INTEGRATED TESTING FOR A/C SYSTEMS

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Abstract

The Concurrent Engineering approach and the significantly reduced time slot for an A/C development require an adaptation of the test process to cope with the resulting requirements. Due to the fact that the flight test phase is always the last step within the qualification and certification chain, a reduction of the flight test phase duration is only possible by intensive integration of the previous test and simulation activities.
Based on the A/C system qualification and certification this paper should show how a highly integrated test process will support the provision of the necessary verification in the given time frame.
The starting point therefore is a function based overall testing strategy at A/C level. This testing strategy should include all available test means like flight test A/C, ground test means incl. multi system integration test means. This top level testing strategy will be based on the multi-system level testing strategies. One focus of these multi-system level testing strategies will be to put as many tests as possible in the phase before first flight. Especially the tests regarding system maturity will provide a high potential to ensure a successful and effective flight test phase.
The system maturity could be improved by a joint approach between all key players within the system development – system design office, system supplier, system integrator, test department, certification office. Therefore a constant information exchange, a coordinated test planning and interacting adaption of activities is absolutely essential. The basic approach therefore will be described in this paper.

1. SYSTEM DEVELOPMENT PROCESS

The principals of the system development process could be shown with a 4 step phase model [1],[2].

- Phase 1: Analysis & Definition
- Phase 2: Design
- Phase 3: Implementation
- Phase 4: Integration & Test

1.1. Phase 1: Analysis & Definition

The analysis & definition phase is characterized by the preparation of the requirements. Within an A/C development process these will be divided in several layers beginning with the top level A/C requirements via the A/C function requirements, the system requirements down to the equipment requirements.

This is an iterative process which will be performed by continuously and systematic validation if the defined requirements are explicit and complete and will meet the functional expectations.

1.2. Phase 2: Design

The design starts when the requirements are defined. This will start with the top level design based on the top level requirements and layer by layer go down to the lowest level.

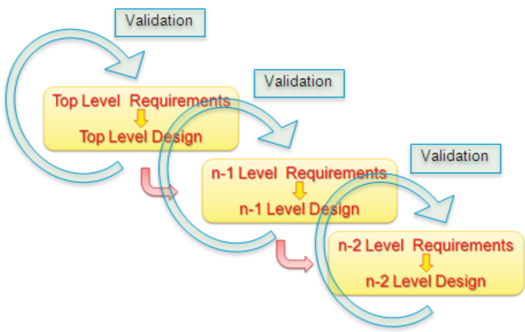

Figure 1. Phase 1 & 2

1.3. Phase 3: Implementation

If the design phase for the lowest level is successfully passed the implementation will be started.

1.4. Phase 4: Integration & Test

After the implementation is finished for the lowest layer the integration of these parts to the next higher integration level will be performed. In parallel the tests for these parts will start and consequently be performed for each higher integration level. This phase will allow the start of the system verification and therefore the results of this phase could be critical for the further A/C development. The opportunities of this thought are the key enabler for the approach described in this paper.

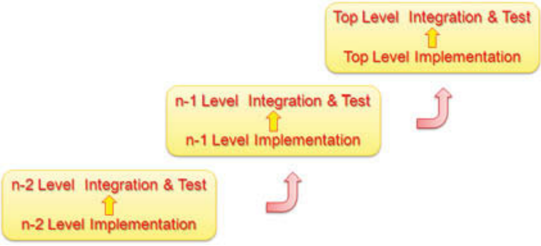

Figure 2. Phase 3&4

2. SYSTEM VERIFICATION AND VALIDATION (V-MODEL)

2.1. Definition

The two definitions below are given in [3]

Validation

The determination, that the requirements for a product are correct and complete.

Validation answers the question: Are we building the right aircraft/ system/ function/ item?

Verification

The evaluation of an implementation of requirements to determine that they have been met.

Verification answers the question: Did we build the aircraft/ system/ function/ item right?

2.2. Verification

The comparison of the results from integration and test with the requirement is the verification. The verification will be done between the corresponding levels.

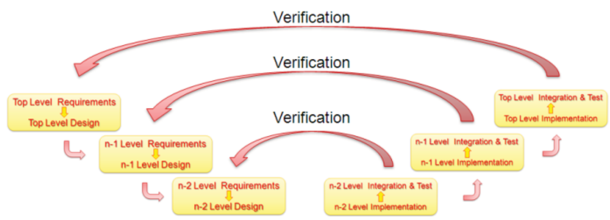

Figure 3. Verification

2.3. V-Model

The combination of verification and validation is the V-Model. The V-Model describes the basic way of showing compliance of an A/C / System / equipment design with the given A/C / System / equipment requirements.

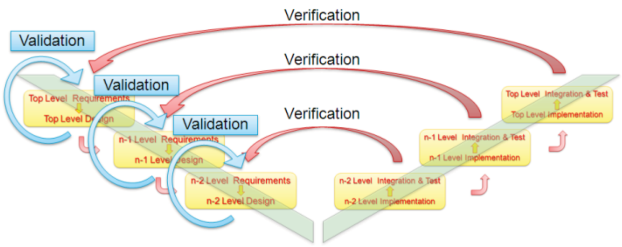

Figure 4. V-Model

2.4. Example

The figure below shows the V-Model for a part of the flight control system of an Airbus A/C.

The left branch of the V starts on top with the TLAR (Top Level Aircraft Requirements) going down to the PTS (Purchaser Technical Specification) which is in Airbus responsibility and ends with the SES (Supplier Equipment Specification), which is in the system supplier responsibility.

The right branch starts at the bottom with the equipment qualification and goes with continuously growing integration level via integration test rigs and ground test to the final flight testing.

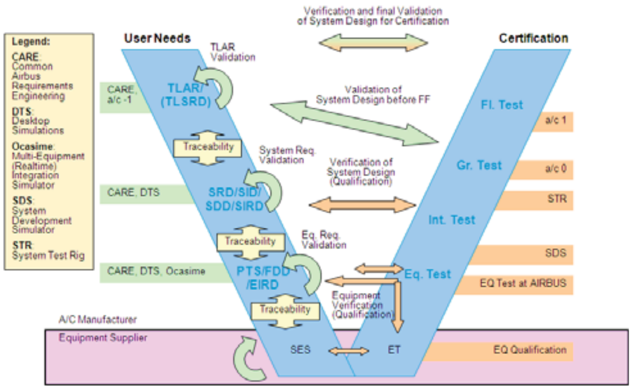

Figure 5. V-Model

3. TEST STRATEGY

The test strategy defines the basic principles for all further test & integration planning steps and is also a key point for the successful evidence of the system maturity. The test strategy will also have a strong link to the work share between all partners involved in a system development program.

The overall goal of the testing efforts within an aircraft development program is to secure the aircraft safety and to show compliance with all requested requirements (e.g. certification req., qualification req., design req. etc.). The appropriate means of compliance for a specific requirement is defined in the system verification & validation matrix (V&V matrix).

The test strategy will show how the tests on the different test means will be combined to get the most efficient test sequence, how the necessary test results could be delivered at the right point in time during the development process and how the tests could help to parallelize the V&V process and the evidence and improvement of the system maturity. Due to short A/C development time slots and the industrial ramp up after A/C entry into service (EIS) the evidence of the system maturity is one of the key elements to secure the commercial success of an A/C program.

Therefore the tests have to be performed according the given V&V matrix. But physical tests are not the only means of compliance and the V&V matrix also shows where other MOCs are chosen, especially models & analysis. During the system development a lot of different computer models will be created to support the system concepts and design. Due to the continuously improving capabilities of computer aided simulation these could also be very helpful to support the test activities and therefore the meaning of physical tests will change. For example the start of the test activities could already start on model level (what means at a point in time long before the first hardware will be available) and during the development process subsequently extended by physical test.

Considering the points mentioned above the test strategy for future A/C development programs will become more complex and the integration of simulation and physical tests is the major challenge for all partners involved in the V&V process.

4. SYSTEM INTEGRATION & TEST

According the V-model the system integration & test flow as shown in the picture below is starting with the equipment level testing at supplier side and ending with the ground & flight testing at AIRBUS.

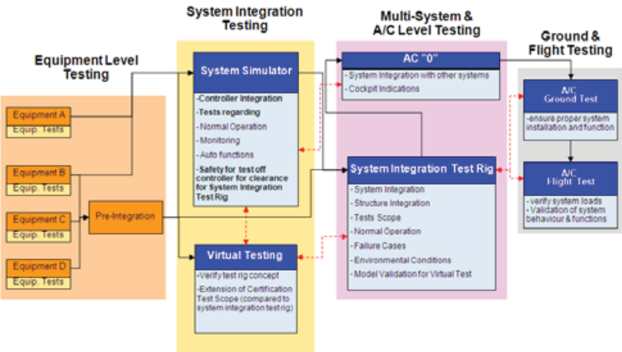

Figure 6. System Integration Flow

4.1. Equipment Level Testing

The tests on equipment level are in most cases performed by the supplier. The equipment qualification is a long term activities starting with simple acceptance testing after equipment manufacturing and ending with an enormous amount of individual qualification tests.

Main goal of these tests is to show compliance with the equipment requirements. During these tests a huge amount of data will be produced and a lot of experience will be collected which will not necessarily have a link to a pass or fail criteria of a test. That means a lot of information which could be significant for maturity on the next integration level will already get lost during the first integration step.

Therefore one topic for the test strategy on equipment level must be to secure the continuous data & experience exchange with the next higher integration level. One of the key elements to succeed in this approach is to establish a common data exchange format which allows to enter, to combine & to evaluate data from highly heterogeneous sources.

Parallel to the testing the supplier also develops models of the equipments – e.g. functional models, CAD models, physical models. These models will be used for proving the concept, design validation and optimization on supplier side. But in the mean time some of these models will be integrated in the higher integration level. Therefore the models must be compliant with a given standard for model integration. But this integration will give the opportunity to perform integration tests on model basis.

4.2. System Level Integration Testing

The next step during integration will be the test of the equipments on a system integration test facility (see BILD 7).

Figure 7. High Lift System Integration Test Rig

These could be done in different combination of physical test rigs and simulations.

The classical approach is a more or less complex integration rig which includes all necessary system equipment to perform tests on system level. This approach strongly depends on the availability of the equipments. That means that the first results on system level will be relatively late during the design process.

The way to avoid this dependency could be to start testing on a virtual integration platform with equipment models. The further steps in this process will be to exchange the virtual integration by more or less complete physical test rig and in parallel the equipment models by real equipments. The picture below shows a function integration bench which combines the real system controller with a simulated system / A/C environment.

Figure 8. High Lift System Integration Simulator

A specific approach therefore is the simulation of the system under test and the test facility to support the rig concept phase and after the validation of the simulation model help to minimize the amount of highly complicated and time consuming physical tests (see picture below) and extend the scope of testing.

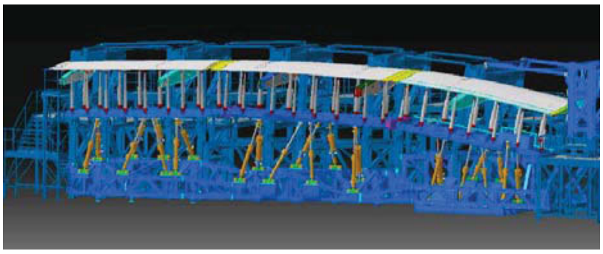

Figure 9. High Lift System Virtual Testing

Another approach could be to combine separate small test facilities on equipment level by direct connection between the necessary interfaces to an integrated system level test rig. This would be applicable for single system testing and also for multisystem testing.

During the last couple of years a lot of additional functionality was added to this kind of integration test rigs – so they will become significantly more than a single system integration test rig, e.g. some of these rigs & simulation cover a lot of structural aspects and the results delivered within the integration tests will be used for structural verification later.

4.3. Multi-System & A/C Level Integration Testing

The classical test means for A/C level integration testing are the multisystem integration simulators and the big integration test rigs like the Iron Bird and AC0. These test means allow multi-system testing and deliver numerousness results considering the big number of system interfaces integrated on these rigs.

Figure 10. IRON BIRD

The major disadvantage of this kind of facilities is that they have a strong link with a wide range of different systems which need to be integrated before the first test results will be available. The other challenge is the rig availability. A multi-system test means will be used from involved systems to perform tests on it. This will end up with a big amount of individual tests which need to be performed during a limited amount of time available.

Therefore especially for these test means the combination of physical test and simulation offers a great opportunity to become more independent from equipment deliveries. This approach could also help the start testing with engineering units of the equipment and via simulation help to overcome the equipment limitation / deviations.

4.4. Ground & Flight Testing

The ground & flight test phase is in most cases the shortest test phase during the A/C certification process. The optimization of the ground & flight test phase will directly influence the overall development process. Therefore one focus of the previous test activities must be the support of a smooth and intensive ground & flight test phase without unnecessary limitations and additional maintenance activities to overcome system deficiencies.

On the other hand it has to be secured that all ground & flight test needs will be reflected within the previous test activities. This also could mean to check ground & flight test procedures already during the tests on the integration test means.

By considering these results the ground & flight test procedures can be optimized, the expected test results can be defined more precisely and the test results evaluation can already be prepared to reduce the test analysis time afterwards.

5. TEST PLANNING & PERFORMANCE

The integration test planning & performance are driven by the major milestones within the A/C level testing. The major steps are A/C Power On, First Flight and the A/C certification.

All test activities have to be harmonized according these program milestones. In parallel the testing should support the improvement of the system maturity from the beginning of the tests. The carefully planned interaction between the test activities, the system & equipment design progress and the equipment availability is one of the key drivers.

The figure below shows an example of such an integrated test plan for a part of the flight control system. It is obvious that the above mentioned current engineering approach is also reflected within this kind of plan. In this particular case it is a requisite to start as early as possible with integration testing to get as soon as possible a feed back of test results into the ongoing system design activities. Therefore one of the major issues for the currently running A/C development programs is to move the start of the integration testing to the left (especially for A/C systems).

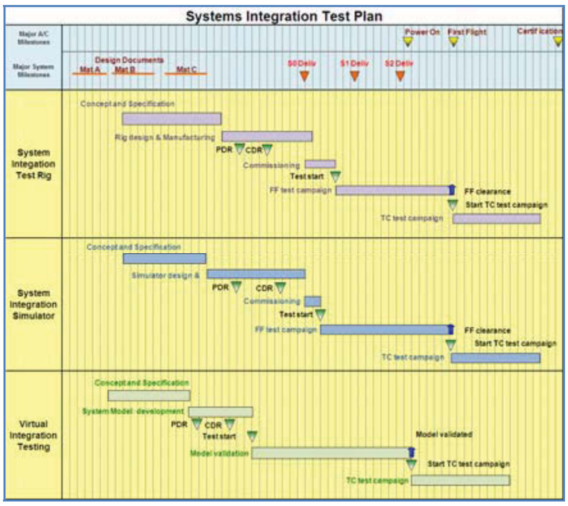

Figure 11. System Integration Test Plan

The other big opportunity to improve the efficiency and value of testing is the exchange and communication of test results and the transfer of basic experience about the system behavior. Due to the complexity of modern A/C systems and the high percentage of software related design issues the amount of test results in the different integration levels is growing significantly. In parallel the responsibility for test definition and performance is subdivided between several different partners – from different companies, from different sites, from different design teams, from different ATA chapters. An integrated test team in combination with a common test data base is one opportunity to overcome this situation and quite the contrary this offers the chance to integrate the specific points of view to a more comprehensive knowledge to increase system maturity.

Integrated test teams means that all involved partners will start working together already during the V&V preparation and the test definition phase. In the beginning it is more focused on the definition of the appropriate test means. The next step is to ensure that all the system requirements are testable. During the test definition the team has to secure that all partners have the same understanding & interpretation of the system requirements. One outcome of this exercise will be the optimized test sequence.

In the test performance all involved specialist and testers have to be present during the test to maximize the gather of experience of the system under test.

After the test the data evaluation has to be done in close contact between testers and system designers to identify problems as early as possible and streamline the trouble shooting. But also after a successful test it is necessary to validate that expected test results are right and no unknown system behavior could be observed.

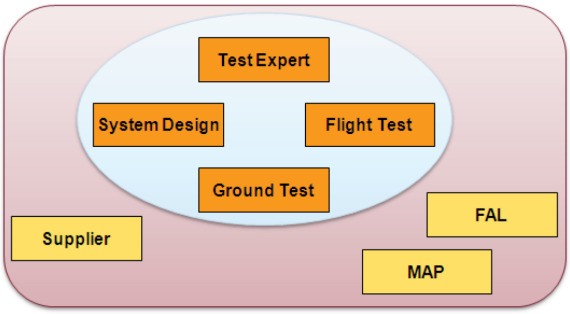

Figure 12. Integrated Test Team

6. CONCLUSION

The “Integrated Testing for A/C Systems” is nothing completely new within the A/C development. The paper shows areas in which more integration could help to overcome some of the challenges for new A/C programs and give some ideas about opportunities for further improvements. In the moment some of the techniques especially within the field of virtual testing & simulation are in investigation and already show some promising results. But the potential of these techniques is much bigger than thought today and definitely needs some further development.

Integration in the sense of this paper is an ambiguous approach and tries to integrate more than only one aspect. Aspects for a successful integration are

- Test strategies for different system
- Test schedules
- Test means
- Physical and virtual testing
- Test teams (internal & external)
- Test results
- Test Evaluation

One of the critical tasks therefore is to find an adequate level for this integration without decelerating the test progress and to avoid doubling of test activities. The other big effort is the continuous adaptation of the integration planning to the test results and the design modifications (especially for the long-term activities).

The integrated testing is the key issue for a successful reduction of test phase duration in combination with a significant improvement of the system maturity.

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