APWI SECTOR?

☐ Yes

☐ No

13. APPROXIMATELY WHAT PERCENT OF THE TIME DID YOU USE THE APWI WHEN PILOTING THE AIRCRAFT?

- [ ] 100 Percent
- [ ] 90 - 100 Percent
- [ ] 75 - 90 Percent
- [ ] 50 - 75 Percent
- [ ] Less than 50 Percent

14. APPROXIMATELY HOW MANY TIMES HAS THE APWI ALERTED YOU TO OTHER AIRCRAFT OF WHICH YOU WERE NOT AWARE?

☐ 0		☐ 0 to 10%
☐ 1		☐ 11 to 20%
☐ 2	OR	☐ 21 to 30%
☐ 3		☐ 31 to 40%
☐ 4		☐ 41 to 50%
☐ 5 or more		☐ greater than 50%

15. IN YOUR OPINION, HAS THE APWI PREVENTED YOU FROM HAVING A MIDAIR COLLISION; NUMBER OF TIMES

☐ 0	☐ 3
☐ 1	☐ 4
☐ 2	☐ 5 or more

16. WHAT PERCENT OF THE TIME DID THE APWI APPEAR TO WORK?

☐ 75 to 100%	☐ 25 to 50%
☐ 50 to 75%	☐ 0 to 25%

17. DID THE APWI INTERFERE WITH FLYING?

- [ ] No
- [ ] Yes

How? ____________________

18. APPROXIMATELY HOW MANY NEAR MISSES PER YEAR DO YOU HAVE?

- [ ] 0
- [ ] 1 to 4
- [ ] 5 or greater

19. WOULD YOU LIKE TO HAVE THIS EQUIPMENT IN ALL AIRCRAFT YOU FLY?

- [ ] Yes
- [ ] No

WHY? ______________________________

____

____

20. WHAT PHASE OF FLIGHT DO YOU THINK AN APWI WOULD BE MOST USEFUL?

- [ ] Taxi
- [ ] Takeoff
- [ ] Climb
- [ ] Cruise
- [ ] Descent
- [ ] Holding
- [ ] Traffic pattern
- [ ] Approach
- [ ] Landing
- [ ] Missed approach

21. WHAT IS THE MINIMUM AMOUNT OF INFORMATION YOU WOULD WANT ON A THREAT AIRCRAFT?

- [ ] Range
- [ ] Range rate (Rate of closing)
- [ ] Altitude
- [ ] Vertical Speed
- [ ] Course (Heading)
- [ ] Velocity
- [ ] Area of closest approach
- [ ] Bearing
- [ ] Type aircraft (e.g., small, light twin, or air carrier)
- [ ] Other

22. DID ANY OF THE WARNINGS APPEAR TO BE INCORRECT?

☐ Yes

☐ No

23. HOW MUCH TIME DO YOU FEEL YOU NEED TO AVOID ANOTHER AIRCRAFT?

Single	Multi	
☐	☐	3 to 4 seconds
☐	☐	5 to 9 seconds
☐	☐	10 to 14 seconds
☐	☐	15 to 19 seconds
☐	☐	20 to 25 seconds

24. DID YOU MANEUVER ON THE BASIS OF ANY WARNINGS?

☐ Vertical

☐ Horizontal

☐ No

25. AT WHAT RANGE WOULD YOU LIKE TO BE WARNED OF THE PROXIMITY OF ANOTHER AIRCRAFT?

☐ Less than 1/4 mile

☐ 1/4 to 1/2 mile

☐ 1/2 to 1 mile

☐ 1 to 2 miles

☐ 2 to 4 miles

☐ Greater than 4 miles

26. WHAT RECOMMENDATIONS WOULD YOU MAKE FOR IMPROVING AN APWI?

27. WERE THERE ANY CHANGES IN YOUR FLYING PROCEDURES WHEN YOU USED THE APWI?

28. HAVE YOU FLOWN ANY OTHER APWI DEVICES?

☐ No

☐ Yes

WHAT KIND, WHEN AND ANY COMPARATIVE COMMENTS