USER REPORT ON AUTOMATIC TEST EQUIPMENT

DAN A. DEGERMAN

The Defense Materiel Administration (Forsvarets Materielverk)
Air Materiel Department
Stockholm 80, Sweden

This paper describes the family of automatic test equipment which provides a completely integrated system for avionics maintenance testing for the aircraft AJ37 "Viggen". The development of multi-level support ATE is described, and user experience with the implementation and operation of the test equipment is reported.

Automatic Test Equipment - Background

The Royal Swedish Air Force began investigation of automatic test equipment for avionics support in 1961. By 1963 the RSAF was ready to order two prototype "autotesters": one tape-controlled, the other computer-controlled. Besides meeting the required technical performance, the manufacturer had to establish certain reliability characteristics of the autotester. The reliability requirement in terms of MTBF was 250 hours. The computer-controlled autotester met this requirement; the tape controlled autotester did not.

In this phase of automatic test equipment implementation, the objective was to gain as much experience as possible before deciding on the avionics test equipment for the new aircraft - the "Viggen". Therefore, both autotesters were operated with an avionic mock-up utilizing a J35 Draken aircraft. While operating the autotesters, the RSAF gained experience in both programming and use of the hardware.

In 1966, four computer-controlled autotesters were ordered for flight line testing of the Viggen. All stimulus and measurement requirements were defined in a test matrix, and then divided between the autotester and separate, special instrumentation. The autotester passed a reliability demonstration with an MTBF exceeding 500 hours, a maintainability demonstration with an MTTR less than 1 hour, and specified environmental tests.

During the period 1967-1969, operation of the automatic test equipment for the Viggen avionics was successfully tested with a mock-up of the aircraft, and on the flight line with prototypes of the aircraft.

In 1969, the decision was made on serial procurement of automatic test equipment, and 16 autotesters were ordered from Hewlett-Packard, with an option in the contract for 16 additional autotesters. The technical performance required of these autotesters was similar to that for the prototypes. Delivery started in early 1970. During serial production of the autotesters, reliability and maintainability verifications were performed. With a high degree of confidence, the MTBF is known to exceed 500 hours, and the MTTR to be less than 1 hour. Some environmental tests, complementing the above tests, were also performed.

Multilevel Support

The maintenance of avionics in the Viggen is divided into three levels (Figure 1):

A-level	Flight line support
B-level	Workshop support
C-level	Depot support

Flight Line Support

The Built In Test (BIT) in the aircraft is generally used as pre-flight test. Necessary ground equipment is only a small power cart connected to the aircraft, which supplies electrical power and cooling air for the avionics. The BIT is operated by a ground support technician or the pilot. The BIT checks certain of the avionics systems in just a few minutes.

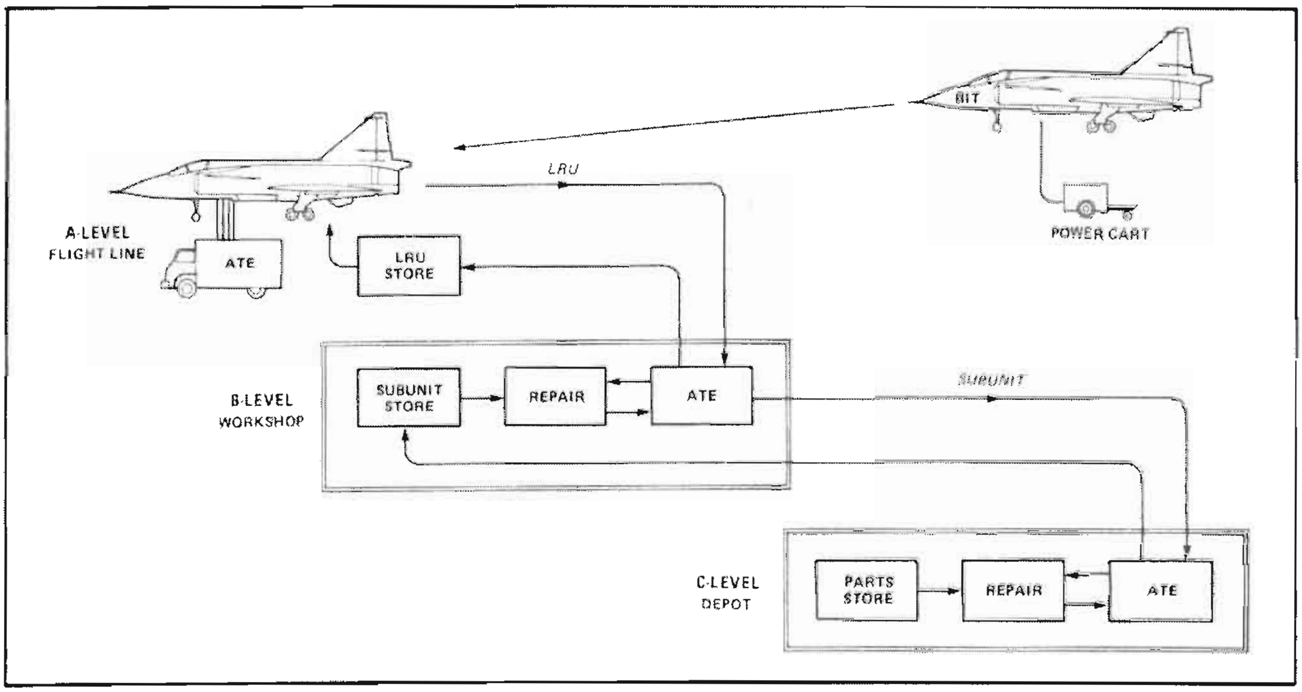


Figure 1. Multi-Level Support for Viggen Avionics

Aircraft BIT identifies faulty avionics system. ATE successively reduces fault to LRU, subunit, and part.

To make a complete Performance Test, and to perform Trouble Shooting (PT/TS), it is necessary to use additional ground support equipment. This equipment is contained in two vans (Figure 2). One van supplies electrical and hydraulic power and cooling air for the avionic equipment. It also supplies electrical power for the test van. The test van (Figure 3) contains the A-level automatic test system along with special instruments for some portions of the radar and air data computer. The van is airconditioned.

Connections are made to the entire avionics via five main cables carrying a total of 1000 test leads, and a few smaller cables, pneumatic hoses, etc. The main cables and aircraft receptacles are shown in Figures 4 and 5.

Test programs for various versions of the Viggen avionics are stored on interchangeable disc cartridges. Interconnections between the autotester and the avionics are established with a detachable patch panel. As the situa-

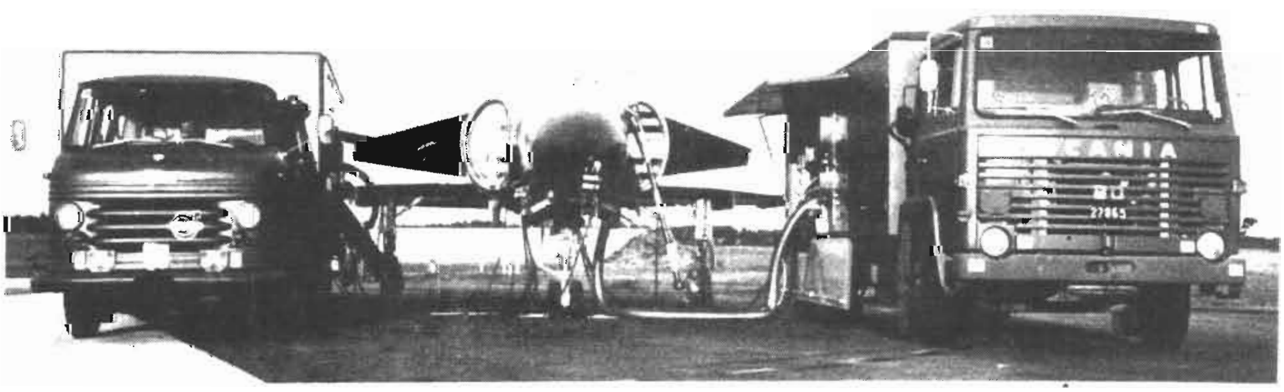


Figure 2. Flight-Line testing

Van on left contains A-level ATE. Van on right supplies cooling air, electrical and hydraulic power to Viggen.

tion requires, the operator chooses the appropriate disc cartridge and patch panel. To ensure that the correct program and patch panel are used for the specific avionics configuration to be tested, a "code connector" (a plug-in connector with certain pins grounded) in the aircraft identifies the avionics configuration. A small section of the patch panel is also used to establish an identification code. The test program interrogates the aircraft code connector and the patch panel to determine if they are correct for the tests contained on that disc cartridge.

If the codes agree, the operator calls up the test program (test number xxxxx) by using the keyboard on the control panel (Figure 6) and then initiates automatic execution of the test. If any operator action is necessary, the test program displays a code number for the operator on the control panel. The operator then looks up the information in the maintenance manual.

The A-level test system is capable of testing about 100 different Line Replaceable Units (LRUs). The existing PT/TS program for the Viggen contains about 3000 tests. A test is defined as the application of stimuli to the LRU, measurement of the response, and comparison with established limits.

Besides its primary testing function, the A-level autotester is also used to load the operational flight program into the Viggen CK37 avionics control computer.

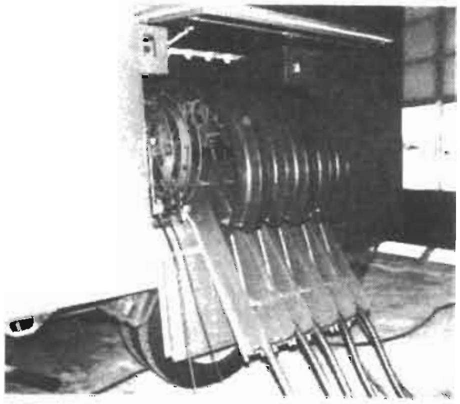


Figure 4. Autotester Cables

Cables for testing Viggen avionics are supported on frames which roll out from A-level van.

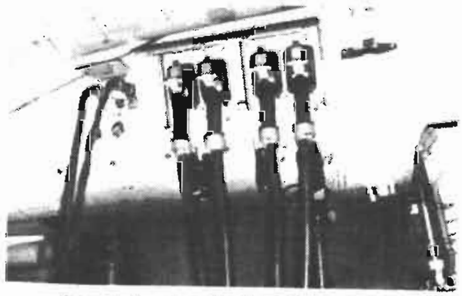


Figure 5. Aircraft Test Receptacles

Test connections to A-level test system are made through these four connectors, plus another similar connector nearby.

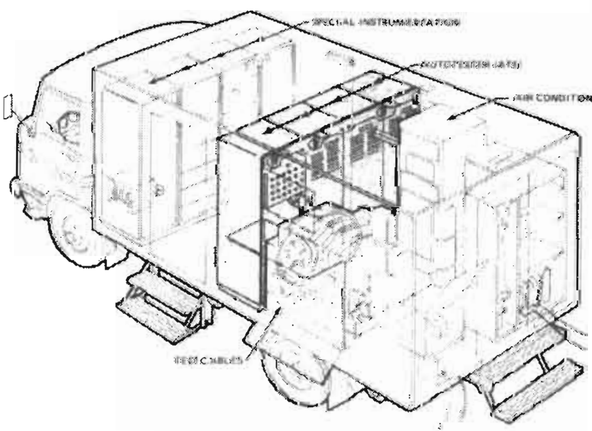


Figure 3. A-Level Test Van

Diagram shows how flight-line ATE and special instrumentation is housed in A-level van. Test enclosure is air-conditioned since temperatures in Sweden range from 30°C (86°F) in summer to –40°C (–40°F) in winter.

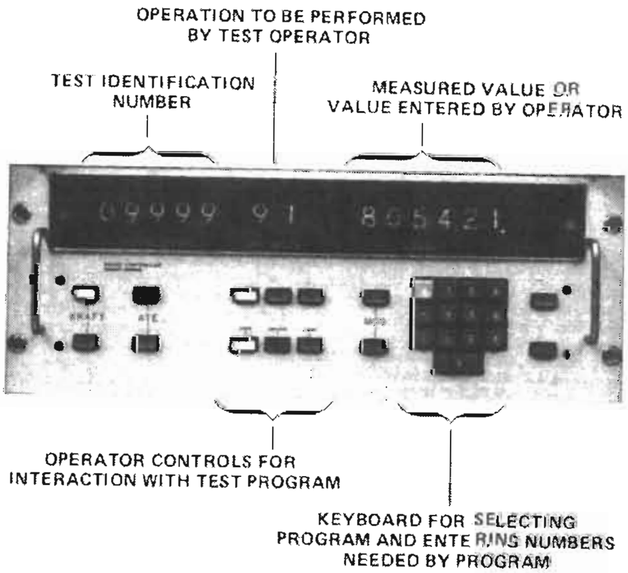


Figure 6. ATE Control Panel

Same control panel is used in A-, B- and C-level systems. All systems have "operator" and "supervisor" operating modes, selected by key-operated switch on equipment rack. In "operator" mode, user can only call up and execute test programs. In "supervisor" mode, user can alter and develop test programs. Only specially trained personnel are permitted to use the "supervisor" mode.

Workshop Support

Line Replaceable Units returned to the workshop for repair are tested on an Automatic Test System 1 (ATS 1) similar in principle to the flight line system, but considerably expanded in capability with additional stimulus and measurement instruments. The B-level test system is shown in Figure 7.

The LRU is connected to the system through a plug-in interface adapter (Figure 8). As with the flight line system, programs are stored on the disc memory and are called up from the system control panel.

The computer print-out tells the operator which LRU sub-unit is at fault and the test it has failed. The LRU is removed from the test system and repaired in another area in the workshop, by replacing the faulty sub-unit. Afterwards the LRU is retested and, if satisfactory, returned to the flight line.

Supporting this system are some Manual Test Sets (MTS). These are used for testing some portions of the avionics (such as electromechanical devices) which are not suitable for automatic testing. A typical MTS is shown in Figure 9.

Depot Support

Backing up the workshop, the depot test equipment tests repairable LRU sub-units and portions of the Viggen avionics requiring test capability beyond that of the ATS 1.

Essentially, depot test equipment consists of:

- ATS 1 expanded workshop system. Besides its use for check-out of LRUs, ATS 1 is utilized for developing LRU test programs. ATS 1 is now operational.
- Automatic Test System 2 (ATS 2). This is a 1-18 GHz system (Figure 10) for RF and microwave testing. It was delivered in October 1973. The checkout of ATS 2 hardware, software and test-programs will start early 1974.
- Automatic Test System 3 (ATS 3). This comprises special-to-type automatic test equipment (Figure 11) for testing the avionics digital computer. ATS 3 is operational.
- Automatic Test System 4 (ATS 4). This system is intended for use as a sub-unit or card tester. The system is in the specification phase and is planned to be operational in 1975.
- Supporting the automatic test systems mentioned above are some Manual Test Sets (MTS) which complement the depot-level test equipment.

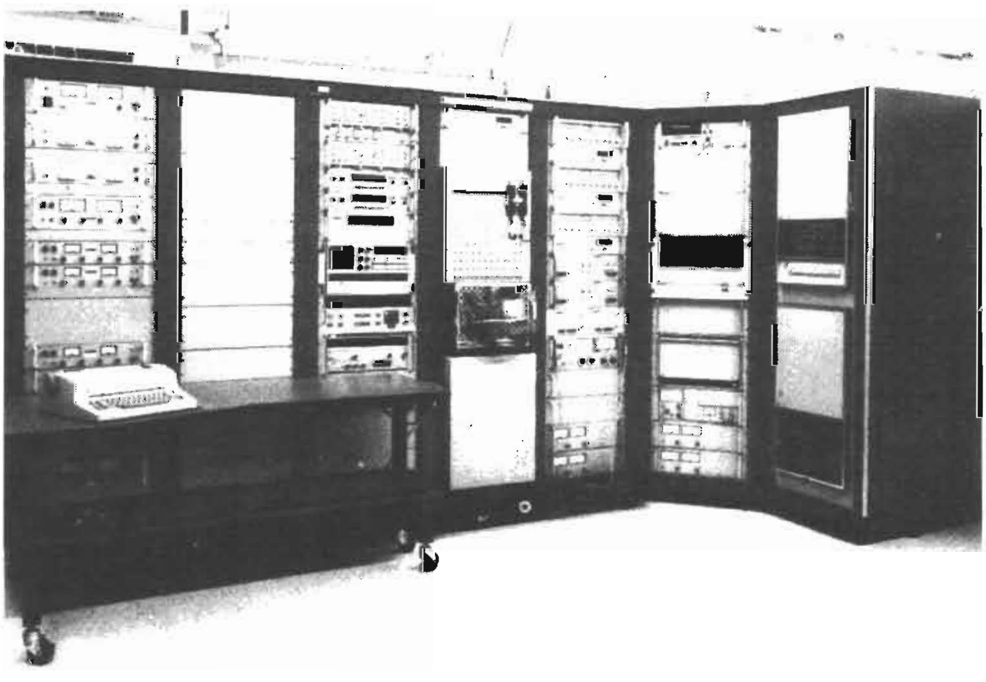
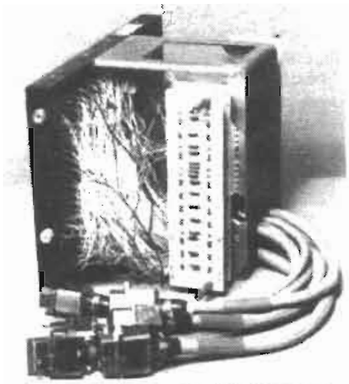
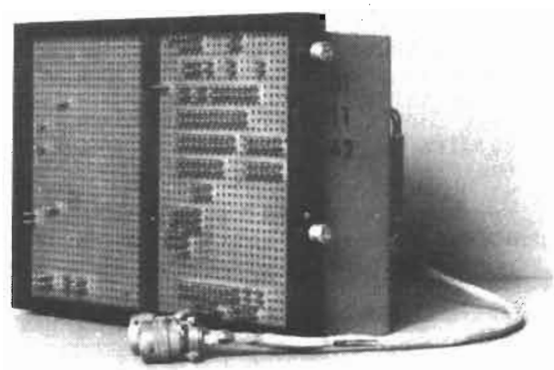


Figure 7. B-Level Test System

System uses same computer, disc memory and essentially same switching and interface method as A-level test system, but has expanded stimulus and measurement capability. Operating software is same.



a) Photo shows wiring from LRU connecting cables to system interface panel.



b) Photo shows interface panel that plugs into system.

Figure 8. B-Level LRU Interface

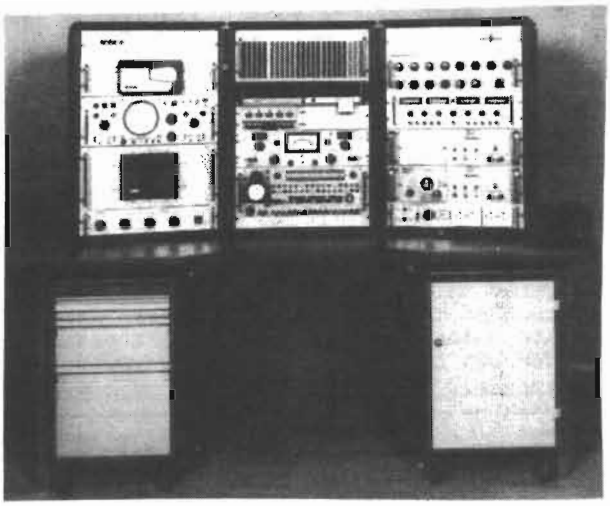


Figure 9. Manual Test Station (MTS)

Typical station used to supplement workshop or depot ATE.

Program Production

Saab-Scania has been responsible for developing the original test programs for the A-level tester, while the depot handles all updating and field support of the Viggen automatic test software for the flight line (A-level), and all programming for the workshop and depot testers (B- and C-level).

The concept of software support activity is shown in Figure 12. Test programs for all levels of ATE are written in HP ATS (Automatic Test System) BASIC. When a portion of the Viggen avionics is modified, the test program is revised by a depot technician.

Because of the volume of software support activity at the depot, all revised programs are punched on tape for the technicians, then rapidly checked for programm-

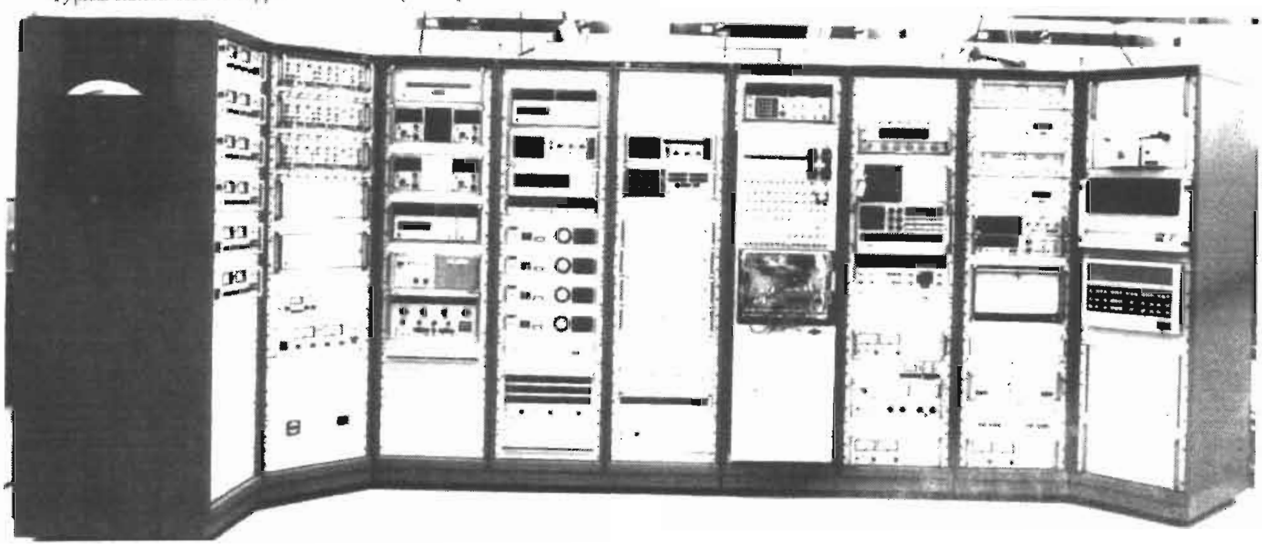


Figure 10. Depot Test System – ATS 2

This system is used for testing in the range 1 to 18 GHz ing accuracy on a computer system dedicated to program production. Programs are printed out on a high-speed line printer with error messages for any syntax errors. These are corrected by the technician and the program is checked again. When syntactically correct, the program is recorded on a disc cartridge and is then ready for a "safety check".

The safety check ensures that the test program supplies the proper stimuli at the

Figure 11. Depot Test System – ATS 3

This system is used to test the CK 37 avionics digital computer.

appropriate test points, and will not damage the Line Replaceable Unit. This is accomplished by running the program on an A-level test system, but routing all 1000 test leads to a 1000-point terminal panel, instead of to an LRU. This allows the technician to run the program in stages, stopping it where necessary to check the programmed stimuli with manual test instruments.

Any errors found can be corrected on the spot by the test technician. The safety-checked program, recorded on the disc cartridge, is then ready for check-out with real hardware.

Final verification of the test program is accomplished with an actual Line Replaceable Unit installed in a test "rig", together with an A-level test van. The rig simulates the avionics installation in the Viggen, with all the LRUs located in the same physical relationship and interconnected by similar cable harnesses. The rig is connected to the A-level test van via cables and connectors identical to those used with the aircraft.

During this final check, any errors can be corrected immediately. The maintenance manual is also revised. The completely verified updated test program is then duplicated on to disc cartridges which are shipped to the field together with appropriate patch panels, the aircraft code connector, and updated parts of the maintenance manual, and the update is complete.

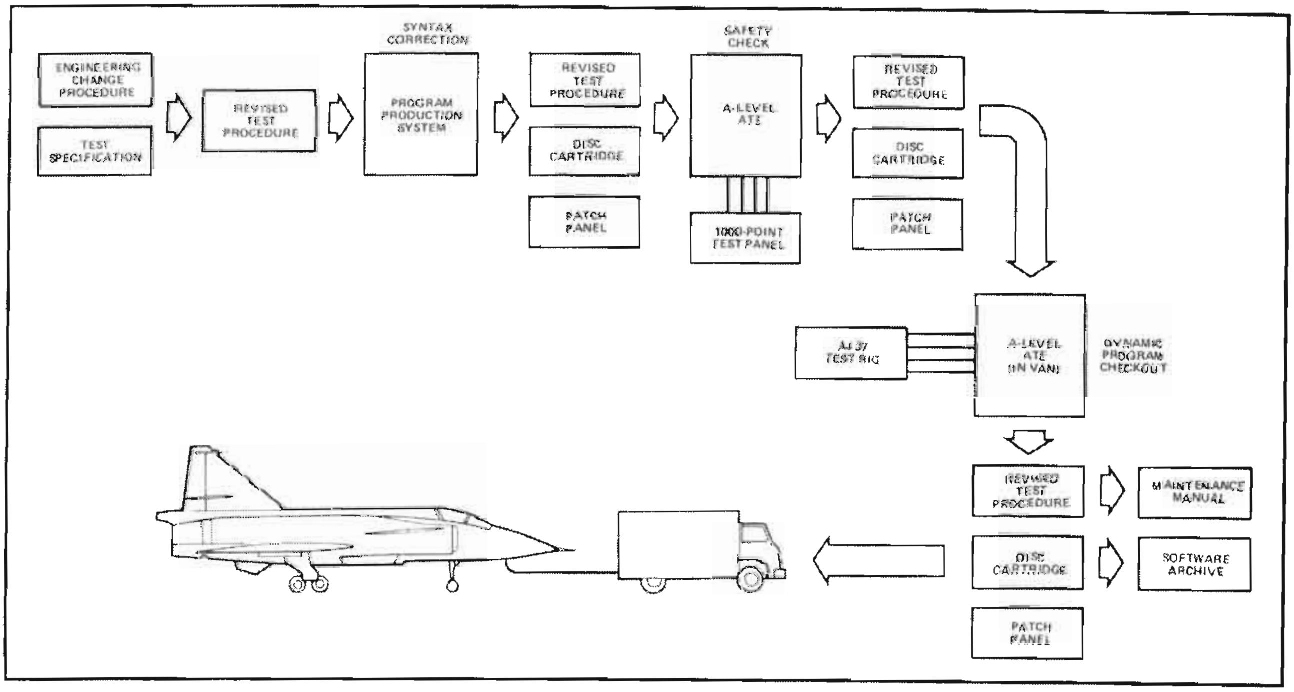


Figure 12. Flight Line ATE support

Diagram shows how avionics engineering change is handled to provide flight line with updated test procedure, disc cartridge and patch panel.

Training
General maintenance technicians attend a four-week training course on the Viggen avionics. However, only three days of this course are devoted to use of the A-level tester. In this abbreviated course, students learn general system principles, communication with the system in the BASIC programming language, and system operating procedures for identifying faulty Line Replaceable Units under field service conditions.

Electronic specialists attend an advanced course of approximately 30 weeks, of which five weeks are spent on the auto-tester. This in-depth training explores the system's stimulus and measurement capabilities in relation to the aircraft avionics. Control of the test instrumentation through the computer is covered fully, such that the electronic specialists are able to handle non-routine test problems at the flight line.

The hardware used in training is a test rig similar to the one used in program checkout at the depot. It is used with a test system built on a platform instead of in a test van. Of course, actual aircraft and test vans are also used in the overall training program.

Test Time Reductions with ATE
An expected improvement with automatic, versus manual, test equipment is decreased test time. Experience with the Viggen avionics automatic test equipment has shown that test times are reduced to between 10% and 30% of equivalent manual test times. Figure 13 shows an actual case: the performance test of the Air Data Computer. The automatic test time, with printout only if a fault is detected, is about 15 minutes. (Including a complete printout of all tests naturally increases the test time.) This test time includes connecting the LRU, warm-up, and post-test disconnection. The overall time for equivalent manual testing is 50 minutes.

Another example is an LRU in the radar system. This program includes 169 tests. Test time with fault printout only is 150 seconds, or 9 minutes with a complete printout. Test time with manual test equipment is 2-1/2 hours.

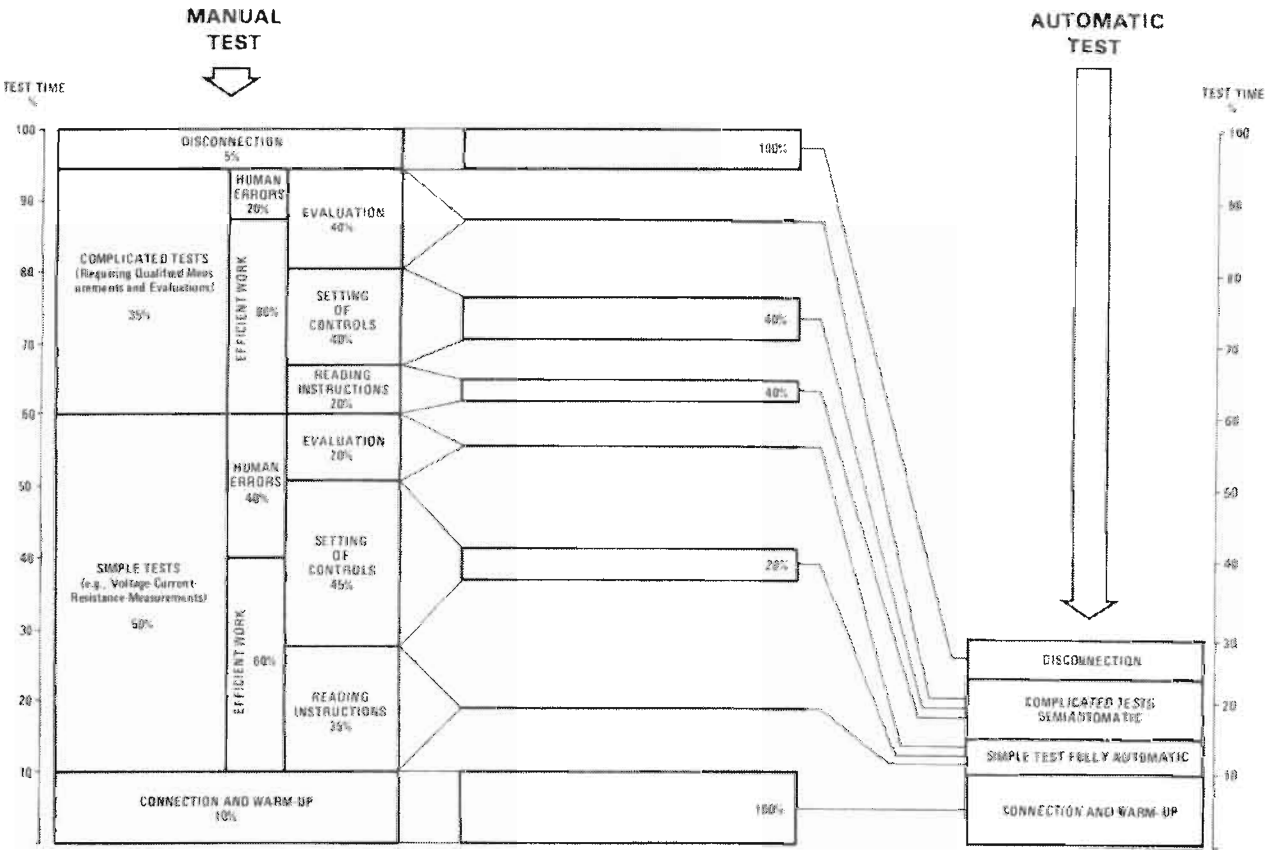


Figure 13. Manual/Automatic Test Time Comparison
Diagram shows actual test time saving with ATE, when testing Air Data Computer.

Conclusions

1. Airbase effectiveness depends, among other criteria, on how well the aircraft can be checked within any period of time a check is necessary. Technical performance and reliability of the automatic test equipment contribute equally to the ATE's operational performance. Good ATE operational performance is fundamental to the correct balance of airbase effectiveness and maintenance cost.

2. Testability must be considered during the design of the avionics. Most avionics equipment designers are primarily interested in the technical performance of the equipment. However, test points, test circuits, etc., must be designed into the equipment from the beginning.

3. It is essential to establish a test matrix (defining all stimulus and measurement requirements) to achieve the desired economic return on automatic test equipment. Otherwise capabilities for some tests will be built into the ATE that are required only infrequently and could be accomplished with special test instruments at lower cost.

4. "Off-the-shelf" commercial instruments combined with a small, general-purpose computer can perform the required tasks in most cases. This solution also allows the user to add or substitute instruments as necessary to meet new requirements.

5. Central control of test programming is essential, to avoid proliferation of modified test programs. In this context, economy in equipment is achieved by preparing and debugging programs off-line, and using a "program production system" for syntax verification. Final checkout of programs can be done with the actual test system.

6. Most of the Viggen avionics test programs are written in BASIC. Use of BASIC language made it practicable to train engineers with knowledge of the avionics in programming, instead of hiring programmers. Only in a few instances were some portions of programs written in assembly language to achieve certain execution times.

7. During an aircraft's life, it is exposed to a number of modifications. Test systems must be capable of handling avionics with varying levels of modifications. A method of infallibly correlating the aircraft's modification status with the interface (patch panel) wiring and the test program is essential. The "code connector" used with the Viggen has accomplished this.

8. Great emphasis must be placed on establishing correct test tolerances for each level of maintenance, to meet the respective operational requirements. The degree of analysis required to calculate these tolerances demands use of a computer.

9. With careful planning given to the tests to be automated, the hardware configuration of the test equipment, and the design of the test programs, test time reductions over manual testing in the order of 70% to 90% can be achieved in practice.