

NEW APPROACHES TO IMPROVE V&V METHODS TO FULFILL THE NEEDS OF FAST AND HIGH VOLUME CONSUMER MOBILE TERMINAL DEVELOPMENT

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Abstract

Objective

The purpose of this paper is to describe the meaning and the challenges of verification and validation (V&V) in the fast cycle electronics product development. In addition, some practical ideas of how to improve the efficiency of V&V in the high volume mobile terminal development are presented.

Introduction

Market share, average sales price and profit margins are the key drivers in the cellular terminal business. We can easier meet these goals by launching more new and innovative models than competitors, that means all the time shorter and shorter design cycles. The mobile terminal business is moving towards more demanding digital convergence business with changing requirements related to product performance, closer customer involvement, and usage of more subcontracting. This change in the business environment has increased the importance of efficient product creation processes including V&V.

Contributions

This study is mostly based on author's several years of practical experience in the electronics products development industry as Design Engineer and also as Process Development Manager. In this paper, we introduce verification methods where analysis, including mathematical models and simulation, and testing are combined in optimum. This study is based on the appliance of the iterative design models.

Key Conclusions

Right timing and integrating verification & validation as part of the design work can improve the whole product development effort remarkably including product development cost and time-to-market. Verification can be done, even without having a physical sample available, by analysis, comparison, and assessment, which are often more cost efficient methods than physical testing [Gill & Graham 1993].

1 Introduction, Business Situation

Wireless telecommunication industry is changing and developing very rapidly. The popularity of wireless communication has grown remarkably during the last few years. Currently the usage penetration of mobile terminals in many countries is over 90% and practically in all industrialized countries over 50 %. The worldwide sales reached up to 520 Million pieces in 2003 and has been estimated to exceed 580 Million in 2004 [Gartner Dataquest 2004]. The huge amount of mobile phones in use naturally means that the product quality and reliability must be high to prevent very expensive repairing costs. Pesonen [2001] estimates that replacing a single mobile phone in the field costs about 210€ which includes the replacement device (170€) and the handling (40€) costs.

The large user population means also that practically all kind of people use mobile terminals in all possible ways and environments. V&V plays a vital role in ensuring that products meet the usage environment, quality and reliability requirements.

1.1 Competitive Market

In the huge cellular terminal market the competition between different manufactures has become very rigorous and reduced the profit margins remarkably. However, both market share and profit margins are the driving forces in cellular terminal business. One way trying to increase the market share is to launch as many new competitive models as possible. Practically this means that the product development must be very short. For example, Samsung has announced to introduce 100 new mobile products a year [Choong 2002]. This naturally means, that the product development time at Samsung is very short. The company claim that it takes, in average, only five months to go from new product concept to the rollout of a new product. The product development time was just six years ago 14 months in average [Edwards 2003]. Similarly Nokia has stated already several years ago that product development may take no more than 9-12 months and in the future the time must be reduced without remarkable increase in R&D costs [Neuvo 1997]. Figure 1 illustrates the importance of the short time-to-market. The shaded curve represents typical product life cycle of about four years with a ramp-up in the beginning, a peak after three years, and a ramp-down in the end. The white curve illustrates about 45% faster development time. We can see in the picture that bringing a product to the market sooner, not only generates incrementally higher sales, but also maintains higher sales volume during its life cycle [McGrath 1996].

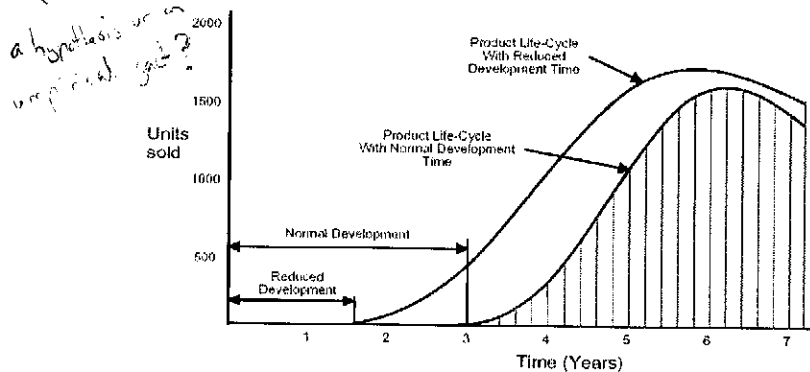


Figure 1, Product life cycle curves for normal and faster time-to-market. Adapted from [McGrath 1996, p.4].

1.2 The Need for Early Error Fixing

To detect and correct errors in the design as early as possible before field use is very beneficial. The figure 2 illustrates Boehm's [1981] study of how the cost of correcting errors increases when the project moves from requirements phase towards field use. The error correction in the field operation might cost up to 1000 times more than at the requirements phase.

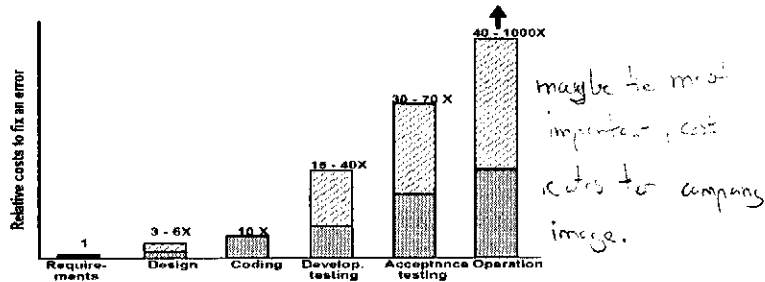


Figure 2. The cost of fixing errors increases when the project is moving towards field use. Data from the analysis of 63 projects [Boehm 1981].

In addition to Boehm's study also Neuvo [1997] states that one of the most expensive stages in product development is the iteration work done close to the end of the development process.

We can conclude that fast product development & early error correction are among the most important issues in the product development. This study is focusing on the methods of how V&V can contribute to these targets.

1.3 Verification

Verification has widely been accepted to be as "proof of compliance with specifications". However, it is not understood so well that verification can be determined by test, inspection, demonstration, and analysis [Mooz et al 2003]. The question to be answered by verification is "Are we doing things right way?"

1.4 Validation

The purpose of Validation is to answer the questions: "Are we doing right things for the Customer?" and "Is this product behaving as the Customer expects?" Validation can also be defined as end-to-end verification to show that the whole system meets its requirements under operational conditions [Stevens et al. 2000].

Is this solution ght for purpose?

1.5 The Purpose of Verification and Validation in Product Development

The purpose of V&V is, in broad sense, to supply information from the design to the management and designers for their decision-making.

We can divide the product development into four main phases, which are technology development, product development, pre-production and mass production. In the technology development phase V&V checks that the technology is ready for integration, the product V&V ensures that the design is ready for manufacturing, early production verification checks that the manufacturing process is correct, and finally in the mass production V&V ensures that the quality of the products is within certain limits which means that the manufacturing

process is in control. Figure 3 illustrates the main development phases with different V&V activities.

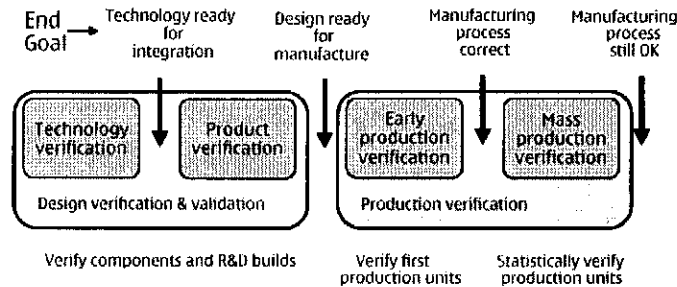


Figure 3. Design and production verification, adapted from [Stevens et al. 2000, p.135]

2 The Methods of Verification and Validation

Stevens et al. [2000] have divided the different verification methods into Testing, Analysis, Comparison, and Assessment, which are illustrated in figure 4 and further discussed in the following chapters.

Test	Functional	<i>Checks functions, interfaces, compatibility (e.g. EMC), and performance requirements</i>
	Environmental	<i>Performed in conditions similar to the operational environment (e.g. temperature, vibration and humidity)</i>
	Reliability	<i>Estimates the life time and reliability of a product or a component using, as usually, accelerated test methods</i>
Analysis		<i>Mathematical models, analysis using software, simulation (e.g. thermal and drop test)</i>
Comparison		<i>Re-use of components previously verified on another system against equivalent requirements (e.g. display module and type approval for copy products)</i>
Assessment		<i>Inspection, demonstration or review</i>

Figure 4. Different methods of verification, adapted from [Stevens et al. 2000, p. 124]

2.1 Testing

Testing is the most common V&V method to check the complete system or part of it. Testing includes functional, environmental and reliability tests.

2.1.1 Functional Test

The main purpose of the functional testing is to detect failures for error removal purposes in order to create a working design. Functional tests check that the design meets interface, compatibility and performance requirements. Error detection and removal should happen next

to each other in order to keep the feedback loop as short as possible. For example, Microsoft continuously uses pairs of developer and testing persons in product creation. This close relationship between testing and design is said to be one of the main reasons of the success of Microsoft [Cusumano 1995].

2.1.2 Environmental Test

The purpose of the environmental testing is to ensure that the design works in the real usage conditions. Environmental tests include, for example, low and high temperatures, vibration, air pressure, and solar radiation.

2.1.3 Reliability Test

Reliability testing estimates the life time and field error rate of the design. Typically the reliability estimation must be done in a shorter time scale than the real lifetime of the design will be. For example, if the product is supposed to be functional in the field for 7 years, the test time certainly must be much shorter. As usual, different kind of accelerated methods are used to shorten the test time. Many environmental tests can be applied for reliability estimation if the severity of each test is adjusted in a proper way and sample size is reasonable.

2.2 Analysis

Mooz et al. [2003] define the analysis as follows "The critical and careful evaluation of a situation or problem". Analysis does not demand physical prototypes or code to be checked but can be done using discussions, documentation, mathematical models, and simulations. Verification by analysis should be applied as much as possible to minimize the need of physical tests because normally it is much more cost efficient. However, testing cannot be removed completely because it is needed to update the simulation model finally. Figure 5 illustrates the linkage between simulation and testing. In optimum case the design is verified only by simulation without testing the physical sample. Testing is only used for the adjustment of the simulation model.

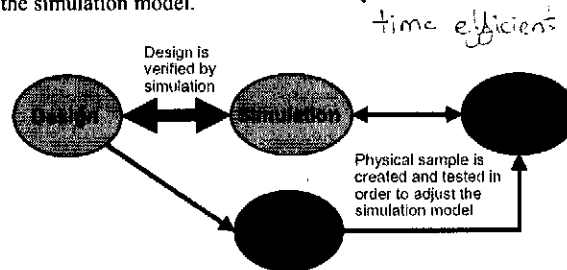


Figure 5. The design is verified by simulation and the simulation model is updated by testing the physical sample

2.3 Comparison

Verification by comparison can be utilized where a product, sub-system or component has been verified earlier and can be re-used again in a new system. For example, if the key material of a mobile terminal has been verified once, it is not needed to repeat it in any other development projects, which are applying the same material similar way. In the optimum case the material supplier has verified the material using the requirements set by the mobile

terminal manufacturer. Similarly, type approval testing can be shortened, or even removed, by re-using the results of similar products tested earlier. Verification by comparison can be done at all design phases.

2.4 Assessment

Verification by assessment includes inspection, demonstration and review. These methods verify that requirements are met without the need of physical testing at early phase. As usual, the working testable prototypes do not even exist during this phase. However review can be done at every phase of the development project.

Gilb and Graham [1993] define the **inspection** as a method to only examine static documents. In addition, Mooz et al. [2003] state that verification by inspection can be carried out in a situation where the specifications are easily observed, such as programming language or physical characteristics like color and shape. The inspection phases are carried out before the testing phases. Figure 6 illustrates the inspection and testing in a software development project.

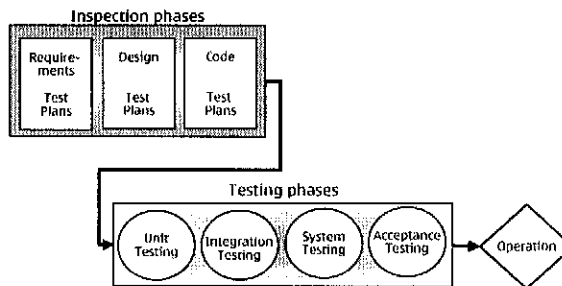


Figure 6. Inspection can only examine static documents, testing can look at the end product. Adapted from [Gilb & Graham 1993, p. 11].

However, inspection does not replace testing and testing does not detect all errors found in inspection. Defects found by inspection, before testing, probably save the total error correction effort. It is obvious that the errors inserted late cannot be found by inspection. Figure 7 illustrates how inspection and testing accompany each other.

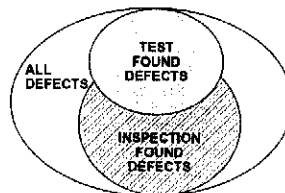


Figure 7. Inspection and testing complement each other in the defect removal business adapted from [Gilb & Graham 1993, p. 12]

In the **demonstration** some of the functionality of the system is presented to the End User in order to get his or her acceptance for further development. Often the functionality is demonstrated using completely another equipment than the product to be developed.

3 Verification and Validation in the System Development Models

In the traditional system development models, like in the Waterfall and Spiral models as well as in the Concurrent Engineering process, V&V happen at the late stage after product integration phase. These models do not focus on component and module verification comprehensively, which can cause late error detection & resolving. This can lead to delays in the product launch. Stevens et al. [2000] have highlighted several benefits of early verification:

- Faults and root causes are easy to locate,
- There is time to correct problems and adjust other components to cope with the deficiencies detected,
- Tests can be more severe,
- Verifications can be performed more quickly,
- Verifications can be carried out in parallel without waiting the turn to work on the system, and
- Component testing encourages clear interfaces, modularity and re-use.

The iterative models seem to provide better approaches than the sequential ones, because the error detection & debugging loop is shorter, and they can be used in turbulent environment with changing requirements. We selected to apply the V-model as our framework when trying to increase the efficiency of V&V in the mobile terminal development.

3.1 The V-Model

The V-model is widely used in software development [Spillner 2000] but it can be applied for hardware and mechanics development as well. For example, the guideline VDI 2206, explains how the V-model can be applied in the mechatronics design [Gausemeier et al. 2001]. In the V-model V&V planning and implementation happen at each design phase without waiting the full system integration.

Figure 8 illustrates the product development V-model. The left hand side of the Vee describes how the system design work starts from End User requirement for the complete system and flows down to detailed component, code, material requirements and V&V plans. The right hand side of this model illustrates how to fabricate, integrate and verify components, subsystems and finally the complete system. The thickness of the Vee describes the amount of the workload involved at each phase. Thus the model encourages us to focus on component and subsystem level requirements definition and V&V implementation.

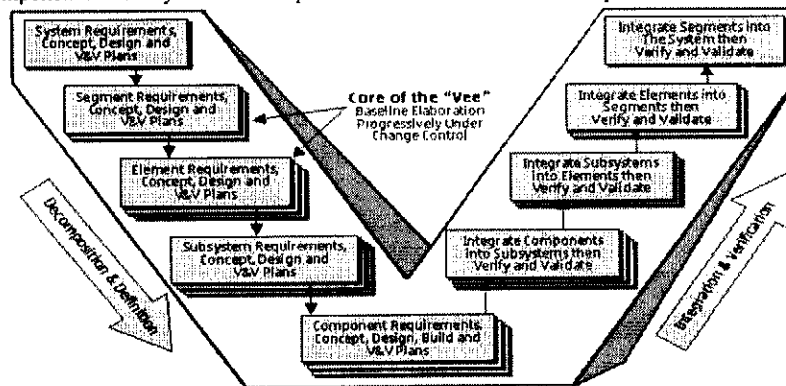


Figure 8. The V++-model [Mooz et al. p.38, 2003]

The leveling structure of the design models guides us at which level each of the requirements will be checked. Is it done by verifying the full system, subsystem or smaller unit (or any combination). The system level verification has plenty of challenges, like it is expensive, time consuming, ties up the whole system, and produces faults, which are difficult to locate and diagnose. In addition, the system level testing cannot stress individual component efficiently [Stevens et al. 2000, p.120].

Why not?

4 Practical Examples of how to Improve Verification and Validation

4.1 Implementation of the V-model in the Mobile Terminal Development

The figure 9 illustrates how the V-model can be applied in mobile terminal display development. We are using seven design levels to cover all design activities from the material development up to the development of full mobile terminal system for the End User. The “product” column lists the products or deliverables created at each level. These are, for example, a complete mobile device sales package, a display module, or glass material for a LCD. The “requirements” column, which is the left hand side of the Vee, lists requirements for each development level including use environment, module and material specifications. The last two columns “simulation” and “testing” are the verification activities and illustrate the right hand side of the V-model.

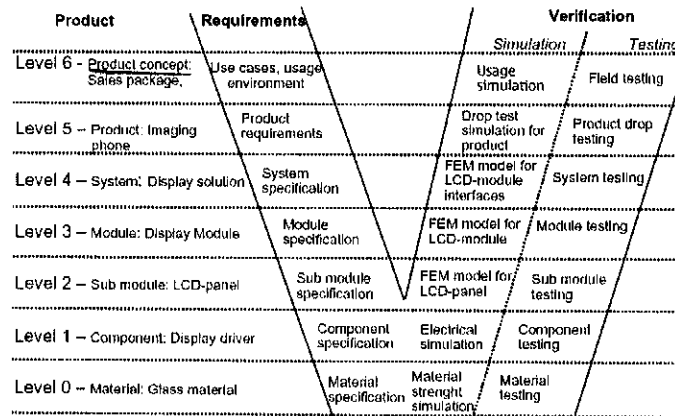


Figure 9. The V-model applied for mobile terminal display verification

We can see in this example that many of the physical tests of a display with its components can be replaced by simulations which are normally faster and easier methods to carry out. Testing a physical sample is needed only to adjust the simulation models.

4.2 Incremental Verification and Validation

We have further elaborated the idea if the V-model towards what can be called as incremental V&V. The idea is to assure the product level requirements by decomposing them to earlier design phases. By verifying these requirements earlier, only a fraction of product requirements actually need to be verified at product phase. This method can be useful and

probably it saves time in the platform-based development where modules and components are developed separately and used in several later products. Picture 10 illustrates how we have included some additional aspects to the V-model approach. The left hand side of the picture describes how we used to carry out verification in the technology and product development. The component and module development with verifications was carried out in technology development phase and product verifications at product development phase accordingly. The right hand side of the picture illustrates the new approach where we utilize incremental verification. For example, the product certification (i.e. type approval) is received by carrying out most of the related verifications at technology development phases leaving just a fraction of it to the product development phase. The product certification is now granted by applying the results from both technology and product development phases.

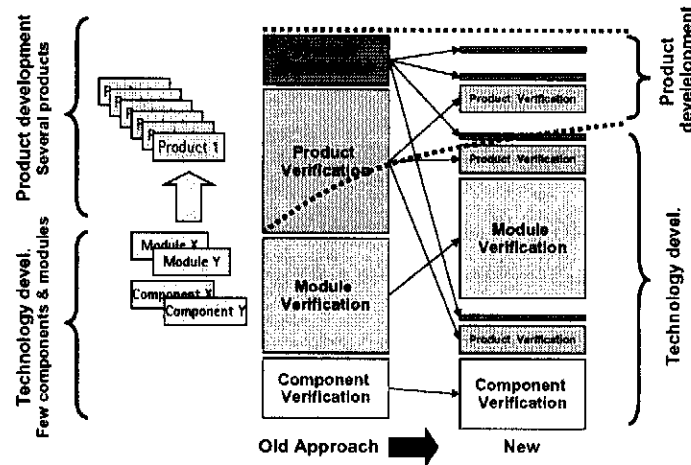


Figure 10. The incremental verification is minimizing the product development time

At the technology development phase we do not have integrated products available and in practice we apply other types of verifications than physical testing as much as possible. For example, we can carry out product level drop testing and thermal analysis for complete product quite extensively by simulation. By focusing on early V&V we can save time and select the right technology for further product integration. This will reduce the risks at product phase, which finally improves the product development efficiency.

5 Conclusion

V&V are among the key processes in the product development. However, most of the design models and processes do not highlight the importance of V&V as an integral part of the design work, but just mention it as a separate task happening after product integration phase. Probably one reason for this is that verification is understood only as testing physical samples and forgetting the possibilities that analysis, comparison and assessment can bring. However some later created design models like V-model see the importance of early V&V. So-called incremental verification can even further improve the efficiency of the whole product development process in the platform based product development.

John Clarkson
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