GENERIC SYSTEM BITE CONCEPT

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1. ABSTRACT

The experience of the BITE (Built-In Test Equipment) integration in the frame of IMA (Integrated Modular Avionics) leads to new concepts of BITE architecture, communication protocols and integration process.

The BITE functions of different systems have much in common. Each supplier has to implement similar functions to comply with the Airbus Directives (ABD) like the communication protocol, failure data memorization, rules related to failure correlation, the interfaces to the Centralized Maintenance System and to the Flight Warning System.

The analysis of common functionalities of System BITE leads to the idea of a Generic System BITE (GSB). This generic function could replace individual System BITE functions by providing the common functions as a scalable generic set and adapting them to specific system layouts by configuration.

2. INTRODUCTION

Today, numerous function applications from different system suppliers are integrated into the IMA modules. Each system supplier develops its own System BITE function taking into account the ABD. The System BITE is running in parallel to the application on the IMA modules either within the application partition or in a separated partition.

There is a wide range of System BITE implementations. Suppliers use non-, twofold- and fourfold-redundant architectures in combination with master-slave architectures or independently working BITE applications. The variety of System BITE implementations led to additional effort during the development and integration. The Figure 1 shows the distribution of System BITE in the IMA modules.

This philosophy has a major impact on the development phase. Modifications of the BITE common requirements have impacts on all system developments, which are especially demanding short before entry into service.

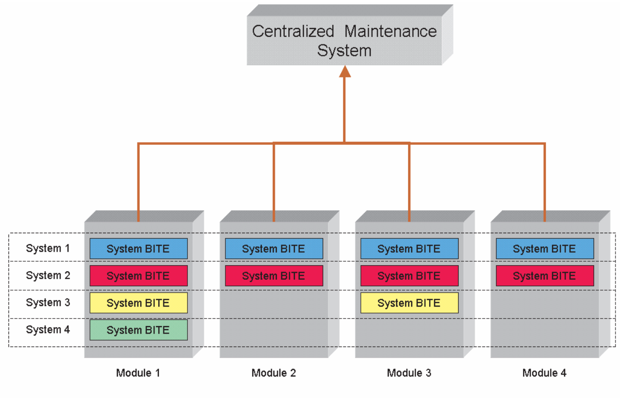

Figure 1 - Current A380 BITE Architecture

The following sections describe a generic BITE function and the corresponding communication protocol, which is able to replace the current System BITE applications, the BITE architecture and the current protocol.

3. BITE PROTOCOL

The BITE protocol standardizes the communication between the onboard Centralized Maintenance System (CMS) and the BITE of each aircraft system. The most promising candidate for the future BITE communication protocol in the avionics domain is the Simple Network Management Protocol (SNMP), which is broadly used in commercial local area networks for monitoring network-attached devices.

For the purpose of surveillance so-called agent applications are running on the devices to be monitored. The agents are capable of the surveillance of a device or a system and are able to report failures to a central failure management instance. Additionally they may provide failure context information on demand. The central failure management instance, also called manager, collects all failure information within a network or meta-system and is able to request additional system state information from the agents.

The communication between the manager and the agents uses the following message types:

1) GET REQUEST, used to retrieve a piece of management information.
2) GETNEXT REQUEST, used iteratively to retrieve sequences of management information.
3) GET RESPONSE, used to provide requested information.

4) SET, used to make a change to a managed subsystem.
5) TRAP, used to report an alert or other events about a managed subsystem.

In the frame of the maintenance system the SNMP agents correspond to the BITE applications and the SNMP manager takes the role of the Centralized Maintenance System. The TRAP command may carry the failure notifications, which will be send from the BITE to the CMS. The GET REQUEST and GET NEXT REQUEST may be used by CMS to request additional failure context information. A further use of those messages may be the request of a system test, which was initialized by the maintenance operator at the CMS. The test result may be provided by the BITE application using the GET RESPONSE message type. With the help of a SET command, the CMS could set configuration items in BITE or change the operating state.

3.1. Management Information Base

The SNMP agent makes use of a Management Information Base (MIB), a type of database used to manage the device or system status and failure context information. The MIB provides the data, which can be requested or set by the manager. The database is hierarchical (tree structured) and entries are addressed through object identifiers. The Objects in the MIB are defined using a subset of Abstract Syntax Notation One (ASN.1).

As a consequence, the future BITE will contain a MIB in order to provide information to the CMS on request. The BITE MIB could manage the following data for Integrated Modular Avionics:

- System Identification
  - Module
  - Flight Leg History
- Failure History
  - Received Failure Notifications
  - Transmitted Failure Notifications
  - Degradation Indicators
- System Tests
  - Test Description
  - Test Parameters

4. BITE ARCHITECTURE

A future BITE architecture, which will be applicable for all IMA systems, has to be carefully chosen in order to satisfy the needs of each individual system. There are several technical solutions with different advantages and limitations.

4.1. Architecture 1: Generic BITE Substitute

The first step of improvement starting with the A380 BITE architecture is the usage of a generic BITE application, which substitutes the variety of System BITE applications, developed by each system supplier. This Generic System BITE (GSB) provides the system all functions, which are needed for its own failure diagnostic related to maintenance. An independent supplier experienced in diagnostic will develop the GSB and the system suppliers will configure the GSB. The GSB will adapt to each individual system by configuration.

Using a GSB, the BITE architectures may be kept regarding to redundant design within a system. The scenario is depicted in Figure 2:

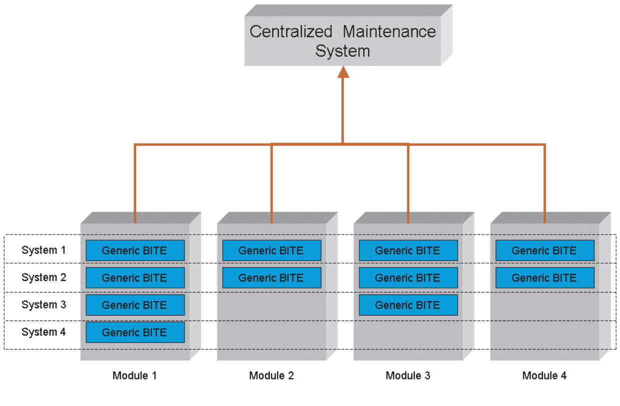

Figure 2 – Generic BITE Substitute

Following a summary of additional improvements compared to the current A380 BITE architecture:

- Generic BITE application
  - System supplier independent development
  - Less BITE development costs
  - Less integration effort
  - Less complex BITE system

4.2. Architecture 2: Shared BITE Partition

Since the System BITE shall be generic in future, only one BITE partition per module, which is shared by several systems, could be sufficient for the failure diagnosis, because the functionality can be commonly used. See here fore Figure 3:

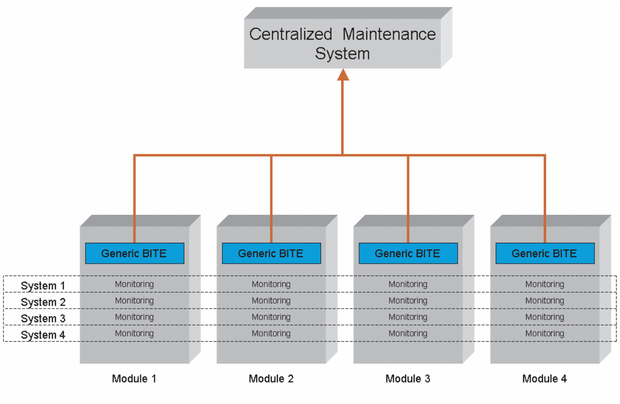

Figure 3 - Shared BITE Partition

The advantages of having one shared BITE application per module responsible for multiple systems are less consumption of resources within the IMA module, in particular processing time and memory. This argument is significant, since the resources on IMA modules are rare and valuable.

Performing the failure diagnosis within one BITE instance allows easier failure event correlation across systems.

This will reduce the number of depending failure messages towards CMS.

Assuming the architecture of one shared GSB per IMA module, it would be possible to integrate the functionality of the Resource BITE, which is responsible for module internal failures in A380 IMA, into the GSB. This step is easily possible, since the functionality of the former Resource BITE is relatively small. The failure correlation between System BITE messages and module internal monitoring could be replaced by considering the internal monitoring information directly in the failure diagnosis of systems.

This architecture includes all improvements of the previously described architecture. Following a summary of additional improvements compared to the previous architecture:

- Integration of Resource BITE function in GSB
- Failure diagnosis and correlation across systems
- More Centralized Approach
    - Reduced number of BITE compared to architecture 1
    - Less integration time and costs
    - Less complex architecture

4.3. Architecture 3: Centralized BITE in Avionics Domain

A third alternative BITE architecture could separate the BITE functionality from their systems and could be operated in dedicated modules. In this scenario the failure detections from the local monitoring is forwarded to a central BITE function. The architecture is shown in Figure 4:

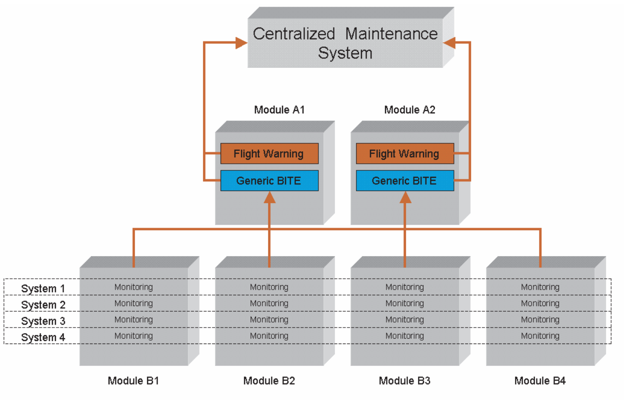

Figure 4 - Centralized BITE in the avionics domain

In A380 the Flight Warning System (FWS), which is responsible for the cockpit indication of critical events, already is operated on dedicated IMA modules. Placing the GSB functionality on the same modules as the FWS would be very beneficial, since the FWS and the GSB have similar tasks. For example a critical failure may lead to a warning notification for the pilot and also lead to a maintenance message processed by the GSB.

If the BITE function is located on a separated IMA module, it is independent from the switching of a system between redundant sides. The function remains on the same module and is able to operate continuously regardless of the operational state of the system and its underlying IMA modules.

Also the integration becomes easier, because the number of BITE applications is reduced again. The system applications have more memory and more processing time available for operational functions.

This architecture includes all improvements of the previously described architecture. Following a summary of additional improvements compared to the previous architecture:

- Centralized Approach
    - Reduced number of BITE compared to architecture 2
    - Less integration time and costs
    - Less complex architecture
- Independent operation from system state
    - No more switching of active System BITE and therefore static connection to CMS
    - Continuous failure diagnosis
- Close interface to Flight Warning System
    - May improve failure message to warning correlation

4.4. Architecture 4: Centralized BITE in Open World

This architecture describes a complete centralized approach of failure diagnostics. All local failure detections are forwarded via Avionics Full-Duplex Switched Ethernet (AFDX) to the CMS outside the avionics network. See therefore Figure 5:

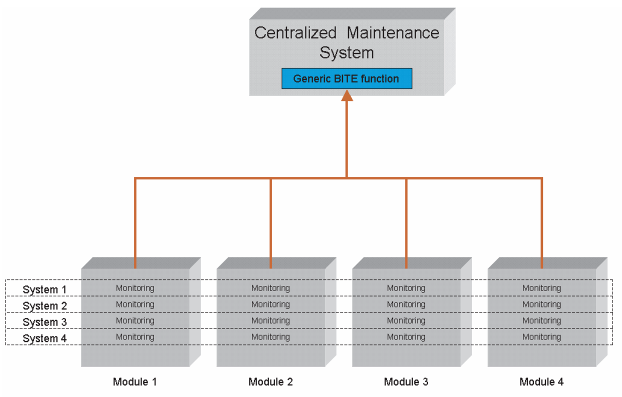

Figure 5 - Centralized BITE in the open world

This architecture is the simplest of all previous mentioned architectures. Its concept is clearly definable and understandable.

The BITE function, which consists mainly of failure localization, correlation and memorization, could be done outside the avionics network, since it processes only maintenance relevant information. It could be realized as a function within the CMS or on a dedicated platform. In this environment more advanced methods of failure diagnostic are feasible, like Model-Based Reasoning. There is much more processing time and memory capacity available than in the avionics network. Implementation costs will be less and the environment allows deeper diagnostic methods. The complete failure information is available at a central point including the basic failure detection information.

This architecture includes all improvements of the previously described architecture except of the closeness to FWS. Following a summary of additional improvements compared to the previous architecture:

- Diagnosis outside the avionics network
    - Deeper failure diagnostic with Model-based Reasoning techniques
    - More processing time and memory capacity
    - Saves rare and valuable resources in the avionics environment
- Central availability of the complete failure information

5. GENERIC BITE FUNCTIONALITY

The generic BITE functionality may be divided into several basic functions, which can be derived from maintenance objectives for a certain system.

The main objective of the maintenance system is the reporting of failures. The failures shall be reported to a CMS and shall be stored into a non-volatile memory of the module. The failure memorization is required for failure investigations in shop maintenance, for costumer support as well as for the module suppliers.

Additional requirements result from the wish for a failure prognostic capability, which will lead to a hardware degradation calculation function.

Hereafter the main GSB functions are explained:

5.1. Control Function

The Control Function is responsible for the initialization phase during the BITE partition start. It acquires the failure events coming from the monitoring layer and calls the BITE functions for failure processing. Secondary it includes an error handler for BITE internal malfunctions.

5.2. Diagnostic Function

The diagnostic function will process the failure events coming from different monitoring, such as the module internal monitoring, the application monitoring or the monitoring information received from a connected device. The combination of failure events may support the failure localization, if several actors monitor the same equipment from a different location. This case can be met on all systems, where one device is connected for reasons of redundancy to divers avionic modules and where the BITE functions within the modules have an intercommunication capability in order to exchange failure information.

Furthermore the diagnostic function has to correlate failure events resulting from a single failure cause. This avoids failure message flooding in the case, where several actors monitor a common function. The correlation will be archived by considering the failure appearance times, the physical failure localization within the system architecture, functional dependencies and information lines.

5.3. Degradation Function

The degradation function may calculate the remaining lifetime of the module or components of a system with the help of relevant parameters, e.g. time, temperature or vibration, provided by sensors within the system or the module. The calculated estimated lifetime shall be stored in the non-volatile memory of the module and the MIB structure of the BITE. The information can be requested by the CMS in periodic time intervals and on equipment replacements.

5.4. Reporting Function

The reporting function is called after the diagnostic function has finished its failure diagnosis. It will generate a failure message, which corresponds to a certain failure case resulting from failure localization and correlation. All relevant failure context information is compiled into a failure message and send to the CMS using the BITE protocol.

5.5. Storage Function

The storage function is in charge of all information to be stored in the non-volatile memory of the module and the BITE MIB. It can be called by other functions e.g. for the memorization of failure events from the monitoring, messages send to the CMS, flight leg data and hardware degradation information.

The memorization shall comply with common memorization directives in order to be able to interpret the data with a common tool after memory dump at the ground station.

5.6. Testing Function

The testing function provides a set of system specific tests and a module test for failure confirmation respectively clearance and further failure localization for the purpose of maintenance.

A maintenance operator at CMS can initialize tests, which are provided by the BITE. The failure messages resulting from a test can be processed through the diagnostic, reporting and storage function. Tests may also provide system status or measured data, which can be requested by the CMS from the MIB.

This function shall be prohibited during flight. It shall be available only when the aircraft is on ground and the engines are powered off.

5.7. Debugging Function

The debugging function is only used for aircraft integration purposes. It supports the aircraft assembly at the Final Assembly Line (FAL) by providing the status information of all IOs of the module. Another scenario for the debugging function is the testing phase for systems. The function may transparently forward the failure event information without processing in order to allow system application testing and debugging.

This function shall be prohibited during flight tests and after entry-into-service (EIS) of the aircraft.

6. CONCLUSION

The benefit of this generic approach will lead to cost and time savings during the system development, since only one generic BITE will be developed instead of one specific BITE for each system. Also late design changes will impact only one supplier, the GSB supplier, instead of all system suppliers. Furthermore the BITE integration process will be significantly eased, because the configuration, verification and testing can be done in a unique way. The reduction of complexity will lead to increased quality and BITE maturity at entry into service.

Airbus is currently launching a set of Strategic Technology Programs in order to develop new technologies related to aircraft health management. The development of the GSB is the objective of the European research project TATEM and Airbus internal research projects.