Improving the VVT Process: Evaluating the SysTest Results in Six Industrial Pilot Projects

Markus Hoppe
Institute of Astronautics
Technische Universität München, Germany
(m.hoppe@lrt.mw.tum.de)

Avner Engel
Advanced Systems & Software Engineering Technology (ASSET)
Israel Aircraft Industries, Israel
(aengel@iai.co.il)

Abstract. Many companies experience extensive product rework and failure cost due to ineffective Verification, Validation, and Testing (VVT). Therefore, there is a great potential benefit in streamlining and optimizing the VVT process. To that end, a consortium of eight European companies, research institutes, and organizations conducted the SysTest project. The stated aim of SysTest was to "…decrease product development cost and time to market by 10%". SysTest intended to achieve this aim by developing a generic methodology and process model to support the process of systems' VVT. This paper describes the results of using the SysTest products in six industrial pilot projects. The diverse pilot projects have shown that the SysTest products are applicable in different industries. Specifically, each project was able to use most components of the SysTest methodology and process model and the pilot projects conducted by the industrial partners exhibited an average of nearly 8% project cost reduction with standard deviation of about 15%.

Introduction

Verification[1], Validation[2] and Testing (VVT[3]) is a branch of Systems Engineering (***Boulding 1956***, ***Klir 1969***) which focuses on ensuring that systems are delivered as error-free as possible, functionally sound, and that they meet or exceed user needs. VVT is normally used as a vehicle for finding and removing errors (***Thome 2003***). Currently, most industries perform VVT during a very late and narrow phase of the product life cycle, typically referred to as the Test phase. As a result, the overall development duration and cost associated with product rework exceeds 20% (***Jones 1996***). ***Sorqvist (1998)*** provides dramatic failure cost data: A total of 30 medium-to-large Swedish companies were surveyed over a period of 3 years. The findings indicated average losses of 9% to 16% of the company yearly turnover due to poor quality. Balancing testing cost and schedule with quality is a difficult task. However, quality problems discovered late in the product life cycle necessitate expensive fixes and may adversely affect the product's and the

---

[1] Verification is defined as "the process of evaluating a development product (system, component, document etc.) to determine whether the products of a given development phase satisfy the product conditions (e.g. requirements) previously imposed" (based on NASA 1996)

[2] Validation means "the process of evaluating a development product (system, component, document etc.) during or at the end of the development process to determine whether it satisfies the user's needs (specific intended use of a product)" (based on NASA 1996)

[3] VVT = Verification, Validation, and Testing. Testing is a subset of verification and validation and is defined as: "An activity in which a system or component is executed under specified conditions, the results are observed or recorded, and an evaluation is made of some aspect of the system or component" (based on IEEE-610)

organization's reputation (***Huber 1999***).

Performing exhaustive VVT in order to fully cover a system is not practical due to cost and time-to-market considerations. Therefore, there is a great potential benefit in streamlining and optimizing the VVT strategy. The first step for achieving it may be accomplished by quantifying the cost, duration, and the effect on product quality associated with VVT activities.

The purpose of this paper is to describe the cost improvements experienced in real-life pilot projects conducted at six industrial organizations. These results were obtained by applying three generic (i.e. industry-independent) SysTest products: (1) VVT Methodology Guidelines, (2) VVT Process Model (VVTPM) and (3) VVT Strategy & Planning Procedure.

More information on the VVTPM and the VVT Strategy & Planning Procedure can be found in ***Hoppe et al. (2003), Lévárdy et al. (2004)***, ***Lévárdy and Hoppe (2004)*** and ***Engel and Barad (2003)***. Two VVTPM derivatives have been developed. Their field application is described in ***Hoppe et al. (2004)*** and ***Engel et al. (2005)***. This research was conducted in conjunction with the European Commission, project SysTest (Contract ***G1RD-CT-2002-00683***).

The SysTest project

SysTest background and products. Given the fundamental role of VVT in achieving product quality and reducing product rework, the SysTest project aimed to rectify two critical VVT problems: The lack of a VVT methodology and the lack of a quantitative means for mapping the relationships between testing cost, schedule, and economic risk. For the purpose of the SysTest project, a consortium of eight European companies, research institutes and organizations has been formed, in order to develop a methodology and a process model for Systems Verification Validation & Testing. (see Vollerthun 2002). The SysTest project was funded by a European Commission grant and was carried out from 3/2002 to 3/2005. The SysTest project delivered the following main products:

<u>VVT Methodology Guidelines (VVTMG).</u> This document describes VVT activities and methods in the systems' lifecycle, along with tailoring rules for different environments (industrial sectors, lifecycles, and project types). The purpose of the VVTMG is to provide a generic and tailorable VVT methodology, identifying VVT activities and methods applicable for different systems and supporting different industrial applications. The VVTMG covers the entire product lifecycle, describing a total of 65 VVT activities and 29 Sub-VVT activities as well as 31 different VVT methods.

<u>Quantitative VVT Process Model (VVTPM)</u>. This model and software tool is designed for estimating VVT cost and schedule, and the resulting product quality (along with the according risk) for a given VVT strategy. The VVTPM was developed in two variants: The official SysTest project version (see ***Levardy et al. 2003***, ***Hoppe et al. 2004***), and the IAI derivative (see ***Engel and Barad 2003***, and ***Engel et al. 2005***). The VVTPM is intended to:

- Predict the VVT cost and duration, and the resulting product quality, depending on the chosen VVT strategy
- Calculate the risk of not achieving cost, duration, and quality targets, based on the uncertainty of the above estimates
- Optimize the VVT strategy with respect to cost, duration, and resulting product quality

There are several expected benefits of applying the VVT Process Model. First, through the definition of target values the risk of not achieving those may be calculated. Concurrently, with the help of target values (or better: intermediate expected values) at the milestones, the project advancement can be assessed. Second, through the stochastic modeling of the process, more realistic predictions for the actual project duration and cost can be obtained. Third, through the definition of expected impacts of the VVT activities on the product quality and on the basis of the chosen VVT process structure, the resulting technical product parameter values can be estimated. Finally, the modeling of feedbacks in the process allows more realistic predictions of the process cost and duration and can consider also quality improvements trough rework.

The VVTPM builds on the work done by Browning (see Browning 1998, and Browning and Eppinger 2002).

VVT Strategy & Planning Procedure (VVT S&P). The VVT S&P is a procedure for defining a VVT strategy. This includes (1) tailoring the VVT methodology to the characteristics of the project and enterprise (based on heuristic knowledge), (2) defining a VVT strategy, which considers business objectives and their relationships to the project, as well as risk issues, and (3) planning the VVT process, identifying specific VVT activities, methods, tools, and products that will be used during the project phases (see Lévárdy et al. 2004).

Assessment Structure and Approach

Assessment structure. The objective of the SysTest project was to develop products that help the user to define an optimal VVT strategy and give him guidance in selecting appropriate VVT activities and methods. This shall allow the user to establish effective and efficient VVT processes based on a generic model, applicable to different industrial domains and product lifecycles. The pilot projects at the industrial partners were intended to show the applicability and the benefits of the SysTest products.

It was assumed that the application of the SysTest products combined with a given VVT strategy will affect the project duration, project cost, and product quality. Therefore, the success of these products was measured in the improvement of the above parameters relative to historical projects. Thus, the collected data includes historical project data (see Engel 2004) and data measured during the execution of six different pilot projects.

The project duration is strongly influenced by various effects, not only by improvements in the VVT area. Its applicability for deriving meaningful conclusions can thus be doubted. Furthermore, product quality is difficult to assess, it is often subjective, and the impacts of improvements in the VVT area on the product quality may get visible only after the pilot project end. Therefore, in this paper it is concentrated on the more objective cost data. Since the high-level criteria cost is difficult to measure directly, two more levels of assessment metrics were established (see a simplified picture of the assessment structure in Figure 1).

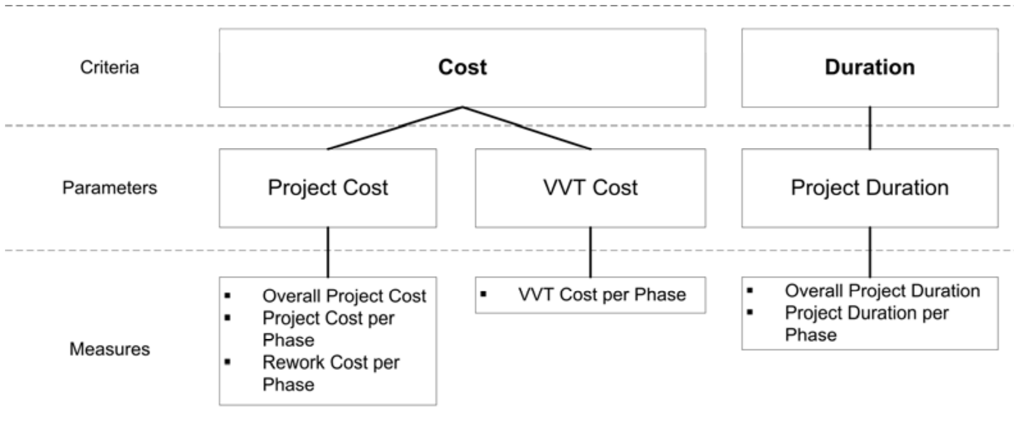


Figure 1: The simplified assessment structure

Assessment approach. A questionnaire was developed, which guided the users through the assessment process. The users were asked to provide data both for the pilot project and a comparable historical project. The historical project data was used to assess the change in the project cost and duration. For each measured improvement in cost or duration (compared to historical projects), the users were asked to attribute it to improvements in the process or product quality experienced in the pilot project. To that end, a list of measures was predefined, which comprises all improvements in product or process quality expected from the SysTest products. Finally, the users were asked to relate the experienced improvements in product or process quality to the different SysTest products. In this way, a qualitative relation between the SysTest products and the experienced cost reductions could be established. If applicable, these qualitative relations are summarized in a table for each pilot project in the pilot project conclusions.

It was decided to collect VVT data as well as data for the overall pilot project. In this way, it was possible to distinguish between effects occurring due to improvements in the product or process quality and effects that simply can be attributed to a different size (i.e. cost and duration) of the pilot project and the historical project. Furthermore, the rework activity cost were measured to assess the quality of the intermediate project results. In this way, the effect of the VVT improvements on the product quality could be at least measured indirectly.

Since the project partners come from different industries, a tailoring of the SysTest approach to their specific needs was necessary. Moreover, each pilot project had its own characteristics, which had to be taken into account for the application of the SysTest products. Therefore, not every SysTest product was applied in every pilot project.

At the beginning of the SysTest project, a standard set of lifecycle phases was defined, which should be applicable across different industries. These lifecycle phases include Definition, Design, Implementation, Integration, Qualification, Production, Use/Maintenance, and Disposal. Therefore, the pilot project data is structured in accordance with this standard set of lifecycle phases.

Certainly, the statistical significance of the presented data can be doubted. However, in the eyes of the authors the results strongly indicate that the SysTest products help to improve verification and validation and to decrease rework.

In the following sections, the pilot project results of six industrial partners are described.

Each section presents (1) general information about the partner and the pilot project, (2) the measured pilot project data, and (3) conclusions for the individual pilot project.

Pilot Project at IAI

Partner: Israel Aircraft Industries (IAI)	
Country: Israel	
Industry: Avionics	
Pilot Project: Development of a new avionics system for a transport helicopter.	

Figure 2: Pilot project at IAI

Pilot Project Description. Israel Aircraft Industries (IAI) is developing military and commercial aerospace technology. The pilot project at IAI was the development of a new avionics system for a transport helicopter (see Figure 2).

Application of the SysTest Methodology. IAI increased VVT in the early project phases (see Figure 3). Therefore, more product defects were detected in the early lifecycle phases (see Figure 4). This lead to a reduction of both the VVT and rework cost in the later project phases. Although the VVT cost increased in the early phases, an overall reduction of 7% was achieved. Similarly, the rework cost increased in the early phases (since more product failures were detected), but was reduced significantly in the later phases resulting in an overall rework cost reduction of 16%.

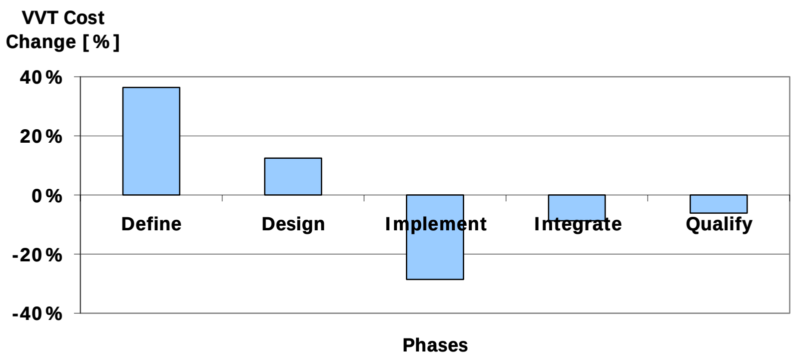


Figure 3: VVT cost comparison (IAI pilot project)

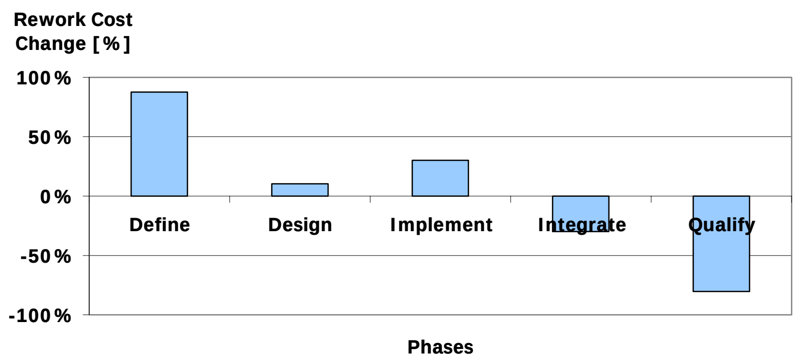


Figure 4: Rework cost comparison (IAI pilot project)

Pilot project conclusions. The cost measurements indicated that the VVT activities required approximately 40% of the total system development cost. Additionally, the rework cost was approximately 20% of the total system development cost, yielding around 60% of the total system development cost spent on quality. Therefore, the total system development cost savings were 6%.

Figure 5 shows the relation between the applied SysTest products, the experienced process improvements, and the cost measurements. Perhaps most noticeable here is that the VVT Methodology Guidelines and the VVT Strategy & Planning Procedure are mainly responsible for the improvement in the VVT and rework cost.

SysTest products ...			... lead to improvements in ...	... lead to a reduction in ...	
VVT MG [1]	VVT PM I [2]	VVT S&P [3]		VVT cost	rework cost
+++		++	requirements traceability	+	
++	++	++	VVT effectiveness	+	
++	+	++	VVT scope (properties tested)		++

[1] VVT MG = VVT Methodology Guidelines
[2] VVT PM I = VVT Process Model, IAI version
[3] VVT S&P = VVT Strategy & Planning Procedure

Figure 5: Relation between SysTest products and improvements (IAI pilot project)

Pilot Project at HS

Partner: Hispano-Suiza (HS)	
Country: France	
Industry: Aircraft engines	
Pilot Project: Development of a control unit for extending the operational life of a jet engine.	

Figure 6: Pilot project at HS

Pilot Project Description. Hispano-Suiza (HS) is a supplier of aircraft engine manufacturers, providing total solutions to optimize engine operation under actual conditions. They are a systems integration-engineering firm within the areas of system design and specification, engine control and monitoring, and power transmission systems. The pilot project at HS was the development of a control unit for extending the operational life of a jet engine (see Figure 6).

Application of the SysTest Methodology. HS decided to decrease the VVT effort in the early phases of the pilot project (see Figure 7). Consequently, also the rework cost decreased in the Design phase, since less failures were found (see Figure 8). However, at least partly due to the VVT reduction in the first phases, the rework cost increased significantly in the Implement phase. The large amount of product defects found in the Implement phase lead to an increase in the rework cost of approximately 88%. To improve the product quality, also the VVT had to be intensified. In summary the overall VVT investment increased by 30%, and the rework cost increased by 13%.

Several other factors were also considered to be responsible for this rise in both VVT and rework cost. First, the definitions of the project phases have changed over time. Although this effect can easily be determined, it was not possible to quantify it and thus remove it from the data. Second, the nature and size of the pilot project is not comparable to the historical project provided. This is supported by the fact that there is a difference between the pilot project and historical project cost and duration of 65% and 70%, respectively. On the other hand, the complexity of the pilot project was considerably higher, since the software share in the product increased and new methods, tools, and processes were introduced in the pilot project.

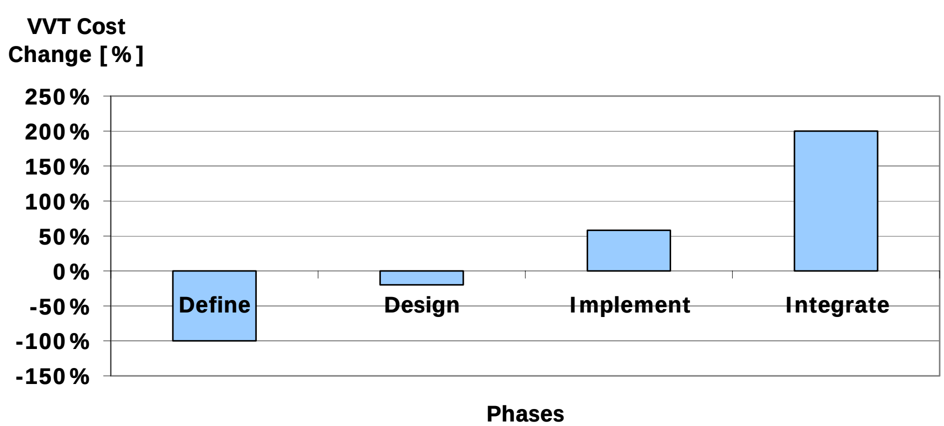


Figure 7: VVT cost comparison (HS pilot project)

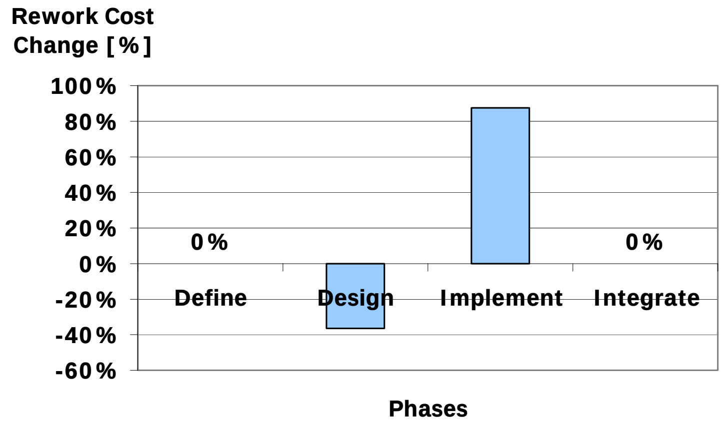


Figure 8: Rework cost comparison (HS pilot project)

Pilot project conclusions. To sum it up, given the fact that 40% and 20% of the project costs emanates from VVT activities and VVT rework activities, the overall project cost has increased by 14.6%. The main reason for this finding is the significant increase in the product complexity relative to previous projects.

Pilot Project at CRF

Partner: Centro Ricerche Fiat (CRF)	
Country: Italy	
Industry: Automotive	
Pilot Project: Development of a cylinder head casting mould for an automobile engine.	

Figure 9: Pilot project at CRF

Pilot Project Description. Centro Ricerche Fiat (CRF) is a research institute of the Fiat Group. Its company mission is to create and transfer new products, processes, and methods, to develop and use advanced engineering techniques for product development and production, and to provide state-of-the-art facilities, equipment, and laboratories. In the pilot project, a mould for a new automobile engine cylinder head was developed and tested (see Figure 9).

Application of the SysTest Methodology. In the CRF pilot project it was decided to frontload VVT activities. Therefore, the VVT cost increased in the design and implement phase by 108% and 39%, respectively (see Figure 10). In return, it was possible to reduce the VVT cost in the following, more expensive phases considerably. Thus, an overall reduction in the VVT cost of 18% could be achieved.

With respect to the rework cost, a moderate increase in the Integrate and Qualify phase (see Figure 11) was experienced. However, this was not influenced by the suggested VVT methodology. According to CRF, the increase of rework cost in the late phases can be attributed to additional customer requests, which was not caused by the SysTest methodology. This is reinforced by the pilot project cost data, which shows that also the pilot project cost increased in the Qualify and Produce phase by 33% and 60%, respectively. In summary, rework cost being 3% higher compared to historical projects were measured in the pilot project.

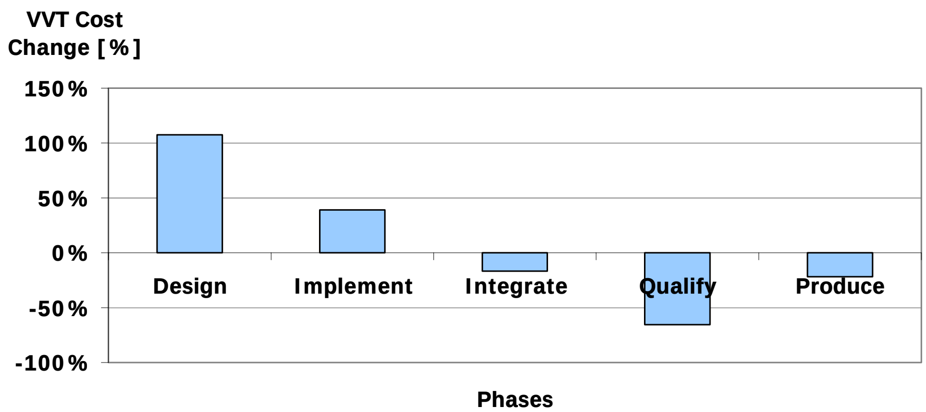


Figure 10: VVT cost comparison (CRF pilot project)

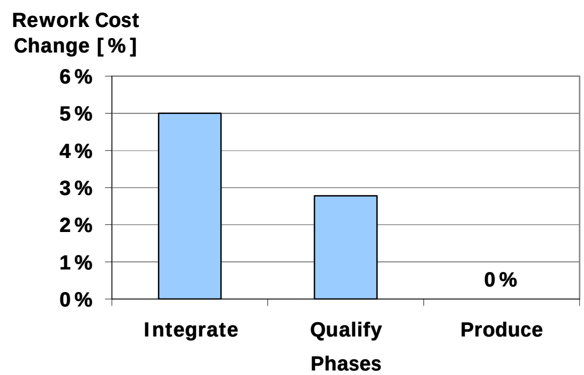


Figure 11: Rework cost comparison (CRF pilot project)

Pilot project conclusions. CRF enhanced the VVT planning and VVT execution in the first phases of the pilot project. For example, simulation techniques were used more intensively. As a result, failures and intensive VVT in the late phases were avoided. This change in the VVT cost is significant, since the pilot project cost was stable compared to the historical project. CRF also noticed a reduction in test redundancy and a better coordination of the quality with the engineering departments in the pilot project.

Since the VVT cost were 13.6% and the rework cost 5.3% of the overall project cost in the comparable historical project, the project cost spent on quality were around 19%. Therefore, in summary an overall saving of 2.4% of the total project cost was achieved in the pilot project.

In Figure 12 the applied SysTest products are related to the experienced process improvements and the cost measurements. Probably the core message here is that the VVT Methodology Guidelines are mainly responsible for the VVT cost reduction.

SysTest products ...			... lead to improvements in ...	... lead to a reduction in ...	
VVT MG [1)]	VVT PM [2)]	VVT S&P [3)]		VVT cost	rework cost
+++		+	VVT process guidance	++	
+++		+	VVT effectiveness	++	
+++		+	VVT efficiency	++	

[1)] VVT MG = VVT Methodology Guidelines

[2)] VVT PM = VVT Process Model

[3)] VVT S&P = VVT Strategy & Planning Procedure

Figure 12: Relation between SysTest products and improvements (CRF pilot project)

Pilot Project at DC

Partner: DaimlerChrysler Research and Technology (DC)	
Country: Germany	
Industry: Embedded software	
Pilot Project: New navigation-based driver assistance system for top of the line passenger car.	

Figure 13: Pilot project at DC

Pilot Project Description. DaimlerChrysler Research and Technology Berlin (DC) is one of several research facilities of DaimlerChrysler worldwide. The department involved in SysTest is mainly concerned with research in the area of software verification and validation. The pilot project was the development of a navigation-based driver assistance system for top of the line passenger cars.

Application of the SysTest Methodology. DC also decided to frontload VVT activities – therefore, the VVT cost in the first phases, Define to Implement, increased (see Figure 14). On the other hand, since it was possible to reduce the testing effort in the Qualify phase, the overall VVT cost could be reduced by 44% (calculated on the basis of expert judgment). Additionally, the rework activity cost was estimated by experts to have reduced by 40%. Moreover, DC expects a better product quality and less problems in the use phase. Thus, it seems that the frontloading of the VVT activities helped to reduce the product defects in the later phases. Since the system is currently in the pre-production phase, no data for the Produce and further phases is available. Compared to previous projects, much more effort was spent in the Definition phase. The Design and Implementation phases are not comparable to historical project, because the implementation was partially performed by DC, which was not the case in previous projects.

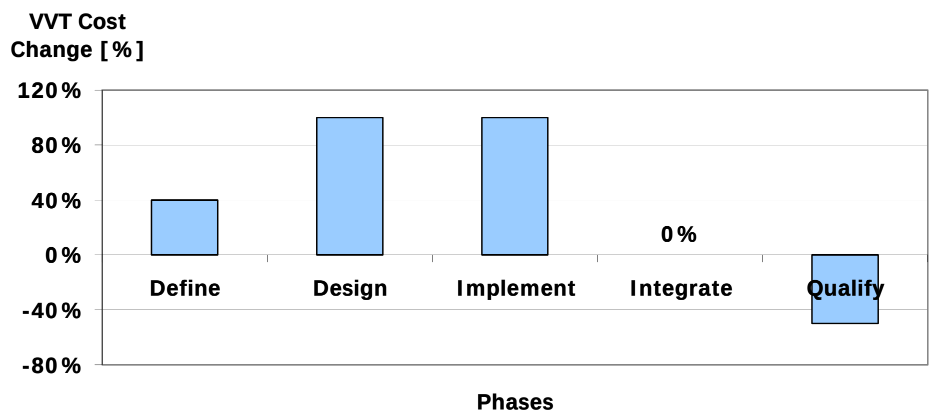


Figure 14: VVT cost comparison (DC pilot project)

Pilot project conclusions. With the application of the SysTest Methodology it was possible to reduce the VVT cost at the DC pilot project considerably. The main reasons for this achievement were the application of new VVT methods and tools and the SysTest VVT Strategy & Planning Procedure. The observed change in the VVT cost is significant, since the pilot project cost was relatively stable.

Since the VVT cost were 61% and the rework cost 18% of the overall project cost, the project cost spent on quality were around 79%. Therefore, in summary an overall reduction of 34% of the total project cost could be measured in the pilot project.

According to DC, there are three main reasons for this reduction in the VVT and rework cost: Improvements in the VVT Methodology scope, the requirements traceability, and the organizational and interdisciplinary integration. This is depicted qualitatively in Figure 15. With respect to SysTest results, DC applied mainly a new method and tool for software testing in the pilot project, which was extended in the SysTest project. This method and tool, the Classification Tree Method and Classification Tree Editor, are included under "VVT MG" in the following Figure 15.

SysTest products ...			... lead to improvements in ...	... lead to a reduction in ...	
VVT MG [1)]	VVT PM [2)]	VVT S&P [3)]		VVT cost	rework cost
+++		+	VVT Methodology scope (lifecycle phases covered)	++	++
+++			requirements traceability	++	++
+++			organizational and interdisciplinary integration	+	+

[1)] VVT MG = VVT Methodology Guidelines
[2)] VVT PM = VVT Process Model
[3)] VVT S&P = VVT Strategy & Planning Procedure

Figure 15: Relation between SysTest products and improvements (DC pilot project)

Pilot Project at TPCA

Partner: Tetra Pak Carton Ambient (TPCA)	
Country: Italy	
Industry: Liquid food packaging	
Pilot Project: Development and evolution of a flexible cap applicator for liquid food packaging.	

Figure 16: Pilot project at TPCA

Pilot Project Description. The company Tetra Pak Carton Ambient (TPCA) is working in the liquid food packaging industry. In this industry, the developed systems include, besides the package, also the packaging lines, filling machines, and the downstream equipment. The pilot project was the development of a flexible cap applicator for liquid food packaging.

Application of the SysTest Methodology. TPCA increased the VVT effort in the early phases and reduced it only slightly in the later phases of the pilot project. A considerable amount of test activities was performed in the early phases in order to reduce the pilot project risk. This frontloading is reflected by the VVT cost data (see Figure 17): Increase in VVT cost in the early phases and reduction in the later phases. In summary, the overall VVT cost reduced by 28%. However, this reduced VVT cost was mainly related to part manufacturing, equipment, and raw material cost reduction, more than to VVT effort reduction. The cost reduction due to VVT improvement is estimated to be around 3%.

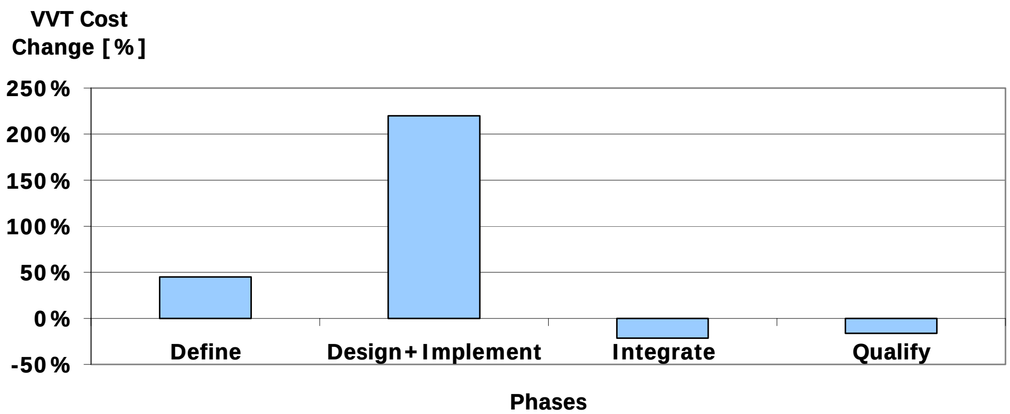


Figure 17: VVT cost comparison (TPCA pilot project)

In addition to the reduced VVT cost, TPCA experienced a improvement in the rework activity cost in all relevant phases (Figure 18). The overall rework cost decreased from 26% to 12% of the total project cost, which is a reduction of 53%. In the opinion of TPCA engineers, this is the most important SysTest achievement.

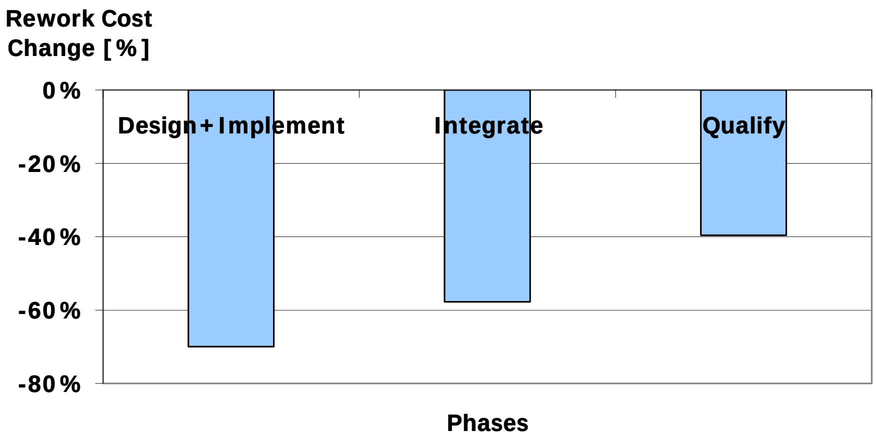


Figure 18: Rework cost comparison (TPCA pilot project)

Pilot project conclusions. TPCA attributes the VVT cost reduction mainly to the application of new VVT activities, to an efficient VVT planning, and to the improved VVT process guidance. Since additional VVT activities were performed, a better confidence level on the product robustness with using less equipment and raw material was achieved; this increased the VVT effectiveness and efficiency. Although new VVT activities were added, a VVT cost reduction was experienced. This is because some of the most expensive tests (which have high personnel and equipment cost) were substituted by cheaper tests upfront. Moreover, the share of VVT cost on the overall pilot project cost could be reduced from 59% to 51%.

The share of the VVT cost in the total project cost relative to a comparable historical project was 59%. The rework cost share was 26%. Hence, the cost of quality-related activities sums up to 85% of the overall project cost. With the measured VVT cost reduction of 3% and the rework cost reduction of 53%, an overall project cost reduction of 15,6% was achieved.

Figure 19 shows the four main causes for the measured cost reductions, determined by TPCA. It can be seen that the VVT Methodology Guidelines and the VVT Process Model are mainly responsible for the improvements.

SysTest products …			… lead to improvements in …	… lead to a reduction in …	
VVT MG [1)]	VVT PM [2)]	VVT S&P [3)]		VVT cost	rework cost
	++	+++	VVT process guidance	+	+
+++	+		rate of virtual versus physical testing	++	++
+++	+		VVT effectiveness	++	
+++	+		failure detection rate		++

[1)] VVT MG = VVT Methodology Guidelines

[2)] VVT PM = VVT Process Model

[3)] VVT S&P = VVT Strategy & Planning Procedure

Figure 19: Relation between SysTest products and improvements (TPCA pilot project)

Pilot Project at ACE

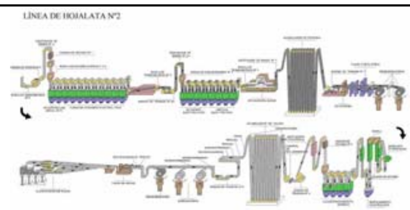
<table>
<tr><td>Partner: Arcelor (ACE)</td><td rowspan="4"></td></tr>
<tr><td>Country: Spain</td></tr>
<tr><td>Industry: Steel production</td></tr>
<tr><td>Pilot Project: Improving the VVT in a tinplate production line.</td></tr>
</table>

Figure 20: Pilot project at ACE

Pilot Project Description. Arcelor (ACE) is working in the steel production industry. In this industry, the development process is restricted to the production phase. It begins with the definition of the new product in terms of dimensions, coating, thickness, surface aspects, etc. The design of a new product could be summarized as the transformation of an idea into a new product with the main steps preparation phase (business opportunity recognition), definition phase (planning, costs, impact,...), and execution & follow up (including evaluation). The pilot project was the improvement of a tinplate production line.

Application of the SysTest Methodology. Arcelor conducted the pilot project within the production phase of the systems' lifecycle. In the pilot project, the VVT approach for a tinplate production line was re-planned and new testing methods were introduced. ACE experienced 50% reduction in the yearly VVT activity cost during the production phase (see Figure 21). However, a one time equipment investment totaling 140% of the yearly VVT cost was necessary to achieve this improvement.

Pilot project conclusions. We use finding reported by ***Engel et al. 2004*** which indicates that some 4.7% of the production cost stems from performing VVT activities. This data coupled with the 50% VVT cost saving observed by ACE yields a total yearly cost saving of 2.4%.

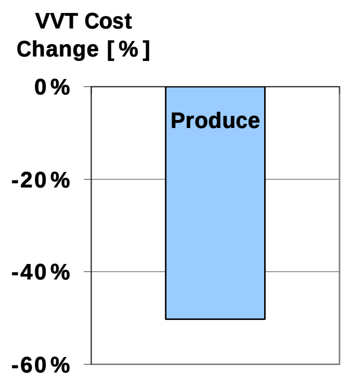


Figure 21: VVT cost comparison (ACE pilot project)

The VVT Process Model and the VVT Strategy & Planning Procedure allowed for a better planning of those improvements. Certainly, the ideas for those improvements came from domain-specific knowledge, but for ACE the main benefits from the SysTest products were an improved guidance for test-planners and an improved effectiveness and efficiency of VVT activity planning. Figure 22 shows this relationship between the SysTest products, the experienced improvements, and the measured cost savings qualitatively. The new VVT strategy lead to a cost reduction, but no significant difference in product quality was achieved.

SysTest products ...			... lead to improvements in ...	... lead to a reduction in ...	
VVT MG [1)]	VVT PM [2)]	VVT S&P [3)]		VVT cost	rework cost
+	+++	+	VVT process guidance	+	
+++	+	+	VVT methodology scope (life-cycle phases covered)	+	
	+++	++	VVT effectiveness	+++	

[1)] VVT MG = VVT Methodology Guidelines

[2)] VVT PM = VVT Process Model

[3)] VVT S&P = VVT Strategy & Planning Procedure

Figure 22: Relation between SysTest products and improvements (ACE pilot project)

Summary

The stated aim of SysTest was to "**Decrease product development costs and time to market by 10%"**. SysTest planned to achieve this aim by developing a generic a methodology and process model for Systems' Verification, Validation, and Testing. Since the pilot projects were conducted at various companies and in various industries, its results are strongly depending on project, company, and industry characteristics. Furthermore, the SysTest partners had different strategies in applying the SysTest products, e.g. frontloading VVT or increasing the overall VVT effort, depending on their needs.

All in all, the pilot projects conducted by the SysTest industrial partners exhibited an average of 7.6% project cost reduction with standard deviation of 14.8% (see Figure 23).

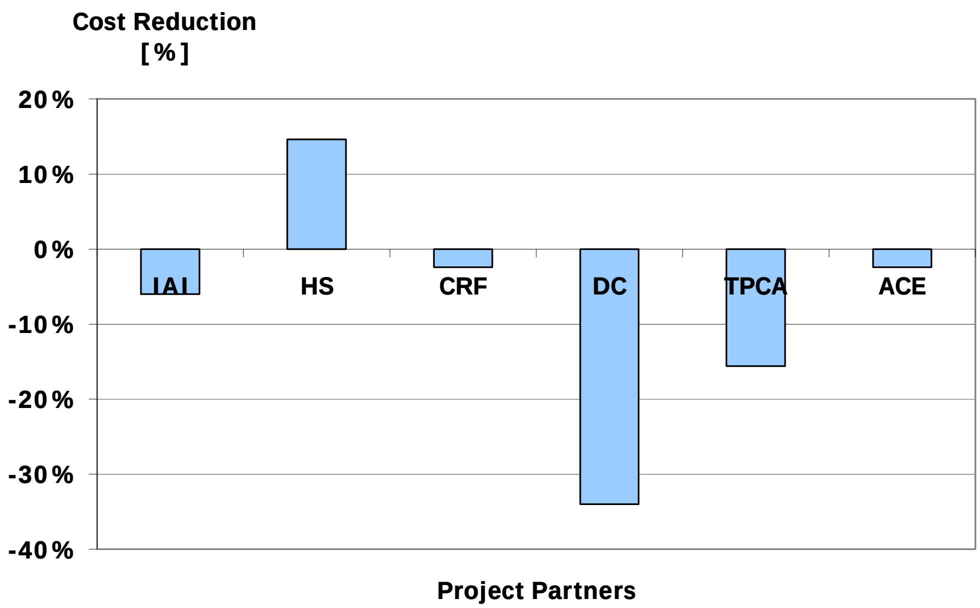


Figure 23: Summary of pilot projects' cost reduction

In addition, the pilot projects have provided important insights:

- **Applicability** – The generic SysTest products are applicable in different industries. Each project was able to use most parts of the SysTest Methodology.

- **Benefit** – The application of the SysTest products bring savings in time-to-market and cost, and can improve the process and product quality. The numbers vary between the different pilot projects, but they show that significant savings can be achieved with the application of the SysTest products.

The assessment of savings in the area of time-to-market is difficult. However, since rework is always associated with cost and duration, the savings in the rework cost suggest that also savings in the project duration were achieved.

The statistical relevance of the data can be discussed, but nevertheless the presented data strongly indicates that the SysTest products help to improve verification and validation and to avoid rework.

Acknowledgements

Partial funding for this research work was received from the European Commission; project SysTest (Contract ***G1RD-CT-2002-00683***). The authors wish to acknowledge the significant contribution to this research, made by the members of the SysTest consortium. For more information regarding the SysTest project visit the SysTest website http://www.secoe.org/0105.htm.

References

Boulding, K. L. General systems theory - The skeleton of science , *Management Science*, Vol. 2, pp. 198-199, 1956.

Browning, T.R. Modeling and Analyzing Cost, Schedule, and Performance in Complex System Product Development. PhD Thesis, Massachusetts Institute of Technology, 1998, http://lean.mit.edu/.

Browning, T.R.; Eppinger S.D. Modeling Impacts of Process Architecture on Cost and Schedule Risk in Product Development. *IEEE Transactions on Engineering Management,* Vol. 49, No. 4, 443-458, 2002.

Engel, A.; Barad, M. A Methodology for Modeling VVT Risks and Costs. *Systems Engineering*, Volume 6, issue 3, pp 135 – 151, Wiley InterScience, Online ISSN: 1520-6858, Print ISSN: 1098-1241, July, 2003.

Engel, A.; Bogomolni, I.; Shachar, S.; Grinman, A. Gathering Historical Lifecycle Quality Costs to Support Optimizing the VVT Process. Proceedings of the 14th Annual International Symposium of INCOSE, Toulouse, France, 20-24 June, 2004.

Engel, A., Shachar S., Bogomolni I., Estimating and Optimizing System's Quality Costs of Transport Helicopter Avionic System Upgrade. Proceedings of the 15th Annual International Symposium of INCOSE, Rochester, New York, USA, 10-15 July, 2005.

Hoppe, M.; Lévárdy, V.; Vollerthun, A.; Wenzel, S. Interfacing the Verification, Validation, and Testing Process Model with Product Development Methods. Proceedings of the 13th Annual International Symposium of INCOSE. Washington, USA. July 1-3, 2003.

Hoppe, M.; Levardy, V.; Leardi, C.; Mendikoa, I.; de Abajo, N.; Gonzalez, J. A.; Lobato, V.; Peregrina, S. Application Experiences of the VVT Process Modeling Procedure for Verification and Validation Planning. Proceedings of the 14th Annual International Symposium of INCOSE, Toulouse, France, 20-24 June, 2004.

Huber, J. Efficiency and effectiveness measures to help guide the business of software testing.

International conference on software management & application of software measurement, Feb. 1999, San Jose, CA.

Jones, C. *Applied software measurement*. McGraw-Hill, Inc. 1996.

Klir, G.J. *An approach to general systems theory*. Litton Educational Publishing, 1969.

Lévárdy, V.; Hoppe, M.; Wenzel, S.; Vollerthun, A. Process Modeling Procedure For Validation, Verification And Testing (VVT) Planning. International Design Engineering Technical conference (ASME-2003), Chicago, Illinois, 2-6 September, 2003.

Lévárdy, V.; Hoppe, M. Verification, Validation and Testing Strategy Planning Supported by a Process Model. Proceedings of the Tools and Methods of Competitive Engineering (TMCE) 2004 Conference. Lausanne, Switzerland. April 12-16, 2004. Vol 2, pp 1021-1032.

Lévárdy, V.; Hoppe, M.; Honour, E. Verification, Validation & Testing Strategy and Planning Procedure. Proceedings of the 14th Annual International Symposium of the International Council on Systems Engineering (INCOSE). Toulouse, France. June 20-24, 2004.

NASA (National Aeronautics and Space Administration). *NASA Software Program – Software Management Guidebook*. NASA-GB-001-96, 1996.

Sorqvist, L. *On poor quality costing*. Doctoral Thesis, Royal Institute of Technology, Department of Production Engineering, Stockholm, 1998.

Thome, B. (ed). *Systems Engineering: Principles and practice of computer-based systems engineering*. John Wiley & Sons Ltd. 1993.

Vollerthun, A. et al. Methodology development for Systems verification, validation and testing. Proceedings of the 12th Annual International Symposium of INCOSE, Las Vegas, Nevada July 28 – Aug. 1, 2002.

Biography

Mr. Markus Hoppe received his M.S. degree in mechanical engineering at the Technische Universität München. He is currently working as research assistant at the Institute of Astronautics of the Technische Universität München in Germany. He works in the SysTest project, funded by the European Community. His major research focus is method implementation and test process modeling.

Mr. Avner Engel holds a B.Sc. in Electrical Engineering (1970) and an M.Sc. in Computer Systems (1971). His professional career spans the areas of programming, systems/software engineering, and technical management with several large companies in the United States and Israel. During the past twenty years, he has been working for Israel Aircraft Industries (IAI), where he was a software manager of large projects. He is currently leading an international consortium, SysTest, funded by the European Commission, aimed at developing a methodology and a process model for Systems Verification, Validation, and Testing (VVT). Mr. Engel is also a Ph.D. student at the Department of Industrial Engineering, Faculty of Engineering, Tel-Aviv University, Israel.