• Have an identified diagnostic shortfall in terms of large ambiguity groups and/or observation of undocumented failure modes
• Have a documented history of BIT false alarms which are of sufficient magnitude to warrant corrective action
• Have a distributed failure population (e.g., failure history which is not indicative of any of several recurring faults).

THE TRANSFERENCE OF THE CAPABILITY

The demonstrated capability is of little or no value unless the capability can be successfully transferred to weapon system designers and acquisition managers in their respective tasks. An end result of the Navy IDSS Program is the transference of the capability. Guidance documentation will be developed to cover the use and operation of the IDSS design tools. This guidance will serve as overall IDSS design tool application and user guide. Each of the design tools will be addressed from a systems perspective and on a stand-alone basis, so as to facilitate their individual use.

PROGRAM DIRECTION

A totally integrated approach to weapon system diagnostics is necessary from an operational and cost viewpoint. The ability to achieve integrated diagnostics come into existence only by virtue of the ability to impact weapon system design. With that ability now in place through MIL-STD-2165, the Navy is developing a system which integrates pertinent diagnostic support elements to achieve a comprehensive diagnostics capability in weapon systems. Integration is the key. The Navy Integrated Diagnostics Support System Demonstration Program will develop the tools necessary to provide the diagnostics capability and will demonstrate their capability to achieve comprehensive diagnostics. Finally, the IDSS Program will transfer that capability to Navy weapon system designers and acquisition managers.

GENERIC INTEGRATED MAINTENANCE DIAGNOSTICS

Harry M. Seaman
Directorate of Support Systems Engineering
Wright-Patterson Air Force Base, Ohio 45433-6503

ABSTRACT

Maintenance Support for a weapon system involves both preventive and corrective maintenance actions. Preventive maintenance is normally associated with mechanical equipment, and requires prognostic maintenance techniques to predict failures before they occur. Corrective maintenance is more closely associated with electronic equipment, and requires diagnostic maintenance techniques to detect and isolate failures after they occur. To pursue a systems approach to weapon system maintenance using both prognostics and diagnostics, the Air Force has initiated a program entitled, "Generic Integrated Maintenance Diagnostics (GIMADs)". This paper provides insight into the GIMADs program at Aeronautical Systems Division.

INTRODUCTION

In 1979, the Air Force Operational Test and Evaluation Command (AFOTEC) concluded an evaluation of field maintenance effectiveness for the E-3A, EF-111 and F-16 aircraft. The evaluation looked closely at the effectiveness of built-in-test (BIT) on these aircraft, and at the effectiveness of electronic support equipment, particularly at the organizational (flightline) level of maintenance. Among the findings reported by AFOTEC was that BIT on these aircraft was not performing up to Air Force expectations. This finding was not particularly surprising, since aircraft BIT has historically fallen short of expectations. More important than the finding were accompanying comments by the AFOTEC team concerning some possible reasons for the perceived failure of BIT to live up to expectations. Some of these comments are paraphrased and summarized as follows:
• BIT is normally specified at subsystem or equipment levels, and rarely at a systems level. Much of the aircraft is therefore not covered by BIT requirements, including for example, such areas as interface cables and connectors, electrical power systems and environmental control systems. With this much omission from BIT coverage, we should not expect to achieve a high system level performance such as "95% fault detection and isolation."

• BIT in general, does its intended job pretty well. There are obvious problems such as false alarms, but BIT enables maintenance technicians to evaluate complex systems quickly and efficiently. BIT performance could be improved greatly by more exhaustive developmental testing and a planned program for problem identification and correction of BIT deficiencies after delivery to the operational environment.

• There is substantial emphasis on achieving high levels of BIT in the various aircraft subsystems and not enough emphasis on achieving complete fault detection and isolation (FD/FI) for a total weapon system. The level of BIT achieved, whether it is 70 or 80 or 90%, is not as important as ensuring that all failure modes of the aircraft are covered, either by BIT, external test equipment, or manual troubleshooting procedures.

The emphasis by AFOTEC on "total system diagnostics" formed the basis of an Air Force Headquarters directive to develop an "integrated diagnostics" approach for Air Force weapon systems. When the directive was formalized in 1984, the program was entitled, "Generic Integrated Maintenance Diagnostics (GIMADS)"; and stressed the requirement for 100% fault detection and isolation of weapon system faults by an optimized combination of testing techniques. The main point that must be stressed with respect to this concept is that it calls for 100% FD/FI by a combination of techniques, and not 100% FD/FI by BIT alone.

BACKGROUND

The Deputy for Engineering at ASD has made an initial assessment of the GIMADS program, and has developed an approach to meet the goals and objectives of the program. Before discussing the GIMADS program, however, it is important to establish a historical perspective with respect to aircraft and diagnostic development. A historical perspective is helpful in understanding how we evolved to our current maintenance philosophy, and in helping determine an appropriate course of action for the GIMADS program.

Aircraft diagnostics have not always been the major maintenance consideration that they are today. Early aircraft of the 1920s and 1930s, for example, consisted primarily of airframes and engines, with little or no electronics. Since virtually everything on these early aircraft was critical to flight safety, a preventive maintenance philosophy was used out of necessity. Plainly stated, the aircraft simply could not be allowed to have a failure. The safety of the aircraft and the passengers depended on it. For these early aircraft, the preventive maintenance philosophy required the development of prognostic maintenance techniques to predict failures before they occur.

From the 1930s through the 1950s, aviation electronics, eventually called avionics, were gradually added to aircraft. Since virtually none of the early avionics equipment was flight critical or mission critical, the equipment could be allowed to fail without significantly endangering either the pilot, the aircraft or the mission. In most cases the avionics was useful but not a necessity. A maintenance philosophy therefore evolved for electronics which allowed the avionics to run until failure, and then diagnose and repair the malfunctioning equipment. This corrective maintenance philosophy required the development of diagnostic maintenance techniques to detect and isolate failures after they occur. Unlike preventive maintenance for mechanical systems, this corrective maintenance philosophy for avionics was not developed out of necessity. It was developed out of convenience and cost considerations, since early avionics failures were easily isolated, and this philosophy allowed the avionics equipment to run full life before replacement.

The same two maintenance philosophies continued throughout the 1960s-1970s-1980s, and will undoubtedly continue on into the future. But during these years the dependency on avionics has increased significantly. In many instances avionics are now mission critical and flight safety critical. But also during this period the complexity of avionics has increased by several orders of magnitude. And as the complexity of avionics has increased, the complexities of diagnostics for avionics has also increased dramatically. There is now a very sophisticated, highly complex and costly maintenance structure built around the once simple concept of "let it fail, then repair it"; and there is no new technology on the horizon that will simplify this problem. The trend is definitely toward more avionics, more complexity and more diagnostics.

The initial ASD assessment of GIMADS shows that we have done very well in meeting the maintenance challenge of modern complex aircraft. Mission capable rates for high performance Air Force aircraft are higher than they ever have been. This can be attributed to several factors including improved system reliability and maintainability, and improved training and human factors techniques. But it is also attributable to maintenance diagnostic techniques that have evolved and improved concurrently with avionics. BIT techniques have improved, automatic test equipment has evolved and improved, and there is a general wide-spread awareness of the important role that diagnostics play in weapon system supportability. There is, however, a high cost associated with this success in terms of dollars, manpower, facilities and military airlift required to sustain our high supportability levels. In addition, there is a serious question as to how long our complex support system could be sustained in a wartime situation.

As part of our continuing efforts to improve weapon system maintenance, there is a need to take a comprehensive look at how we do maintenance, and how our current methods and techniques could be improved. This is particularly important at this time, because of rapidly changing electronics
technology that may help provide maintenance solutions, but may also create additional maintenance problems. The GIMADS program at ASD provides the means to accomplish a comprehensive maintenance assessment for Air Force weapon systems, and to develop the tools and techniques necessary for improvements and continued evolution of Air Force prognostics and diagnostic capabilities.

THE GIMADS PROGRAM

Definition: The GIMADS program at ASD is primarily a technology-based program with the ultimate goal of developing and institutionalizing both a technical and a management approach to integrated diagnostics for Air Force weapon systems. Integrated diagnostics, in ASD’s view, encompasses both prognostic and diagnostic maintenance techniques, and the GIMADS program will be structured to apply whichever technique or combination of techniques that is most cost effective for a given application. The basic definition of GIMADS is as follows:

- GIMADS is an interdisciplinary systems process for incorporating into weapon systems a capability to most effectively predict or detect and unambiguously isolate, 100% of the faults.

Scope: The preponderance of diagnostics problems and challenges in current weapon systems are associated with electronics equipment, and not with mechanical equipment. There are various reasons for this. One of the major reasons is a high degree of electronics complexity that results in a corresponding high degree of diagnostic complexity. A second major, but rarely discussed reason, is that virtually all electronics maintenance is based on a corrective maintenance philosophy which dictates extensive use of diagnostics. Conversely, while mechanical equipment does require diagnostics, the primary maintenance philosophy is preventive, which dictates extensive use of prognostics, rather than diagnostics. A cursory examination of the overall maintenance picture could lead to a somewhat shortsighted conclusion that only electronics diagnostics need be addressed under GIMADS. The ASD view of GIMADS, however, is one that encompasses both prognostics and diagnostics for the entire weapon system. The GIMADS program will therefore address electronic and non-electronic areas for aeronautical, support and training equipment. This summarizes into the following four major areas of investigation:

- Task Area 1 — Aeronautical Electronics
- Task Area 2 — Aeronautical Non-Electronics
- Task Area 3 — Support/Training Electronics
- Task Area 4 — Support/Training Non-Electronics

Specific Sub-Tasks: Within the four major task areas previously identified, several sub-tasks areas will be studied and evaluated. Among the primary areas for investigation are the following:

- Non-Electronics — Current diagnostic practices in non-electronics systems will be assessed and evaluated to determine potential areas for improvement. The applica-
is a vital part of integrated diagnostics. Verification methods and tools will be identified and evaluated.

- Acquisition Procedures — A meshing of technology and acquisition management is necessary to accomplish integrated diagnostics. Acquisition documentation including specifications, standards, handbooks, regulations, etc., will be written or revised to ensure that integrated diagnostics becomes an institutionalized part of weapon system acquisition.

**GIMADS Products:** The ultimate product of GIMADS will be an institutionalized systems engineering process for weapon system maintenance, using both prognostic and diagnostic maintenance techniques. While GIMADS is a technology-based acquisition process, and cannot be defined in terms of hardware and software products, the GIMADS program will still result in some specific products that will contribute to the overall process. The types of products include, but may not be limited to, the following:

- Military Specifications (Mil-Prime)
- Military Standards (Mil-Prime)
- Handbooks
- Regulations
- Technical Reports
- Software Tools
- Hardware Tools
- Prognostics/Diagnostics Techniques

**PROGRAM STRATEGY**

The GIMADS program is being managed by ASD engineering, and will be accomplished by a combination of in-house engineering effort and contracted effort. The primary in-house effort will be technical integration, but will also include in-house studies and analysis and preparation of specifications, standards, regulations, and other appropriate documentation. The contracted effort will be performed by a single contractor to conduct detailed studies, analyses, design and testing for the types of task areas discussed earlier in this paper under Specific Sub-Tasks. The results of the contracted effort will be integrated into the GIMADS program by ASD engineering.

GIMADS will strive to not duplicate on-going efforts in diagnostics related areas, especially in the area of software and hardware tools. First priority will be given to other completed projects or project in progress, second priority to existing or on-going projects that can be supplemented or revised for GIMADS, and third priority to new projects conducted under the GIMADS program.

GIMADS is planned as a five-year program that began in mid-1985, and will conclude into 1990 with an institutionalized integrated diagnostics process. The application, however, of integrated diagnostics to Air Force weapon systems will not be delayed until 1990. Integrated diagnostics will continue to be applied to on-going weapon systems, using the best available knowledge and technology. GIMADS will, in fact, monitor and receive feedback from on-going ASD managed programs, so that the results of these programs will actually become part of the GIMADS institutionalization process.

**SUMMARY**

The evolution of weapon system diagnostics is closely tied to the evolution of weapon system avionics. From its very inception, avionics maintenance philosophy has been corrective in nature, as opposed to the preventive maintenance philosophy traditionally used for non-electronic systems. The GIMADS program at ASD, over a five-year period will investigate both corrective (diagnostic) and preventive (prognostic) maintenance techniques to develop and institutionalize a systems approach to weapon system maintenance. The program will utilize a combination of ASD in-house engineering and contracted engineering support to gather data, perform studies and analyses, prepare technical and management documentation, and develop hardware and software tools needed to implement an integrated diagnostics approach to maintenance for both electronic and non-electronic systems. Technical integration will be accomplished by ASD engineering, and will consider and utilize on-going integrated diagnostics efforts in industry and government.

**CALL FOR PAPERS**

This *MAGAZINE* solicits articles that cover all aspects of electrical-electronic functional systems for space, air, ocean or ground environments. These systems include, but are not limited to: navigation, avionics, spacecraft, aerospace power, radar, sonar, telemetry, defense, transportation, and command and control. The *MAGAZINE* reaches a broad audience whose interest is not limited to narrow specialties; articles are usually survey or tutorial in nature and cover the state of the art or important emerging developments. Submit 3 copies of the text along with illustrations and authors’ biographies to the Editor-in-chief and we will help you tailor your article to our Readers.