Test engineering methodology integrated in the Project System Engineering

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1. Abstract

Lifecycle (development, production, maintenance and operational use) Tests Infrastructure is a crucial part of a project and consume significant budget and effort.

Definition and selection the right Tests concept by considering the overall Lifecycle tests aspects in early stage of the project, can reduce the Project Life Cycle Cost (LCC), improves the Project profit and will deliver a better product to the Customer.

The importance of the System Tests Engineering (STE) activities is well known for many years but it is not implemented in most of the companies. The main reasons for this are

a. At early stage of the development there are many uncertainties and information gaps. The project team feel that they don't have the knowledge to define in this stage the System test concept.

b. There are many aspects which should be taken in consideration for the Test concept definition, Maintenance, Safety, production, Operation Use, development phase etc. What will be the process to achieve the optimal Tests concept technically and commercially.

If such STE activities exist in a project then usually it is done intuitively by the Integrated Project Team (IPT) and probably it will not lead to the best and the optimal solution.

This article describes a methodical tool which can be integrated in the Project STE activities in-order to define the optimal Lifecycle tests infrastructure at early stage of the Project.

The concept is integrated in the System engineering activities from the Project Kickoff and step by step in a structural and clear way defines the optimal Test concept technically and commercially.

The process connects the Development tasks, Maintenance concept, product safety aspects, production requirements and the Customer Operation uses with the STE.

Since this STE activity starts from the Project start-up when the development activities are still on goings, it is an iterative process which progress continually with the product development till a well-defined stop condition is met and the final Test concept is frozen.

Some examples for Project tests optimization which can be analyzed in this STE process are:

a. Tests which will be performed by the product Built In Test (BIT) vs Tests which will be performed by External Testers

b. Commercial Optimization

- System Level Tests only vs including Subsystem level Tests in the Production and Maintenance activities
- Dedicated Testers for each Lifecycle phase vs Common Testers.
- Complicate and Automatic Testers vs Simple and Manual Testers

2. Introduction

During Project startup the Project team focuses on initiating the Project activities, such as contract evaluation, system engineering, program planning, etc. Their priority is to meet the technical requirements of the Project, and less the System Testability which is considered at this time as not urgent. This causes usually the Tests issue to be left aside for a later stage.

The results of this will be that:

a. Testability coverage gaps of the product will be detected late in the development process, or sometime after completion the development, while changes in the product are complicates and expensive.

b. The Test Infrastructure (the Built In Tests (BIT) and the Testers) will be delayed, and the production people will not be able to test the product properly.

This methodical STE which is described in this article evaluates the tests requirements for the overall product Lifecycle, as part of the Project System Engineering activities from the Project kickoff. The STE defines the Lifecycle Test Concept (LTC) iteratively in parallel to the progress of the development .

It is performed step by step in a structural and clear way to achieve the optimal and the most efficient Test concept technically and commercially.

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The STE is performed by a professional Test Engineer (TE) who is part of the System Engineering team of the Project, or for bigger programs, by a test engineers team.

2.1. Stakeholders in the STE

Figure 1 describes examples of Stakeholders who are involved in the Project STE process.

For example the marketing people would like to reduce the cost and the price of the product LCC, which is affected by the STE process.

Figure 1 – Examples of Project STE Stallholders

The ILS manager wants to ensure that the Test infrastructure support the ILS Plan and the management looks for the Project deliveries on time and the expected profit.

2.2. STE Process Optimizations

The STE process includes optimization of the Test infrastructure., for example the following analysis can be performed as part of the STE process:

a. <u>Tests which will be performed by the Built in Test (BIT) vs Tests which will be performed by the External Testers</u> - The initial approach is to maximize the tests which are performed by the BIT and to reduce the amount of Testers. This approach is limited, since improvement of the BIT coverage requires more hardware (H/W) test resources, which affect the False Alarm Rates (FAR), system reliability, etc.

   Note: BIT False Alarm is notification of a system failure when in reality there is no real failure in the system.

b. Commercial Optimization

   Commercial optimizations are performed as part of the STE using the Project Tests commercial model.

   Examples of commercial optimizations can be:

   - <u>System Level Tests only vs including Subsystem level Tests in the Production and Maintenance activities -</u> This is a cost optimization which takes in account the effort which is required to repair a failure in the System Level relative to the Subsystem Tests and Testers costs. This decision is affected by the production yield, BIT Coverage, repair time etc.
   - <u>Dedicated Testers for each Project phase vs Common Testers</u>– Cost optimization between Dedicated Testers for each lifecycle phase or Common Testers for more or all Lifecycle phases.
   - <u>Complex Testers vs Simple Testers</u> - Decision between Complex (e.g. Automatic) Testers which are more expensive or Simple (e.g. Manual) Testers which are cheaper but the tests will take longer and therefore will cost more in overall.

3. STE Process

The STE is implemented in the Project according with the flowchart which is described in Figure 2.

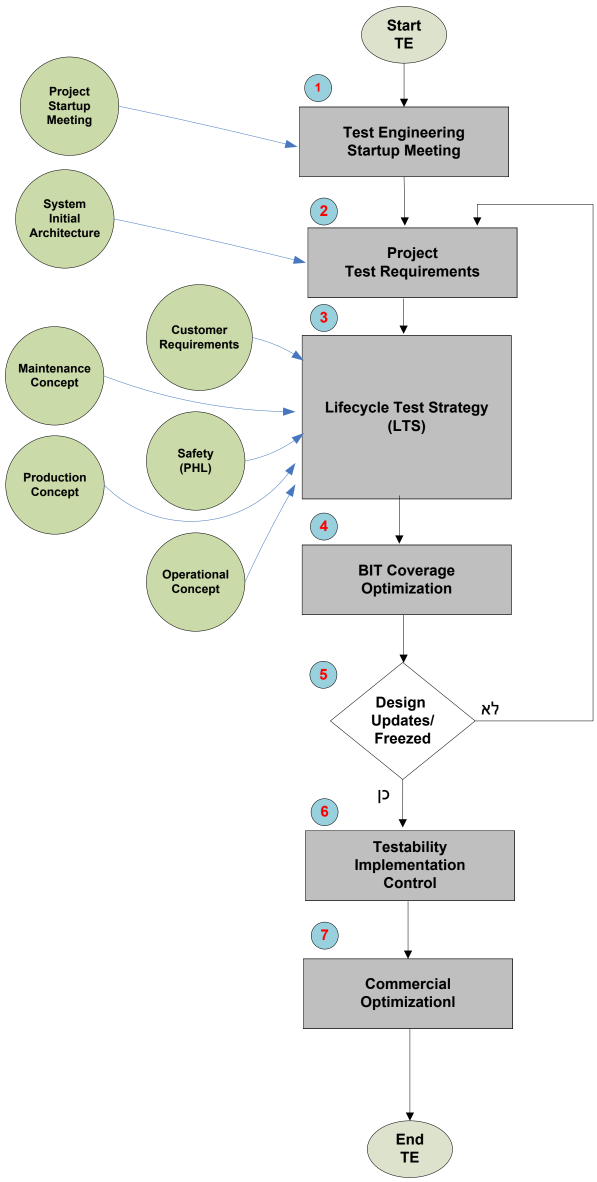

Figure 2 – STE process in the Project

The STE Process starts together with the Project Kickoff and it progresses in parallel with the Project development, to enable the Testers and the BIT to be available on time for the Project Integration and verification.

A typical Project schedule is described in Figure 3.

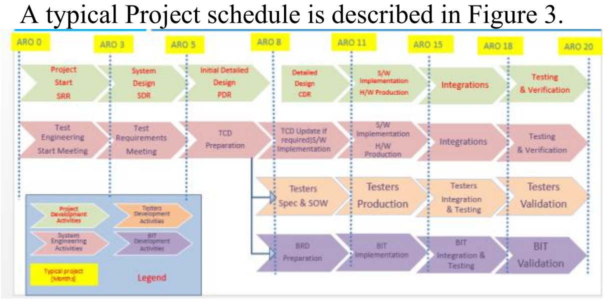

Figure 3 – Typical Project schedule and the STE process

Since there are changes in the system design as the development progress, the STE is an iterative process which starts based on the system initial architecture and is adapted later according with the changes in the design, until the design is frozen, usually in the system Critical Design Review (CDR).

3.1. Test Engineering Start Meeting (1)

The Test Engineering Start Meeting (1) initiates the Project STE activities. In this meeting the TE describes the activities of the STE process in the Project and coordinates the Project Test Requirements Meeting (2).

3.2. Project Test Requirement Meeting (2)

The Project Test Requirements Meeting (2) is held after definition of the system initial architecture of the System (before SDR).

In this meeting the Projects leaders present the tests requirements of the Project Lifecycle, e.g. for the development phase the tests requirements can be system integrations, system validation, Software (S/W) Tests etc. The tests for the production and maintenance phase will be in accordance with the initial production and maintenance concept, respectively.

3.3. LTC Process (3)

The Life Cycle Tests Concept (3) is the main STE task. The Input Data and Output Results of the LTC are described in Figure 4.

The LTC constitutes the basis for the Tests Infrastructure of the Project. The tests requirements which were presented by the Project leaders (2), are analyzed and evaluated by the TE based on the latest known system architecture in-order to define the BIT concept and the Testers main requirements

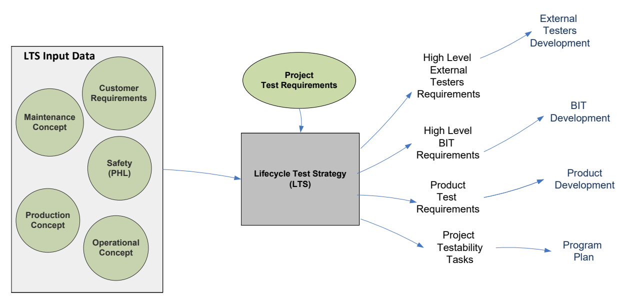

Figure 4 – LTC Input Data and Output results

The LTC definition process is described in Figure 5.

The Input Data for the LTC process includes

a. The Project's leaders tests requirements.

b. Customer requirements for testability, maintainability and safety

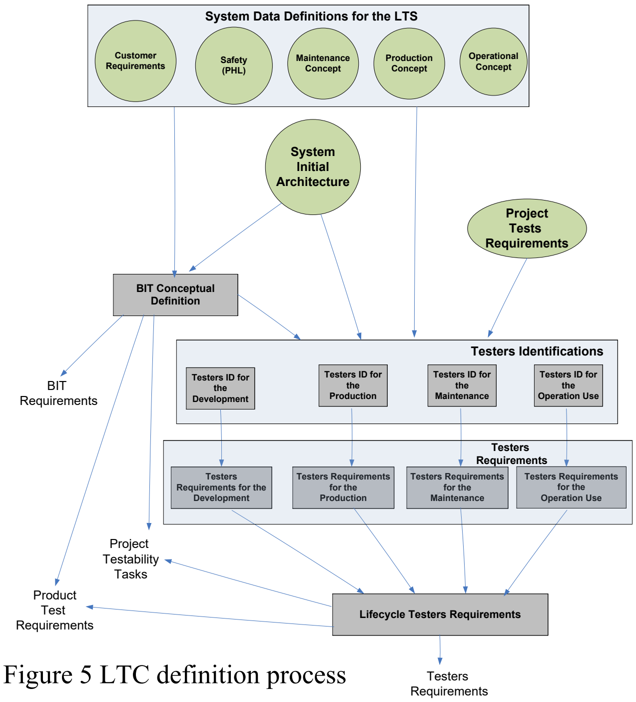

Figure 5 LTC definition process

c. Initial maintenance concept.

d. Initial Production concept

e. Operation use concept

3.3.1. BIT Concept in the LTC

The BIT definition in the LTC starts with the initial approach of maximum BIT coverage with no or minimum added Hardware (H/W). This initial BIT assumption will be analyzed and optimized in the next step of the BIT Optimization (4).

The BIT Concept includes three main topics:

a. Subsystems BIT - definition of the BIT concept for each subsystem. In this task The TE works together with the Subsystem leaders.

b. BIT Manager – The BIT Manager is a Software (S/W) module which manages all the BIT activities and provides the data and information interface with the system (usually the System Main Computer).

c. BIT General Concept –BIT Concept definition, for examples.

- ➢ BIT Failure Reports – Definition of the BIT reports e.g. Different Failure Reports for the maintenance task (The faulty unit) and for the operation use (the faulty system function)
- ➢ Test tolerance concept - decision if similar or different BIT tolerances will be used both production and maintenance.
- ➢ Filtering concept – Usually in order to reduce system FAR the BIT results are filtered before the preparation of the BIT report. This BIT results filtering can be done in the Subsystem level or in the BIT Manager S/W.
- ➢ Failures Log Concept – definition of the Failure Log management e.g. Annotation data which will be added each Failure, Failure Log Downloading process etc.
- ➢ Failure isolation – Concept of Failure isolation for the production and maintenance phases (usually according with the maintenance concept).

3.3.2. Testers Requirements and Functionalities in the LTC

In the first iteration the Testers requirements definition identifies the product functionalities which are not tested by the BIT.

Figure 6 describe an example of the table which summarize the Testers requirements for all the Lifecycle phases.

Each Tester requirements for each Lifecycle phase (Development, Production, Maintenance and Operation Use) are described in the table.

This broad view description enables to take decisions and recommendation for each Tester, for example – If there are commonality between the Tester's requirements for the Production and for the development then probably the recommendation will be to develop a common Tester for the two phases, or for some Tester's the recommendation can be to move a Tester's functionality to the BIT etc. These recommendations will be rechecked in the Commercial Optimization stage (7).

S/N	Tester ID	Req. for the Development Phase	Req. for the Production Phase	Req. for the Maintenance Phase	Req. for the Operational Use Phase	Recommendation
1	Tester A	Environment Simulation, BIT activation	Environment Simulation, BIT activation, Unit A Calibration	Environment Simulation, BIT activation, Unit A Calibration	Not Required	To combine the Tester requirements. The same Tester will be used for all the phases

Figure 6 Example for a Testers Requirements Summary table

3.4. BIT Coverage Optimization (4)

The BIT Coverage Optimization (4) process is described in Figure 7.

The BIT Coverage optimization is an iterative process which starts with the initial BIT coverage which is the results of the BIT definition in the LTC stage (3).
In each iteration, the gaps in the BIT coverage are identified and an improvement is proposed by adding dedicated Tests H/W to the system. This improvement increases the BIT coverage.
The decision to accept the proposed change or not is taken by checking if the "payments" in the System Performance due to the proposed change (e.g. increase in the False Alarm Rate (FAR) , reduction in the System reliability, etc.).

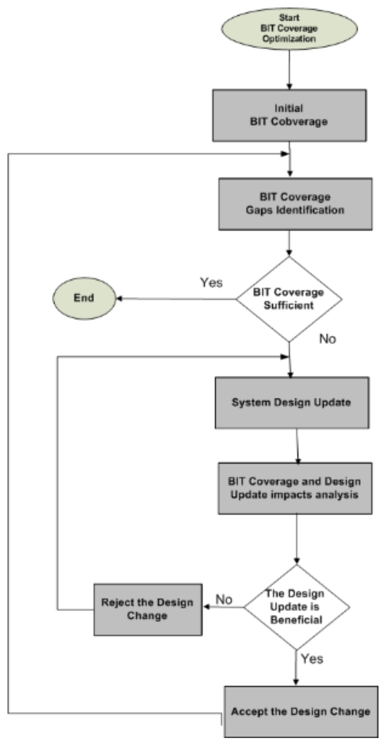

Figure 7– BIT Coverage Optimization process

This iterative process continues until the BIT meets the stop conditions as follow:

a. The BIT performance meets the requirement specifications (BIT coverage, FAR etc.)
b. The BIT meets the production, maintenance and operational use requirements e.g. BIT failures isolation.
c. All the Safety H/W is tested or at least it meets the Safety Analysis Requirements.
d. The Gaps in the BIT coverage include parts with high reliability (which in this case can be accepted).

3.5. Commercial Optimization (7)

The Commercial Optimization (CO) is based on the Project tests commercial model using a software simulator like Excel or any similar tool. The analysis evaluates the relevant parameters and variables of the Project tests e.g. production quantities, testers types (different complexity, manual testers or automatic testers), Product Life period etc. to provides the optimal Project tests working point like Testers complexity, Product Tests during production (Subsystem level or just in System Level Tests), common testers for development, Production and Maintenance or to split the Testers etc.

The aim of the CO is to define the lowest cost Test concept for the Project Lifecycle while still meeting the technical tests requirements.
Figure 8 describes an example of CO analysis. The chart present the overall Project Tests cost vs Deliveries Quantity while changing Project Tests variable of the Tester Complexity and the Subsystem level test (in addition to the System level test or just System level test).

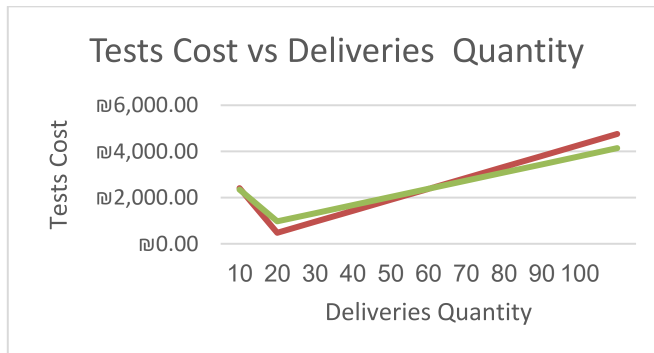

Figure 8– Example of Commercial Optimization

The analysis shows that for Quantity of 60 units there is a breakeven point where the green graph starts to be more economical.

4. Integration of the STE in the Project

The integration of the STE in the Project activities is described in Figure 9.
The STE output results are the basis for the Testers development, BIT implementation, and the product testability design while the Testability tasks are combined in the Project Working Plan..

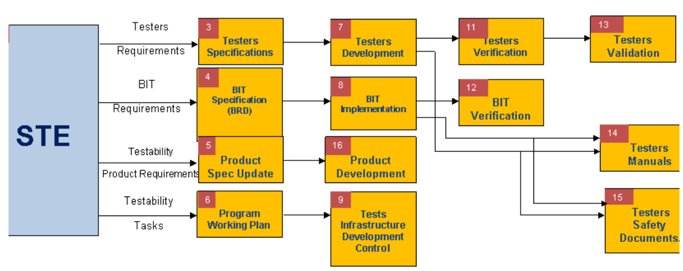

Figure 9– integration of the STE in the Project

The Integration of the STE in the Project working plan is described in Figure 3.

5. Experimental Results

We started to implement this STE process at Rafael in some pilot Projects. We got very good feedback from the Project team and the Customer.
The main benefits which we observed in the implementation of the STE at Rafael were:

a. The gaps in the BIT requirements were identified at early stage of the Project. The system design was updated to overcome these gaps. Since it was in an early stage of the Project while the design was still in progress, the delay and the cost due this change were negligible, for example selection Power Supply which includes BIT capabilities instead of similar Power Supply but without the BIT.

b. The identification of the testability requirements at early stage of the Project allowed to add the testability requirements to the contracts with the subcontractors. This prevented conflicts and delays (if the requirements would be added later after contract award with the Subcontractors)

c. The LTC document was prepared before the System Preliminary Design Review (PDR). The testability tasks were combined in the program work plan, this enabled the availability of the Tests Infrastructure on time.

d. Due to the methodical analysis which was performed during the LTC preparation, the Project production and delivery processes were improved and the product cost was reduced, for example we found that there was no need for the involvement of the Production engineer in some of the Subsystems deliveries.

e. The process was presented to the Customer in the System PDR, who expressed his satisfaction and furthermore he requested to include this process in his other Projects.

f. The STE Lifecycle viewpoint of the Tests Infrastructure, recognize commonality between the development and the production Tester requirements. The Tester will be implemented accordingly and the Tester overall cost will be reduced.

6. Limitations

The STE begins early stages of the Project, immediately after Project Startup while the system architecture is usually not defined, and therefore the STE process will be delayed till the System Design Review (SDR) when the Initial System Architecture will be available.

7. Discussion

Although the System Architecture is usually not defined while the STE starts (the main STE activities are after the SDR), the STE in this stage has two important benefits to the Project.

a. Awareness of the Project team to the STE activities before they start the actual design, allows the testability to be in the background and part of the design considerations.
b. Involvement of the TE in the Project system engineering activities will add the tests perspective to the System design.

8. Conclusions

This methodical STE process provides the following benefits to the Project.

a. The overall STE Lifecycle viewpoint of the Project Testability subject provides optimal solution technically and commercially to the Project, it meets the customer's needs and reduces the LCC.

b. The Tests Infrastructure (BIT and Testers) are available at early stage of the Project, which will provides the following advantages:

- The BIT and the Testers will be used during the development. This will improve the testability of the system and the maturity of the test's infrastructure before the delivery to the customer.

- The production line will be able to deliver the systems to the customer on time with minimum support from the development engineers from the first batch.

- Testability gaps in the product will be discovered early which will enable to adapt the design to overcome the gaps. Since it will be raised at early stage of the Project, the delays and cost will be low.

c. The Tests infrastructure will meet the Customer's expectations due to the involvement of the Integrated Logistic Support (ILS) and the operation people in the Testers Requirements definition process.

9. Acknowledgements

N/A

10. References

N/A

Haim Noti Biography

Haim Noti is the Chief System Engineer and R&D Manager in the Ground and Naval division of Rafael. He holds a BSc degree (Electrical Engineering) and ME (Master of Engineering) from Technion Israel Institute of Technology.

He has over 30 years' experience applying System Engineering and Project Management work on Military systems.

His current interests are within systems engineering and system testing optimization process technically and commercially.