GENERIC INTEGRATED MAINTENANCE DIAGNOSTICS (GIMADS)
DESIGNING WEAPON SYSTEMS WITH THE MAINTAINER IN MIND

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ABSTRACT

The Generic Integrated Maintenance Diagnostics (GIMADS) Program, managed by Aeronautical Systems Division's Deputy for Engineering, is a joint effort by the Air Force and Industry to formulate a systems engineering approach for maintenance diagnostics. The program is developing written guidance -- a Military Standard and Air Force Guide Specification -- to integrate maintenance diagnostics considerations into every phase of the weapon system development process, from operational requirements determination through production and deployment. Using GIMADS guidance, the program manager, systems engineer, and design engineer can determine the best diagnostic approach for their weapon system and ensure unambiguous fault isolation in the resulting diagnostic design.

INTRODUCTION

Essential to the U.S. Air Force's efforts to provide the best possible maintenance and supply support to all its weapon systems worldwide is the ability to rapidly and accurately diagnose failures. The Generic Integrated Maintenance Diagnostics (GIMADS) Program, managed under the Aeronautical Systems Division's Deputy for Engineering, is aimed at changing the way USAF weapon systems are designed so that maintenance diagnostics can be performed quickly and efficiently. This will minimize the time and resources necessary to keep our weapon systems in the air where they belong—not on the ground waiting for someone to figure out what's wrong with them.

BACKGROUND

While recent advances in Built-In-Test (BIT) and Automatic Test Equipment (ATE) have shown great promise for improving diagnostic capability over conventional manual testing, actual diagnostic capability has not kept pace with the increasing complexity and testing demands of weapon systems. Examples of problems with current diagnostics approaches include the following:

- Recent systems will not reliably detect failures without also incurring frequent false alarms and high Could-Not-Duplicate (CND) Rates;
- Test tolerances for BIT and intermediate level ATE are often incompatible, resulting in high ReTest OK (RTOK) rates;
- Fault isolation cannot reliably be performed to the desired level, often resulting in the removal of several components to cope with a malfunction caused by a single faulty item.

These problems not only result in increased maintenance down-time, but also lengthen the logistics train necessary to support weapon systems. More spare parts and manpower are needed to support unnecessary/erroneous component removals. Additional expensive, bulky support equipment is often needed to compensate for diagnostic design deficiencies. This, in turn, increases airlift and host base support requirements at the expense of mobility and sustainability.

Recent technological advances, such as Very-High-Speed Integrated Circuits (VHSIC) and Artificial Intelligence (AI) offer tremendous potential for resolution of these problems, and the increased capability to collect and process maintenance data makes it possible to keep detailed equipment 'medical records' that could likewise be applied to improve fault isolation. However, no systematic process exists to take advantage of these emerging capabilities and others by applying them in an orderly fashion toward the development of easier-to-troubleshoot weapon systems. Diagnostics has traditionally been considered only during the latter stage of a system's development—much too late to exploit new diagnostics techniques in the system's design.

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The key objective of the GIMADS Program is to alleviate this deficiency by developing a systems engineering approach to diagnostics design. GIMADS will define the appropriate steps to be performed during each phase of a weapon system's development—from operational requirements determination through production and deployment—in order to optimize the system's diagnostic capability. The program will also identify the full range of design tools and techniques required to do the job.

**HOW WILL GIMADS ACCOMPLISH ALL THIS?**

To accomplish its objective, the GIMADS program will develop written guidance to be used by the major participants in the acquisition process—from the government program manager (and his counterparts in industry) to the equipment designer. The guidance will consist of the following:

A **GIMADS MILITARY STANDARD** that defines the systems engineering tasks that must be accomplished during each phase of development in order to ensure the weapon system's diagnostics capability is optimized for its intended operating concept and matured along with the other system characteristics. A GIMADS ROADMAP, included in the Mil-Standard, pictorially displays the relationships of diagnostics tasks to each other and to major weapon system milestones. An appendix to the Mil-Standard contains the rationale behind each task, guidance for task accomplishment and verification and a compendium of lessons learned.

A **GIMADS USAF GUIDE SPECIFICATION** that contains design requirements that can be tailored to specify the diagnostic capabilities of individual weapon systems. Along with each requirement is an associated verification. An APPENDIX to the Guide Specification contains the purpose and rationale behind each requirement, design methodologies to satisfy it, and tailoring instructions for the person who prepares the weapon system / equipment specification. A compendium of lessons learned is also included.

To support the development of GIMADS guidance, it is essential to explore all technical areas with potential application to diagnostic design and integrate appropriate technologies into the documents. The GIMADS approach is to identify the questions the participants in the design/development process must ask in order to properly integrate diagnostics capability into their products and to conduct technology investigations to provide answers. The GIMADS technology investigations, and the questions they will answer are as follows:

**FAULT DETECTION/FAULT ISOLATION (FD/FI) ALLOCATION:** How can we choose the levels at which component/subsystem failures are detected and isolated in order to best support the weapon system's operational concept? What is the best mix of onboard, flight line, intermediate-level and depot-level test equipment for this system?

**TESTABILITY/BIT:** Once we have determined the level at which a fault will be detected and/or isolated, how do we design the system so that these allocation requirements are met? How can we specify and verify that the design is testable? What can we do to mature the system's diagnostic segment?

**DIAGNOSTIC DATA BASE:** What elements of data are needed to support the diagnostic segment of this weapon system? What 'medical history' data is needed by the diagnostician to perform more efficient fault isolation? What kind of data can we collect on the performance of the weapon system's diagnostic segment in order to mature it and provide 'lessons learned' for design of follow-on systems? What type of data base is needed by the designer to analyze the diagnostic impact of his design decisions? [NOTE: The GIMADS Program will not develop a separate data base, but will identify existing data bases that contain needed data elements. Where necessary, the program office will recommend changes to existing data bases to accommodate integrated diagnostics requirements.] How can diagnostic information interfaces be standardized to assure and document test verifiability?

**MAINTENANCE AIDS:** What maintenance aids are available and practical for application to this weapon system? What is the optimum mix of maintenance aids—from paper tech orders to 'expert' systems?

**MECHANICAL SYSTEMS:** What diagnostics techniques are available for mechanical systems? How do we determine which measures are cost effective? What similarities and differences can be found between these techniques and those used on electronic systems?

**SOFTWARE DIAGNOSTICS:** What diagnostic techniques are available for mission and diagnostic software? What special diagnostics requirements exist for distributed software systems, artificial intelligence software, and firmware? How can software be structured to facilitate fault isolation?
**Avionics Prognostics:** What methods are available to predict when an avionic system is likely to fail, based on measurements of system output and operating environment? What are the key parameters in this process and how can they be collected, stored, and analyzed? How does prognostics fit in with the overall system diagnostic concept?

**Emerging Technologies:** What are the diagnostic impacts of artificial intelligence, VHSC/VLSI, and other emerging technologies? How can they be used to improve the system's ability to detect and isolate faults? What new problems do they impose? What generic failure criteria can be developed for reconfigurable systems? When do you repair a reconfigurable system? When is it practical to use expert systems for diagnostics?

**Human Factors Design:** Since human beings comprise integral parts of every diagnostic function, what impact does each technique/tool have on the person who will use it? How can human/machine interfaces be optimized, particularly in the areas of data entry and display?

**GIMADS Process Development**

The development of the GIMADS process is a joint effort by government and industry. A five year full-scale development contract was awarded in February 1987 to a nine-member industry team headed by General Dynamics/Ft Worth Division. Other members of the team include:

- General Dynamics/Electronics Division
- Bell Helicopter
- Marcon Industries, Inc.
- Giordano Associates, Inc.
- General Electric
- TRW
- Hughes Aircraft Company
- Rockwell International

Under the contract, the GIMADS industry team will perform the above diagnostics technology investigations and provide inputs to the GIMADS Mil-Standard and Air Force Guide Specification.

Annually, draft versions of the GIMADS Specification and Standard, designated GIMADS Interim Guidelines will be submitted to participants at a joint Government/Industry forum for review and
comment. The program office, with contractor assistance, will then integrate the comments and release the Interim Guidelines for application to ASD acquisition programs throughout the following fiscal year.

During that year, while the Interim Guidelines are in use, a refinement process will take place, wherein information from three sources will be used to prepare for the following year's release. First, as results are obtained from the contracted diagnostics technology investigations, new and revised requirements will be generated for the draft Specification and Standard. Second, as GIMADS requirements are levied by various SPOs, the GIMADS Program Office will receive valuable feedback on their effectiveness and ease of implementation. Finally, as other government- and industry-managed integrated diagnostics initiatives are identified by the GIMADS Program Office or General Dynamics/Ft Worth team, they will be incorporated in the GIMADS guidance.

At the end of the five-year development period, the formal GIMADS Mil-Standard and Air Force Guide Specification will be coordinated and released. Where necessary, changes to other documents that govern the development of systems' diagnostic capability will be recommended by the GIMADS Program office to the agencies responsible for the documents. These recommendations will be made throughout the GIMADS development, as the needed changes are identified and validated.
THE BOTTOM LINE....
MORE AIRPLANES IN THE AIR

THE PAYOFF: MORE AIRPLANES IN THE AIR, MORE BOMBS ON TARGET

While GIMADS will certainly reduce the life cycle cost of the weapon systems the Air Force buys, the primary benefit of this program is in terms of improved operational effectiveness. By reducing the time it takes to diagnose system malfunctions, shorter repair times, and quicker turnaround times can be achieved. That means each aircraft can fly more sorties per day. Reducing or eliminating CNDs and RTOKs prevents aircraft from aborting their missions because of repeat malfunctions, and the unambiguous fault isolation capability that will result from a GIMADS design approach is absolutely essential for reconfigurability and fault tolerance in near-term systems. This results in better mission completion rates. By eliminating the need to remove several parts to be assured of finding the broken one, GIMADS' improved diagnostics approach will substantially reduce the manpower, spares, and transportation needed to support a flying unit. That contributes to better mobility and sustainability. For the small investment Aeronautical Systems Division is making in the development of the GIMADS process and an equally modest up-front payment by weapon system program offices, the Air Force is buying a lot of bombs on target!