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RESULTS OF THE RECENT PRECIPITATION STATIC FLIGHT TEST PROGRAM ON THE NAVY P-3B ANTISUBMARINE AIRCRAFT

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ABSTRACT

The Naval Air Test Center's Electromagnetic Pulse Section recently investigated severe precipitation static problems affecting the communication equipment onboard the P-3B aircraft. This investigation was conducted at the request of Naval Air Systems Command after precipitation static created potential safety-of-flight problems on Naval Reserve aircraft. A specially designed flight test program was conducted in order to measure, record, analyze, and characterize potential precipitation static problem areas. The test program successfully characterized the precipitation static interference problems while the P-3B was flown in moderate to extreme precipitation conditions. Data up to 400 MHz were collected on the effects of engine charging, precipitation static, and extreme cross-fields. These data were collected using a computer-controlled acquisition system consisting of a signal generator, RF spectrum and audio analyzers, data recorder, and instrumented static dischargers.

This paper outlines this test program and describes in detail the computer-controlled data acquisition systems used during flight and ground testing. This paper also discusses the correlation of test results recorded during the flight test program and those measured during ground testing.

1. INTRODUCTION

For over 50 years, precipitation static (P-static), its causes, and cures have been examined in numerous reports and papers. These studies indicate that the U.S. Navy has been concerned about the effects of P-static on its aircraft for at least the past 45 years. After all this time and research, however, P-static remains somewhat of a mystery.

The biggest problem concerning P-static appears to be lack of awareness on the part of designers, users, and maintainers of aircraft, despite the abundance of technical literature on the phenomenon. The Naval Air Test Center's program, the focus of this paper, extensively utilized the research previously performed by the experts in the field of P-static. The aim of this paper is to provide some continuity between the information gathered in past P-static cleanup programs and in this more recent one.

P-static testing at the Naval Air Test Center is performed by the Electromagnetic Pulse (EMP) Section of the Electromagnetic Systems Department. The EMP Section also performs high-altitude EMP and lightning testing. Prior to 1986, P-static testing at the Test Center was conducted only on demand. Presently, however, all Navy aircraft being processed through the Test Center's shielded hangar for electromagnetic testing is also subjected to simulated P-static testing.

2. TEST AIRCRAFT BACKGROUND

P-static problems on aircraft can be attributed to several causes. The main causes historically have been the advanced age of the airframe, a new avionics installation, or unfamiliarity on the part of aircraft personnel with P-static. All three of these are factors with the P-3B aircraft (see figure 1). Specifically, the P-3B test program was initiated because the aircraft was being outfitted with a replacement communication receiver offering increased range, greater flexibility, and broadband. As a result of this new receiver's greater sensitivity (by 10 dB), P-static on the P-3B changed from a mere nuisance to a safety-of-flight issue.

The program described in the following pages was not the Navy's first attempt to clean up the P-3 airframe. An extenstive and successful effort was made 10 years earlier. As an outcome of this program, flight manuals were revised to include guidance on maintaining a clean airframe. But as often happens, no major problems were noted for years, so the requirement for periodic checks for P-static problems was eventually dropped.

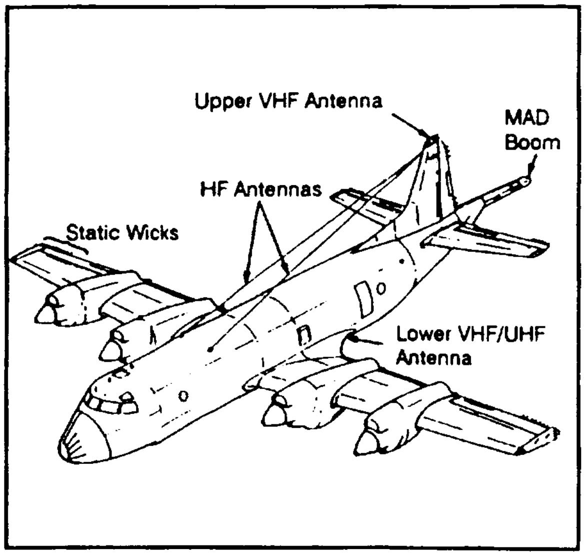

Figure 1. The Navy's P-3B Aircraft

Further compounding the Navy's problem was the lack of standard, acceptable test procedures for ground testing of aircraft. The EMP Section had a local test method, but not one that had been confirmed as adequate by a flight test program. Tasking for cleaning up the P-3B airframe came to the Test Center after six months had been expended by other, unsuccessful cleanup efforts.

To accomplish this task, a test program was developed jointly at the Test Center by the Force Warfare Test Directorate and the Systems Engineering Test Directorate's EMP Section. This collaboration resulted in a two-phase program. In Phase I, characteristics of the P-3B inflight environments were obtained, and the ground testing methods were modified as required. In Phase II of the program, other aircraft were tested for trends and common problems.

3. AIRCRAFT INSTRUMENTATION SUITE

In developing its P-3B flight instrumentation suite, the EMP Section thoroughly researched the technical literature outlining previously conducted P-static flight test programs. In particular, data from the aforementioned P-3 program that was conducted 10 years earlier provided excellent guidance. With this information, along with data gathered from related Boeing and Stanford Research Institute test programs, the Test Center designed its flight instrumentation suite. A block diagram of the P-3B instrumentation suite appears in figure 2.

One requirement for P-3B instrumentation was to record continuous P-static interference on all communication receivers and analyze the audio output of receivers. Since the charge levels for frontal areas had already been extensively documented, no data on these were gathered during this program. Three static dischargers were isolated from airframe and used as indicators for P-static conditions. Dischargers were sufficient to provide data on engine charging, P-static conditions, and crossfields.

The P-3B instrumentation suite (photo 1) provided a continuous recording capability, visual indicator meters to monitor outside conditions, and an in-flight hard copy printout capability. The PC controller saved interference events on disk for immediate or later processing.

Hewlett Packard 8562A Spectrum Analyzer
Hewlett Packard 3561A Dynamic Signal Analyzer
Honeywell 101 Magnetic Tape Recorder
COMPAQ 101709 Portable PC
Hewlett Packard 8640B Signal Generator
DATUM 9300 Time Code Generator
Dayton-Granger Static Discharger Wicks
Associated Microammeters, Preamps, Switches, Cables, and Connectors

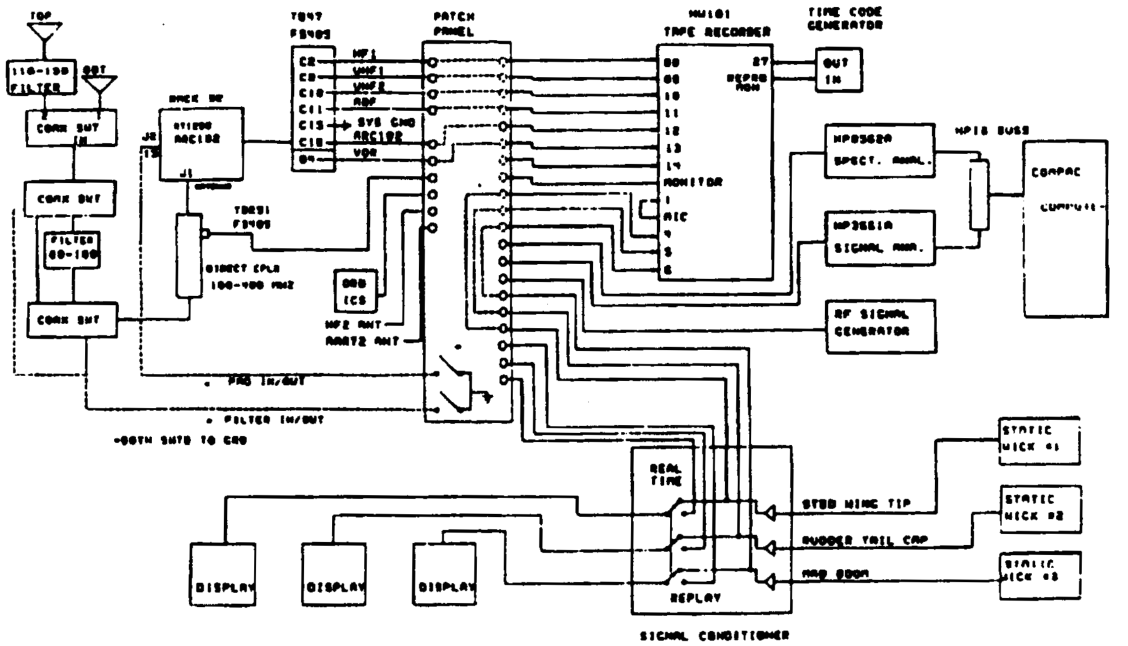

Figure 2. The Instrumentation Suite

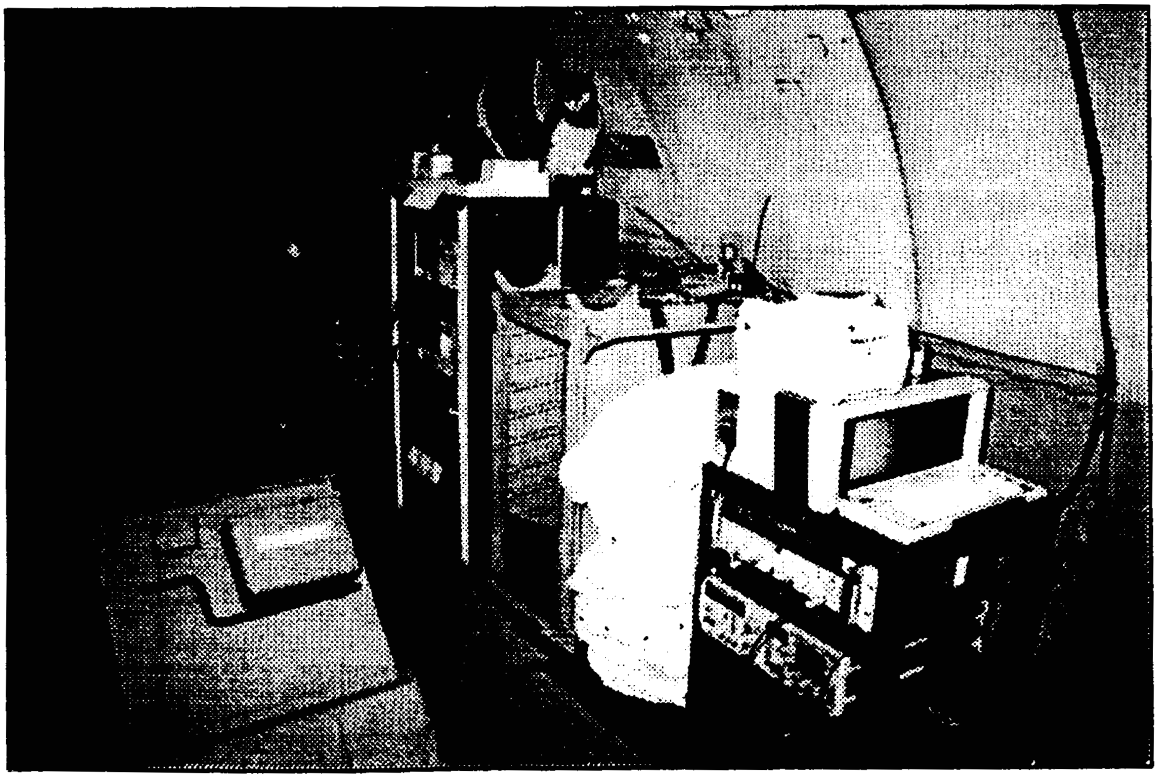

Photo 1. P-3B P-Static Interference Data Acquisition System

4. TEST FLIGHT PHASE

After extensive ground testing to confirm the operation of instrumentation and to characterize the P-static problem areas, the aircraft was ready to be flown in P-static conditions. The problem areas identified by ground testing were left uncorrected in order to obtain interference records reflecting an aircraft with known P-static problems.

By early January 1989, the aircraft, crew, and test team were ready to proceed with the test program. Initial flights were conducted from Glenview Naval Air Station north of Chicago, since weather forecasts indicated conditions were more favorable to encounter P-static in the midwest during this timeframe. Flying out of the Chicago area with the P-3B's range put the entire midwest within reach.

By consulting daily with weather forecasters at Glenview Naval Air Station, the test team could select an appropriate area for test flights. After a few flights, the test team became very successful at locating and documenting the P-static environment. A typical flight condition is described in table I.

Table I. Flight in Severe P-Static Conditions (Before Fixes)

- Altitude = 16,000 ft
- Outside Air Temperature = -16° C (actual)
- Airspeed = 235 Knots
- Discharge Current
  - — Mad Boom = 70 μA
  - — Wing Tip = 50 μA
  - — Fin Cap = 50 μA

Once team members were satisfied with the acquired data, their next step was to perform cleanup on the airframe. The following is a sampling of the types of cleanup necessary. Cleanup was required on the high-frequency antennas, MAD boom, and static wicks. The high frequency antenna parts were replaced to prevent corona discharge. The MAD boom had numerous isolated diverter strips which formed a Faraday cage. Rebonding the diverter strips and access door cleaned up this problem area. The worst problem, and the easiest to correct, was the static dischargers. The test aircraft's dischargers were measured open and were not effectively discharging any current. The static dischargers were replaced, and the isolated bases were grounded. Operating from a P-3 unit provided the personnel with the expertise needed to implement all corrective actions. Validity of these repairs was then confirmed by ground testing.

After ground testing of the fixes, the aircraft was flown once again to confirm that fixes were adequate to prevent the P-static interference that was documented during previous flights. Ideally in this situation, the environment must produce discharge currents on the instrumented static dischargers that are similar to those produced in the previous flight tests.

Unfortuantely, weather took a turn for the better, and the severe environmental conditions needed for testing could not be located in the midwest. The test team then decided to return to the Test Center and make the final flights from there. With patience, the test team eventually found conditions that were more severe than those encountered during flights with a "dirty" airframe. Interference-free aircraft communication receivers confirmed that corrective action had been successful in eliminating P-static interference. Typical before-and-after data plots are presented in figures 3 through 5.

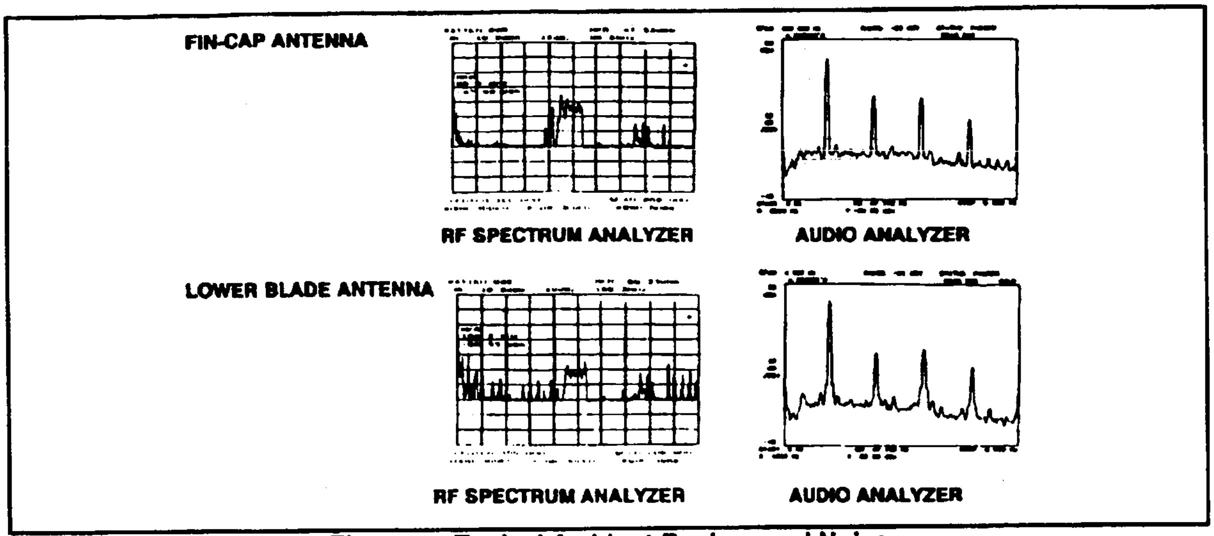

Figure 3. Typical Ambient Background Noise

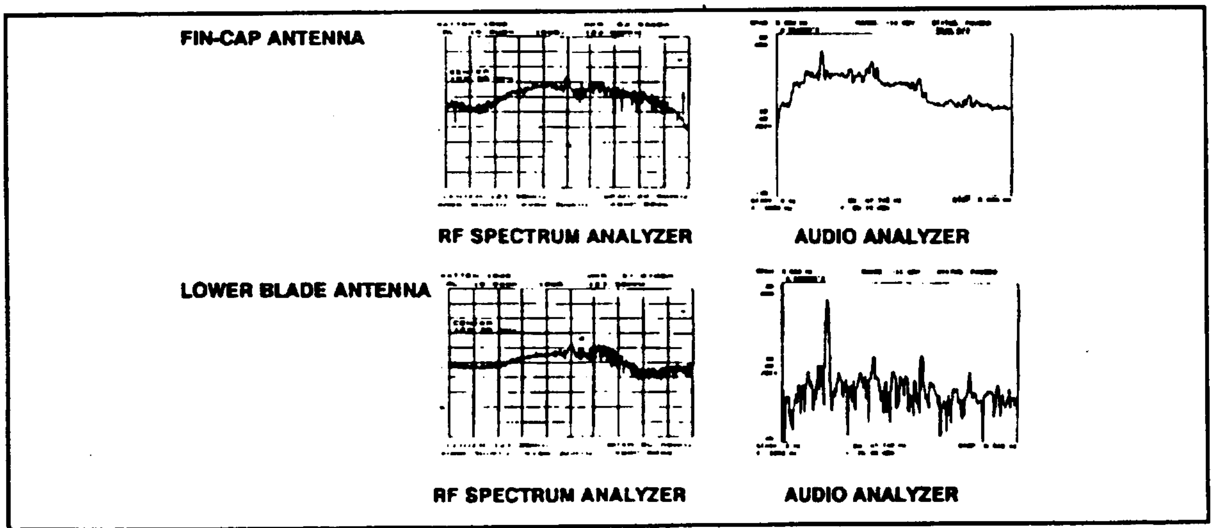

Figure 4. Severe P-Static Noise (Before Fixes)

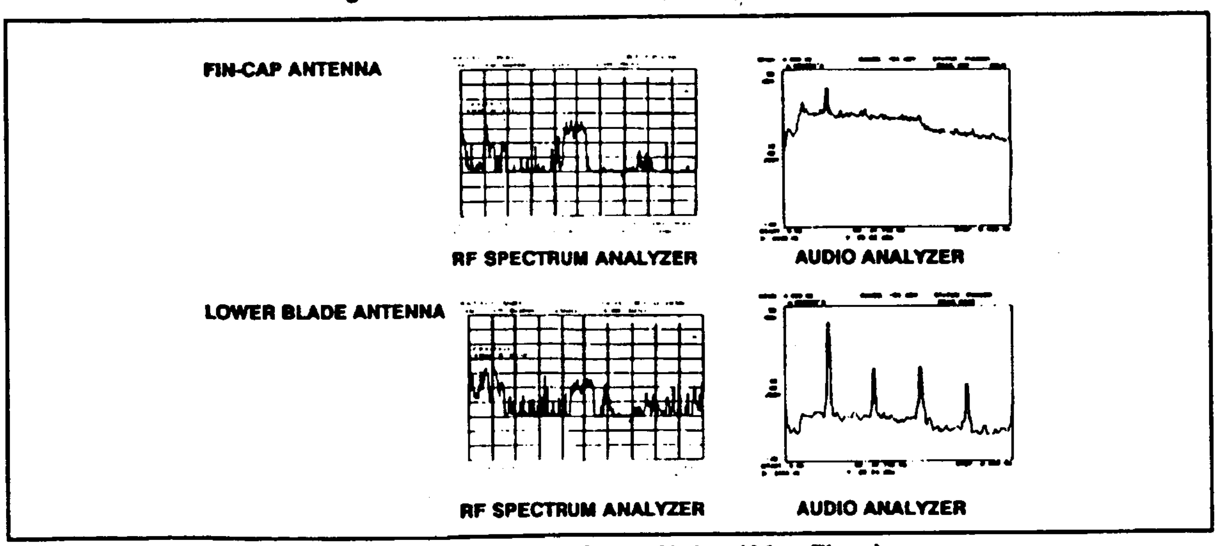

Figure 5. Severe P-Static Noise (After Fixes)

P-static conditions were similar during the different plots of figures 3 through 5. It should be noted that the audio analyzer plot for the fin-cap antenna of figure 5 was caused by improper bonding and was later corrected.

5. GROUND TEST CRITERIA

Preparations for this phase were made in parallel with preparations for the flight test program. This effort utilized a ground-based instrumentation suite similar to that used during flights (photo 2).

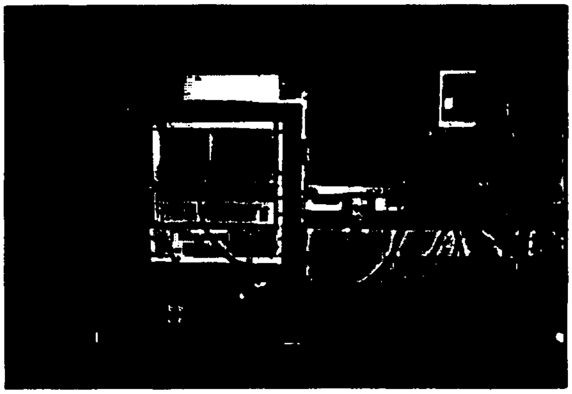

Photo 2. Ground Test Instrumentation Suite

In order to simulate the environment documented in the flight test phase, it was essential to first establish accurate guidelines. The high-voltage test set had to be a variable current source that could deposit charge onto a 1-foot-square area. According to applicable studies, the worst P-static conditions are established at 20 microamperes per square foot. In addition, the test team agreed upon a SINAD and signal-to-noise ratio. With the aircraft fully instrumented, it became very simple to determine which problem areas should be immediately repaired and which should be considered minor. Establishing these criteria resulted in a cost-effective corrective action program.

6. STANDARDIZED GROUND TEST METHOD

The method used by the Test Center for P-static testing is similar to the method employed by numerous aircraft manufacturers and repair facilities. This commonly used test method was simplified by Dayton-Granger, the manufacturer of the electrostatic test set used by most testers (photo 3). The Navy then adopted Dayton-Granger's testing method and refined it. Table II shows the main steps of a typical aircraft P-static evaluation.

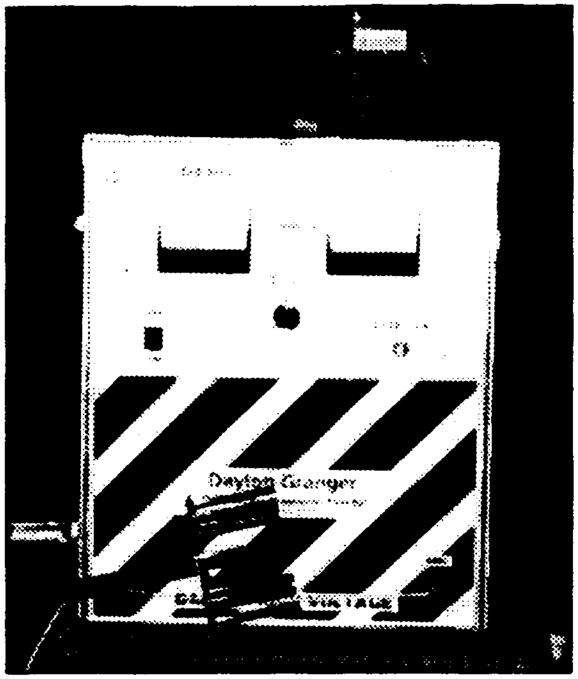

Photo 3. Electrostatic Test Set

Table II. Test Methods

Step 1	Deposit simulated P-static charge using an electrostatic test set.
Step 2	Monitor hand-held radios for noise generated by induced arcing.
Step 3	Document all problem areas for database.
Step 4	Monitor onboard radios and instrumentation while problem areas are resprayed.
Step 5	Record interference on the victim radio, both graphically and in data form.
Step 6	Incorporate fixes to problem areas.
Step 7	Evaluate fixes and record the results.

In ground testing, aircraft preparation is minimal. The test is performed on a grounded aircraft with fuel tanks topped off. The first sweep of the aircraft is made with applied ground power. Discharge capability of static wicks is confirmed by drawing current from wicks while monitoring a sensitive broadband receiver. Once instrumentation is installed (figure 6), the next step is to spray problem areas while monitoring receivers and recording data plots with the instrumentation system. Information collected is then entered into the P-Static Problem Area Tracking System (table III) for comparison with existing data and for further analysis. Aircraft deficiencies are then reported to the aircraft manufacturer and users through a variety of methods.

7. CONCLUSIONS

The preceding pages describe the process that the Naval Air Test Center uses to identify aircraft P-static problems and to correct them. Information has also been presented as recommended test levels for determining adequacy of aircraft's protection against the adverse effects of the P-static environment. Procedures discussed here are presently being used for verifying the specification compliance of Naval aircraft.

8. ACKNOWLEDGMENTS

This program could not have been performed effectively without the excellent documents produced by Stanford Research Institute, which are too numerous to be referenced here.

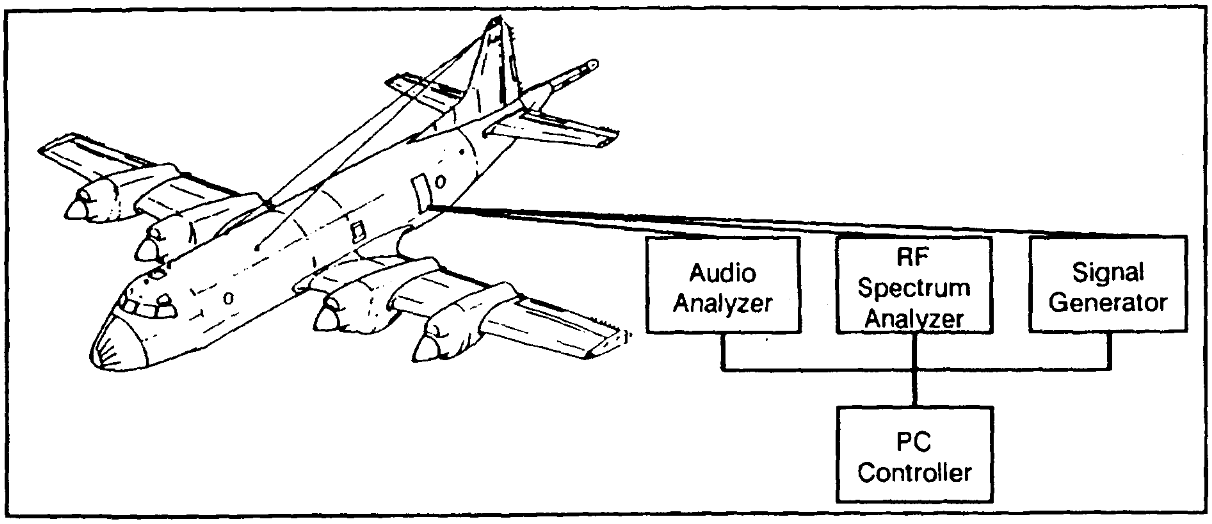

Figure 6. Typical Instrumentation Test Setup

Table III. P-Static Problem Area Tracking System

- Essentially a digital version of a traditional Microfiche cataloging system
- Hewlett Packard Scan Jet Plus replaces the camera
- Iomega 20 megabyte 1/4" cartridges replaces transparency films/fiches
- New generation graphical database Superbase 4 is the cataloging system
- Database allows direct on-screen preview of graphical data
- Intuitive VCR-like control panel allows easy database searching
- Key fields include:
  - A/C model
  - Bureau number
  - Problem area ID number
  - Problem area description
  - Work unit code
  - Category