TEST PRACTICES FOR NEXT GENERATION AIRCRAFT CABIN SYSTEMS

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Keywords: *aircraft Cabin systems, Test Methods and Means, Test Facilities, System integration TESTS*

Abstract

Next generation aircraft designs will have to follow general tendencies as in the reduction of development costs and product lead time, as a result of the growing competition between aircraft manufacturers. Also a major goal for aircraft manufactures and operators is reliable and mature aircraft cabin systems at entry into service.

To comply with these requests new test practices must be originated in compliance with the developing system technologies, especially for next generation aircraft cabin systems, due to the increasing significance of cabin comfort and passenger entertainment which the aircraft operator will require for their marketing strategy.

This paper describes the main contents of the development activities in the area of new test practices for next generation aircraft cabin systems.

The new test practices will combine a new generic test system architecture with test methods & means in order to offer an increased test coverage and therefore a higher safety level in a cost and time effective way.

A new developed full-scale cabin system integration & verification test facility offers an early demonstration of new cabin systems functionalities and the testability of interactions between system hardware, controller and interfaces to other aircraft systems before assembly of first aircraft.

1 Introduction

The technical & technological progress of aircraft cabin systems will grow significantly in the future and cabin comfort and passenger entertainment demands will also consequently increase. There are several reasons for this.

The increase in aircraft cabin system functionalities resulting from the new developed electronic standards which gives rise to new cabin system technologies and new cabin and passenger oriented services (see **fig. 1**). The new information society will request in each transport vehicle (car, train, ship or aircraft) the same entertainment and the same access to information sources and inter-communication as in the home. This has more than one effect on the on-board aircraft cabin systems. Firstly the development and integration of these new electronic systems technologies and secondly, which may be of more importance, is the quick renewal and adaptation of the aircraft cabin systems, following a very fast self-accelerating development on the private and business communication technologies sector.

The integration from these extended cabin systems functionalities and the simultaneous increased application of system controlling & monitoring by SW leads to an increasing cabin systems complexity, which requires more comprehensive testing. A further increase of the cabin systems complexity is being derived from the new integrated modular avionic concept, which will be deployed to adapt future aircraft

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systems to the new electronic standards without having to reorganize the complete system concept and to obtain standardized modules, e.g. for processing and power supply modules, which in turn reduces system weight and space as well as reducing the maintenance costs.

The future growth of air transport and the economical means of air transport requested, together with the introduction of extended cabin systems functionalities and new integrated modular avionics concepts, will require more cost-effective cabin systems with high dispatch reliability from the beginning of entry into service. For a very large capacity aircraft, as the Airbus A340-600 or A3XX, dispatch reliability greater than 98% at entry into service has to be guaranteed. Considering this, the development of a new standard of test practices has to be in compliance with the technical / technological progress of next generation aircraft cabin systems, their related new cabin system technologies and new cabin and passenger oriented services.

The purpose of this paper is to highlight the main innovations regarding

- new test strategies
- new test methods & means
- new test facilities

to verify & validate aircraft cabin systems into the next century in an effective, safe and economic manner.

Complementary national and European R&D projects will provide a high-quality knowledge base concerning new test technologies and validate these technologies with experiments.

2 New Test Strategies

The SAE recommendation ARP 4754 proposes certification considerations for highly integrated or complex aircraft systems by systems integration requirements [1] to ensure the quality of the designed system before entry into service. These considerations apply on one hand, to the design phase by a design assurance concept, which requires an identification of the system requirements from which the design derived, and to validate that the design was satisfy the system requirements. On the other hand, the real product is tested and verified against the design and the requirements at each level of the product design:

- component level
- system integration
- lti-system or functional integration
- rcraft level integration

and validated against aircraft functional requirements.

These processes and methods have been defined for the certification of complex systems and will be one of the most important sources for the definition of new test strategies for aircraft cabin systems into the next century.

Another source for the development of new test strategies is the Airbus Directive ABD 200 [2], which describes the complete development process and includes the certification considerations from the ARP 4754. The ABD 200 is a basic document for all Airbus Industrie Partners and describes also validation & verification processes to be executed for aircraft systems. **Fig. 2** illustrates the complete development process and the associated documents acc. ABD 200.

The frames in **fig. 2** indicate the areas where research & development activities have been started. The new developed test strategies [3] consider a high level system-wide expression of major activities that collectively achieve the overall desired test results, as expressed by the described validation & verification processes for aircraft systems in the ABD 200.

These new test strategies are:

- plementation of multi-system tests to enable the verification of the increased inter-dependencies between the new cabin systems before ground & flight tests
- plementation of system integration tests to maximize the reliability of new system technologies at entry into service and to reduce number of aircraft ground & flight tests

- plementation of scalable test resources to enable an increase in resources for future cabin system technologies
- plementation of a continuous computer-aided tool chain from the system design process to the systems test process to accomplish an increased test coverage in a cost and time effective way
- plementation of standardized simulation interfaces to allow the interchangeability of validated simulation models and simulation data between Airbus Industrie Partners and system & component vendors
- plementation of simulation models e.g. for passenger behavior enabling a representative environment to be tested before assembly of first aircraft.

To achieve these new test strategies for next generation aircraft cabin systems best practice studies [3] were performed to form a generic Test System architecture for system, multi-system and system integration tests with new test methods & means and new test facilities.

3 New Test Methods & Means

The following describes the new Test Methods & Means which are the result of the best practice studies and will present the required modules of the selected new generic test system architecture (see **fig. 3**).

Test Engine

The Test Engine will process all interfaces to and from the System Under Test (SUT). All behavior simulations models and test scripts generated by CATEGA shall run on the test engine. It has to simulate e.g. for the Airbus A3XX the passenger behavior of about approx. 600 passengers and it has to be able to process approx. 3000 interfaces and approx. 20 data buses in a frame rate of models between 5 … 200 ms e.g. for the scheduled cabin systems tests for the Airbus A3XX.

The acquired test data will be sent to the Test Data Management for further processing.

For an “unlimited capability” in the number of interfaces and computational power for future cabin systems tests the test engine must have a “modular architecture” with standardized HW-interfaces to provide the ability to include simulation models from different simulation SW-tools.

In addition the test engine will allow an automatic configuration control, self-tests and self-calibrating capabilities.

Simulation Models

The use of generated simulation models by the test engine is the key input to perform the

- aircraft behavior
- system behavior
- equipment behavior
- passenger behavior

for representative tests before the assembly of the first aircraft.

Aircraft Behavior

The simulation of the aircraft behavior is required to prepare the basic aircraft data e.g. speed, altitude, engine data etc. for the tests.

System Behavior

To check the system functionalities it is necessary to simulate the complete environment of the system including all inputs e.g. sensor simulations.

Equipment Behavior

The equipment behavior has to be simulated, especially in the case of a fault simulation, to validate the behavior of the Build-In-Test-Equipment (BITE) functionality. Real equipment or simulations have to be exchangeable without re-configuration of the test engine.

Passenger Behavior

The possibility to simulate the passenger behavior is one of the basic requirements on a cabin systems test system. Only comprehensive simulation capabilities allow computer-aided tests with a high test coverage.

Computer-aided Test Generation Assistant

Main objectives of the novel computer-aided test generation assistant (CATEGA) are the standardization of an automated test procedure preparation process and the connection to specific tools and data bases, which will be partly applied in the system design process.

CATEGA will be directly connected to the computer-aided Requirements Tracing Management Tool (see **fig. 4**). The available data based system & test requirements are used as the basic inputs to be assigned to an automated test generation. Using this **System Requirements Data Base** permits the linking of test cases, test results to the basic system & test requirements. The effect of changes of requirements on test cases and test procedures can be easily followed and documented.

The second basic input of the system design process is the data description in the **Test Inter Systems Data Base**. The Test Inter Systems Data Base is a duplicate of the Aircraft Inter Systems Data Base used in the aircraft systems design process and contains the complete description of all signals of the aircraft systems and the test system. The descriptions include all types of signals; analog, discrete, data busses etc. It includes also the sources and sinks of the signals and their boundaries. Special extensions of the data model for test purposes make this data base directly usable for the computer-aided test generation, test data presentation and test data analysis.

The data of the Test Inter System Data Base will be used to define the sources and sinks of data, the point of observation (POO) and points of control (POC). Sources and sinks can be real equipment and/or simulation models of systems or equipment.

The **output-documents** of the novel computer-aided test generation assistant CATEGA are:

- Test Plan
- Test Design
- Test Cases
- Test Procedures
- Test Scripts

The **test plan** includes information about the system, which functionalities are to be tested. The **test design** describes the test object, test definition and the expected reaction of the System Under Test (SUT). The **test cases** are the lowest level of test description. The test cases describe the single test steps with the definitions of Point Of Control, where to control the inputs, the Point Of Observation, where to look or to measure and the expected result. Based on the test design we can combine numbers of test cases together to produce a **test procedure**. This combination will be performed by considering e.g. the points of control, or the points of observation or the type of measurement tool. The computer-aided arranged test cases and procedures can also be used for a guided **manual test execution**.

For the complete automation of the test generation process, the test cases and procedures can be used as an input for a **test script generation**.

Test scripts based on test procedures but contain additional information about the test environment, test engine etc. The required information will be stored in the **test system configuration data base**. The test system configuration data base will be used to control and document the configuration of the test system itself including the configuration of the system under test. The contents of the test system configuration data base will also be a part of the test data file in the archive to permit a later re-configuration of the test system to the same status for comparable tests of systems e.g. after modifications many months later.

The generated test scripts can be formed, after an adaptation to the original test engine, into an **executable test program for automatic tests**.

The linked **Test Preparation Data Base** is the related “results” data base of CATEGA and stores the generated output-documents.

Human Machine Interface

The features of the human machine interface are responsible for the test system acceptance and for the quality of test results. The philosophy is based on providing the test engineer with a maximum of flexibility including the assistance of a **novel tool box** to display the data for indication, acc. to the actual test situation and to allow the test engineer to select the type of data presentation, numeric or graphic, binary or in engineering units. All the necessary aircraft panels & indications, simulations and test panels will be virtual panels displayed on the test engineers monitor and easily adaptable.

The configuration of the test engine with the human machine interface will be realized via connection to the Test Data Management Tool.

Test Data Management

The Test Data Management Tool (TDM) captures the test data in real-time, stores data locally, distributes the data to different users via an Ethernet network and in the future external users will also be able to access the data. The amount of test data to be stored in real-time will be e.g. in the cabin domain of the new very large capacity aircraft Airbus A3XX, worst case about 16.5 MegaBits per second, due to the high number of approx. 3000 cabin systems interfaces, and several hundred Megabytes of data from approx. 20 data buses.

An additional function of the TDM is the option to repeat tests. The integrated teach-in function stores all performed manipulations during the test and allows the test to be repeated in the same time frame and with the same interactions to compare the behavior of different versions of equipment and to have an effective way to make comparable tests of systems e.g. same system with different development statuses. A simple replay of test data for further examination is also provided by the TDM.

The TDM separates the test engine from the “non-deterministic” world of the test system environment. The application of the TDM ensures the undisturbed execution of real-time processes in the test engine.

Test Data Analysis

The Test Data Analysis made by the individual test engineer who performs a free configurable data reduction and puts the test data into forms that can be used to deduce conclusions about the system under test at the test process.

Test Data Archive

The Test Data Archive stores all test data files inclusive of the test configuration data, relevant data base files of requirements and signal descriptions. In a worst case calculation a requirement to store 57 Gigabytes of test data per hour must be achieved e.g. audio data from cabin system. Additionally to the enormous storage capacity, a fast access to test data and the possibility to support several search criteria e.g. date of test, system configuration or test configuration must be achieved.

Data Base Interface

The Data Base Interface operates as a standardized interface for the different data bases and ensures that a modification of a data model in one of the data bases does not affect any other data models.

4 New Test Facilities

From the general designed test objectives exists a requirement for two new types of test facility for multi-system and system integration tests.

Multi-systems test facilities allow the test of the inter operability of a network of systems, to check the effect of e.g. common mode disturbances on data busses or power supplies. These types of test facilities have to be designed to behave very closely to the real aircraft (aircraft in the lab). The installation environment for equipment, the length of wire harnesses, common power lines and thermal behavior have to be carefully considered.

Following the test strategies it was decided to design and build system test benches as well as multi-systems test facilities e.g. a Cabin Systems Integration & Verification Test Rig. The design of both types of test facility follows the requirements of new test strategies and will implement the described new methods & means. The test facilities will use the same basic HW and SW for test engine, the same data bases and tools like CATEGA and test data analyzing and archiving tools.

Fig. 5 shows an example of a simplified structure of the **system test bench** for the Cabin Inter Communication Data System (CIDS) with Signal switching and conditioning units, fault insertion units, etc. and the possibility to replace original equipment by simulation of equipment for fault simulation and to allow automatic test execution by simulation of passenger and cabin crew inputs. Based on the same generic architecture the test benches can easily be connected together to build a **multi-systems test bench** with central test control and monitoring. All services and tools are designed for common use via the Ethernet and will be centrally maintained following the general strategy.

According to the new test strategies a **Cabin Systems Integration & Verification Test Facility** (see **fig. 6**) as a multi-systems and system integration test facility based on a physical full-scale mock-up of a A3XX fuselage and ready for installation of all components of cabin systems and their wire harnesses, enabling all systems functions in parallel, will be developed. It will allow the installation of all necessary sensors and actuators and where necessary simulations. The Integration & Verification Test Facility will be fully equipped with all cabin interior e.g. ceiling panels, seats, hat racks, galleys etc.. It allows further the installation and testing of the cabin air systems to check passenger comfort. A central test control and monitoring also of allows simulation the aircraft behavior and different flight phases for tests. Fault insertion units will be installed to generate common mode failures to test the behavior of systems in a network. The power supplies of the Integration & Verification Test Facility will also allow the variation of voltages and of frequencies for tests.

The new Cabin Systems Integration & Verification Test Facility with a fully equipped cabin is also suitable for the demonstration of the passenger and cabin crew interfaces of systems, to verify the developed Man Machine Interfaces and to check maintenance procedures. This will support the early acceptance of the cabin systems by cabin crews and passengers and ensure the smooth introduction of new aircraft cabin systems.

5 Conclusion

The increased aircraft cabin systems functionalities and new avionic technologies requires new test practices to accomplish the verification & validation process acc. the newest regulations for aircraft systems.

On the basis of new developed test strategies a new generic test system architecture in combination with new test methods & means and new test facilities are described.

The development activities presented in this paper describe a new approach to achieve more effective, safe and economic verification & validation processes. This work supports the general goals to reduce the program risks and to obtain more reliable aircraft cabin systems at entry into service.

References

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[3] DaimlerChrysler Aerospace Airbus, Annual Results Report 1999 of the national R&D project CASIV. DaimlerChrysler Aerospace Airbus, 2000.

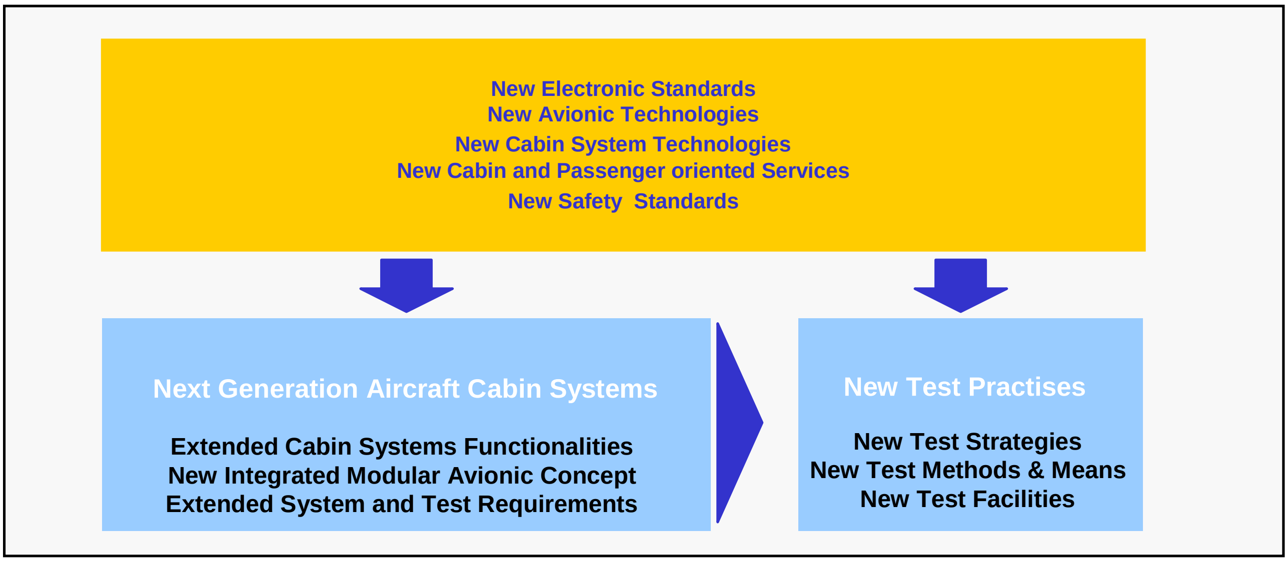

Figure 1 Impact of new Electronic Standards and new Avionic Technologies

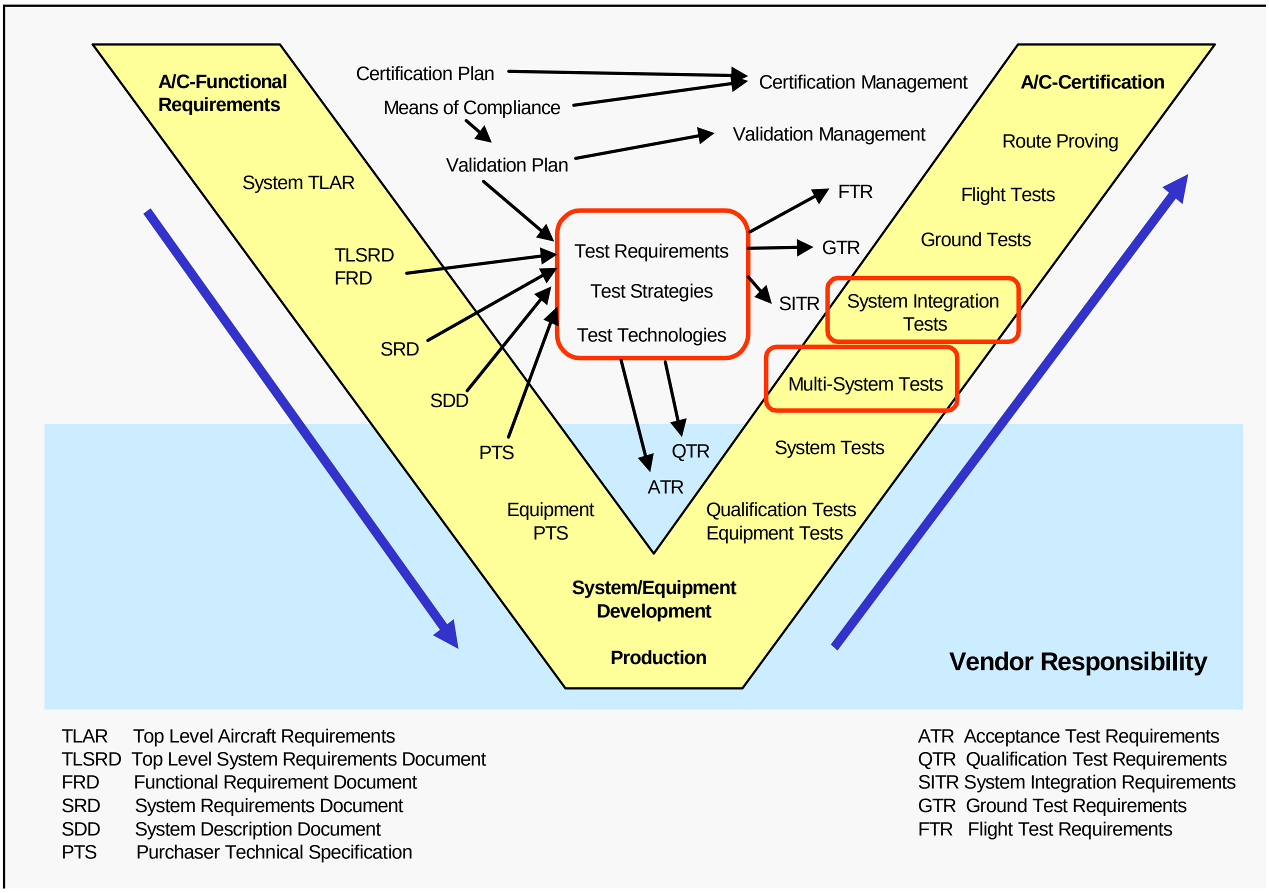

Figure 2 Development Process and the Associated Documents acc. ABD 200 [2]

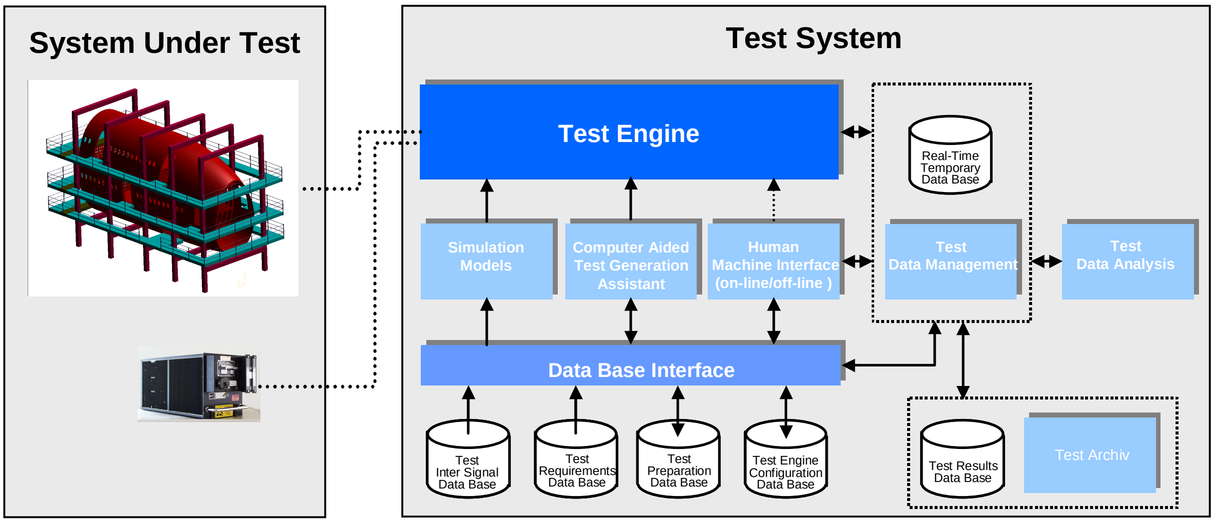

Figure 3 Selected new generic test system architecture

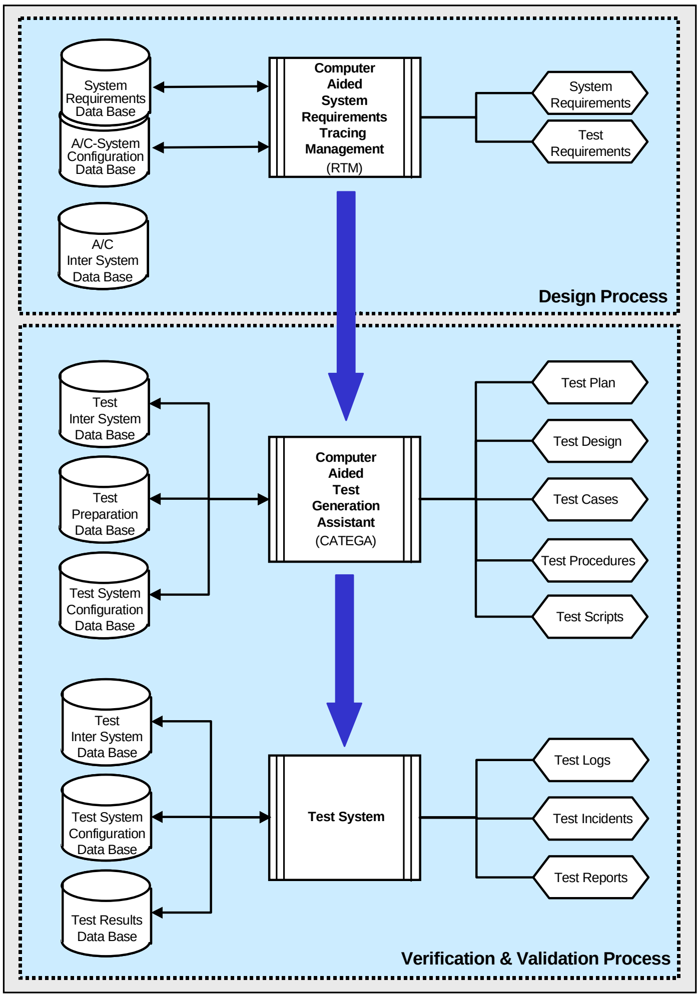

Figure 4 Implementation of the novel Computer-Aided Test Generation Assistant (CATEGA)

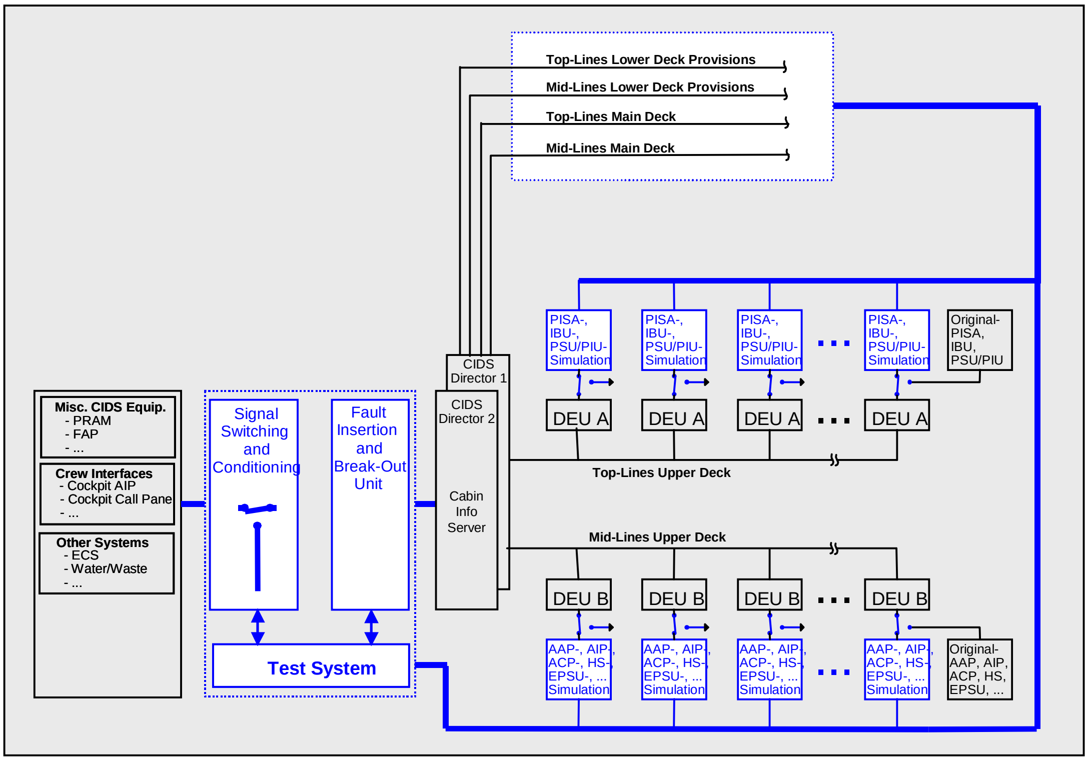

Figure 5 Simplified Structure of a System Test Bench for the Cabin Inter Communication Data System (CIDS)

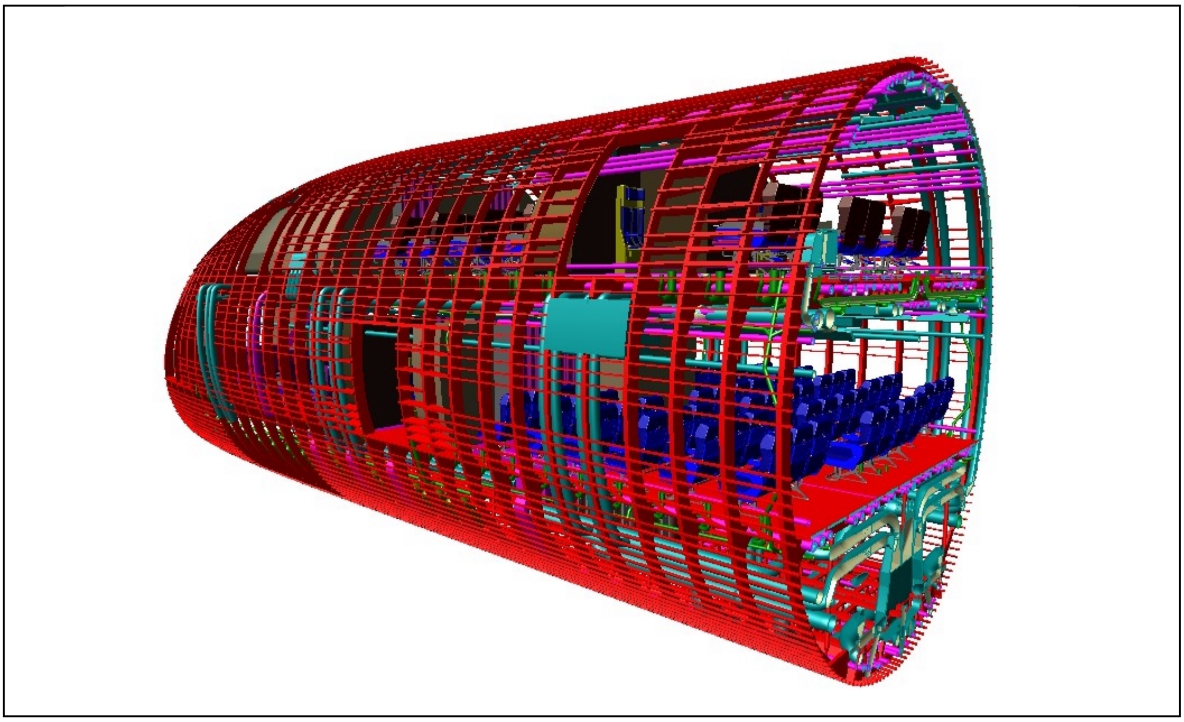

Figure 6 Cabin System Integration & Verification Test Facility intended for the new Cabin Systems of the Very Large Capacity Aircraft A3XX