Abstract—Over the past two decades, the US Department of Defense (DoD) has seen the introduction of weapon systems that do not meet their diagnostic requirements when initially fielded. Some suffer false alarm rates over eighty percent [1]. During a product’s lifecycle, the ability to determine how well it performs is based on the capability to test and the evaluation of those tests. Different tests and evaluations are required throughout the product’s lifecycle. These tests must, therefore, have the standards that define parameters, techniques and procedures for measurements that present an accurate and precise communication of information. In order to effectively accomplish this task, the development of quality tests capable of supporting these tasks must be defined and documented for the design, production, and operations-and-support phases of a system’s lifecycle. As a product proceeds through its life cycle, the information collected at each phase must be used for the support of subsequent phases.

Demonstrations of avionics system and subsystem diagnostic capability are performed before a system or subsystem is verified. This ordinarily happens during the System Design and Demonstration phase of a program. In the case of aircraft or ground vehicles, there are several subsystem demonstrations, followed by a single system-level event. A major issue plaguing the development of aircraft avionics systems is the lack of standardized methods to demonstrate full testability in a scientific and efficient manner before an aircraft is fielded. This is usually due to budgetary, schedule and knowledge constraints. Shannon and Knecht [1] surveyed diagnostic managers in government and Industry regarding the current state of test on major aircraft acquisition programs. The authors reported that there was “agreement that current guidance was insufficient to prevent erroneous, incomplete or insufficient testing at the system or subsystem level” before an aircraft was fielded.

Each phase of the acquisition process can be decomposed into a set of processes that can be grouped together. These groups can be further decomposed until there is sufficient information to completely describe the process. Using this technique, a hierarchical set of data items and their associated processes can be defined. From this group, the processes involved in testing can now be identified and used in activities that have multiple applications. In this paper, the authors present the process flows associated with the development and testing of a system. The

![Figure 1. A0: Overall Product Lifecycle Process](image-url)
The authors identify where those processes typically break down “in the real world”, due to constraints such as budget, schedule, lack of training/guidance for those involved, and other factors. The authors then recommend use of existing standards, at appropriate "break points", and suggest where new industry-wide standards need to be developed if one does not currently exist.

Keywords-component: ATS Framework; diagnostics; prognostics; testability

I. INTRODUCTION

The authors have previously described a process for operational system test and repair [2]. It included elements such as Collect Operational Data, Test System, Perform Diagnostics, and Repair System. The authors defined points in the process in which IEEE standards P1636.1 [3], P1636.2 [4] and 1232 [5] could be leveraged to improve maintenance and repair.

It has become apparent over the past decade of US Navy and Marine Corps aircraft acquisition that there is a need for an analysis of processes that describe the development of a system and the subsystems that comprise it. Shannon and Knecht [1] found that both DoD and Industry often lack guidelines, standards and/or personnel with enough training or experience to effectively evaluate the performance of a system or subsystem and predict how the system or subsystem may perform once integrated or fielded.

This paper defines an overall process for developing a product, as well as three sub-processes that involve diagnostic testing and verification. The processes are illustrated using A0 format, with A0 being the overall process. The overall process is shown in Figure 1, above. The high-level tasks defined are:

(A1) Design Product, (A2) Produce/Manufacture Product, (A3) Operate Product and (A4) Support Product. It is a process that can be applied to a myriad of products. In this paper, the products discussed are assumed to be Navy and Marine Corp aircraft and the weapons replaceable assemblies (WRAs) that are integrated to form their avionics systems.

The sub-processes that are discussed in this paper are:

• A11: Develop Prototype Design
• A12: Test and Evaluate Design
• A2: Produce/Manufacture Product

The authors have analyzed these subprocess and defined where they typically break down in practice. Their breakdown leads to several real-world negative effects, such as high false alarm rates, unnecessarily high maintenance costs and reduced operational availability (Ao). The authors suggest where standards can be leveraged to mitigate or avoid process breakdown at these critical junctions.

II. PROCESS BREAKDOWN

Figure 2 shows the process of developing a prototype design. The input to the process is product materials, such as requirements specifications. The outputs of the process are the prototype itself, design data and a supportability report. The tasks in this process are: develop a detailed design, develop reports gauging supportability, reliability and producability, and finally, define a support concept. In this process, a frequent break point is just after, and often during, the iterative task of developing a detailed design. Often, the testability of a design has not been taken into account. When design-for-testability (DFT) is implemented, it is often implemented in a manner that is different across organizations, due to a lack of standard
guidelines. Moreover, there are currently no industry-wide standards of testability assessment. IEEE-STD-1522[6] was meant to be such a guide, but was not adopted by Industry or DoD. Therefore, several prime contractors rely on their own standards, many of which are based on MIL-HDBK-2165[7]. The myriad on implementations makes it increasingly difficult for DoD representatives to accurately assess a product for testability or to provide oversight to prime contractor testability verification. Another contributor to process breakdown is the financial incentive for companies to create proprietary architectures and proprietary protocols in areas where standards exist. For example, it may be of greater incentive to develop a system which communicates with a piece of ATE using a proprietary standard over Ethernet, rather than to design in compliance with the Local Area Network (LAN) eXtensions for Instrumentation (LXI)[8] standard protocol.

Figure 3 shows the process of testing and evaluating a design. The input to the process is design data. The output of the process is test results. The tasks in the process are: develop test specifications, develop design test procedures, develop tester requirements for design and manufacturing testing, and test and evaluate design. In this process, the breakpoint is at the point at which the design is tested and evaluated. There is often insufficient, or no, guidance concerning the scientific evaluation of diagnostic functions of a system. Shannon and Knecht [1] stated that both lack of qualified personnel and "programmatic inertia" contribute to process breakdown here. Programmatic inertia is defined as the tendency for a program to continue to move forward without sufficient time or resources to do complete and/or scientific testing. The managers interviewed by Shannon and Knecht stated that the lack of qualified personnel can be attributed to insufficient opportunities for on-the-job training, as well as a lack of available training courses. The problem is compounded by the fact that there are no industry-wide standards or guidance which an inexperienced engineer could follow.

Figure 4 shows the process of producing and/or manufacturing a product. The inputs to the process are the product design package and the prototype system. The outputs of the process are product data, production feedback and the completed, integrated product ready to be fielded. The process tasks are: develop production process plan and configure resources, produce product technical and support materials, screen product component, assemble product, identify test equipment, perform assembly testing, perform product acceptance, and record manufacturing test results. The breakpoint here is at the point of performing assembly, or system-level, testing. In [1], the authors site several reasons for breakdown at this point. First, the same causes as the breakpoint in component/assembly testing, showing in Figure 3, hold here as well. However, there is the added complexity of integration testing. Programmatic inertia is a contributing factor here, as well as a lack of common understanding between vendor and customer as to what the testing is meant to accomplish. This breakpoint is also susceptible to all of the "Causes of Discrepancies Between Test and Field Results" and "Causes of Optimistic Test Results" listed in MIL-STD-MIL-HBK-470A Table B-III[9]. Some of those reasons include:

- The demonstration maintenance technicians are not representative of typical field maintenance personnel because they have more education and training or greater knowledge of the equipment’s design.
- The monitoring situation imparts to the technician an urgency not normally encountered in the field.
- Known probable tasks are rehearsed beforehand.
- Necessary support equipment is readily available.
- Observed times are not contaminated with such
factors as administrative or logistic delay, as field results sometimes are.

- Difficult to isolate faults, such as intermittent and degradation failures, are not simulated during demonstration.

III. BREAKDOWN PREVENTION

By leveraging several different standards, process breakdown can be prevented. This will enable the fielding of more testable, reliable and open systems; reducing the amount of resources necessary for false alarm reduction after a product is already fielded. Applying these standards will not solve factors such as programmatic inertia or make up for requiring a standard where none exists, but the application of these standards can be viewed as a first step in a larger process of improving testing and integration of systems.

For process A11 (Figure 2), there is general agreement across government and Industry that an industry-wide testability standard and/or design-for-testability guidance would be of great benefit [1]. While such a standard and guidance do not yet exist, engineers can mitigate process breakdown by leveraging IEEE 1671.3 [10] to fully describe the product to be tested and easily update and exchange that information across competencies within an organization. A product description which uses IEEE 1671.3 may also be easily shared with an organization's customers or partners.

In process A12 (Figure 3), the breakpoint is at the point at which the design is tested and evaluated. This breakpoint can be mitigated by applying standards dealing with testing requirements and analysis. By applying IEEE 1671 [11] to the Develop Test Specifications action, a test engineer with any level of experience leverage the Automatic Test Markup Language (ATML) environment to develop a comprehensive, open test specification. Furthermore, by applying IEEE 1671, IEEE 1671.1 [12] and IEEE 1641 [13] to the Develop Design Test Procedures action, an engineer can fully define the test procedures, test data and test result format to be used. Finally, by applying IEEE 1671.2 [14] and 1671.5 [15] and 1671.6 [16] to the Develop Tester Requirements action an engineer can fully define any equipment necessary to run the test. Taken together, the conscientious application of these standards ensure that the process is not broken or misunderstood when it comes time to test and evaluate the design.

Process A2 (Figure 4) is similar to process A12 in that its breakpoint occurs at the point of testing. However, process A2 is concerned with integration testing. Too often individual components, or WRAs, pass individual testing, only to fail in integration testing. Again, the application of standards can mitigate against process breakdown. Though they will not completely mitigate factors such as lack of time, resources, programmatic inertia or other factors described above. During this process, IEEE 1636.1 [3] and IEEE 1636.2 [4] can be leveraged to bring some level of standardization and openness to the test results by saving them in a standard format, which can be easily shared or archived. This is important if the results need to be revisited after a product is fielded.

Integration testing of an aircraft typically brings together WRAs from different manufacturers, as well as government-furnished equipment. Leveraging these standards ensures that test results captured from the system can be easily understood and shared across multiple organizations.

IV. CONCLUSION

It is clear that there are several points during the design and
testing of a product where the process can breakdown. Additionally, it is clear that some of the breakdown is due to factors such as resource constraints or lack of training. The authors have shown that some of these breakpoints can be mitigated through the use of applicable standards. While it will not alleviate some programmatic constraints, or eliminate programmatic inertia, the use of the standards is a step in the right direction. It must also be noted that these standards are new. As they become more widely used and applied to various applications and use cases, application-oriented guidelines can be developed.

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REFERENCES


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