

# Verification & Validation; an Inconvenient Truth

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## ■ ABSTRACT

This paper addresses several inconveniences regarding the proper use of verification and validation. We address the inconvenient truth by discussing reality in projects and domains, versus the widely accepted definition of verification and validation, versus the way we think both projects and developments should be managed and versus the aim to achieve transparency in the relationship between principals and contractors.

## INTRODUCTION

Looking at definitions of verification and validation (V&V), one generally sees that both activities are to provide objective evidence against clearly identified requirements and/or the users needs, as defined in ISO 9001 (2005) and ISO 15288 (2008). James Armstrong (2011) presented a paper identifying the multiple definitions of both terms.

We identify several inconveniences regarding V&V. One well known inconvenient truth is that testing never improves a specific existing product. It is like a bottle of wine; tasting the first glass does not make the remaining wine in the bottle any better. However, from testing, we can learn how to improve processes and to make future harvests into better wines. And yes, preferably, we can prevent bad bottles entering the market.

We discuss several inconveniences, related to the following topics:

- Poor integrity and coherence: a recipe for disaster
- Subjective V&V: a blessing in disguise
- V&V incentives: a core problem in infrastructure projects.

Aside from identifying the inconveniences, we give a set of potential solutions for each topic addressed.

## POOR INTEGRITY AND COHERENCE; A RECIPE FOR DISASTER

Throughout all lifecycle phases the integrity and coherence of the system needs to be sustained. With the ever-increasing number of subcontracts during development, production and operation, all involved parties (both principal and contractors) need to focus on sustaining this system integrity. Here we discuss some of the V&V topics, related to sustaining the integrity and coherence. In some cases we also identify differences between domains.

### *Strict Separation of V&V Creates a Gap*

**V&V are different activities:** In theory, V&V are different subjects (Armstrong 2007) and it is good to understand the differences between both. However, an artificial or dogmatic split-up in applying V&V can become very counter productive. Treating V&V totally separate can lead to an explosion of plans and reports for proving compliance with each (derived) requirement. In the Dutch infrastructure domain, this is a proven case. Thousands of requirements per contract result in a scattered V&V approach. As an example: in a road construction contract a certain quality of the road surface is required. For each element in the contracted system contributing to this requirement, a derived requirement,

a separate V&V plan, a test plan and a compliance matrix item is generated. Even worse, this full set of documents is generated for each individual sample test taken every few hundred meters of a multiple kilometre asphalt road.

**Verification is for the contractor, validation for the principal:** This is an approach followed in several domains, as presented by Armstrong (2007). To avoid any risk of delivering a system that does not comply with the users need, many contractors refuse to do any validation activities. However, if a contractor has even a small design freedom in its system of interest, he should prove that design choices made do not negatively affect the use of the system. The more design freedom the contractor gets, the more need to prove compliance with the use related requirements. Whether they approve with the term validation or not, they need to show compliance with all requirements that are affected by their design choices. Moreover, treating V&V as totally separate activities may end-up in legal disputes whether validation is the responsibility of the principal or the supplier. Dogmatic splitting of V&V activities between the supplier and contractor will most likely result in bureaucracy and lost oversight on the total functioning of the system.

The solution for this matter is: No matter what your position is in the chain, always treat the V&V activities as a whole for your system of interest, in relation to the next level up. Even though this is 'stating the obvious' to systems engineers, it is not common practice in the infrastructure industry.

#### *No Differentiation Between Contract and System Breakdown Hinders Proper V&V*

Preferably, a system under development is structured based on a logical subdivision of systems and system elements. This division is to be optimised towards clustering of functionality and minimised interfaces. However, large scale and complex systems are often developed and built by multiple contractors. The contractors develop contractual subsystems, which in the end, need to form the entire system. The basis for a contractor to develop its subsystem is the contract and the contract only. The contractor's responsibility is to deliver a subsystem, which fulfils the requirements of the contract. In practice, the responsible organisation, which integrates the subsystems, needs to manage the interfaces created by the different contracts. These interfaces are not necessarily the optimal interfaces of the logical subsystems and their verification and validation.

In other words: For Dutch infrastructure projects (Luling 2007), the principal mostly does not differentiate between the development system breakdown structure and the contract breakdown structure. This hinders optimised V&V activities and thus should absolutely be avoided.

**The contract structure becomes the 'de facto' system architecture:** Often, large projects are characterised by many (sub) contracts. In cases where the principal has selected a small number of main contractors, those contractors tend to use subcontractors to provide services.

In the Dutch infrastructure each contractor is generally specialised in one discipline only, for example, civil construction, installation, electro-mechanical, and more. Very limited knowledge is available related to the management of the integral system, especially between these contractors. This forces the principals to contract parts of the system on a discipline-oriented basis. Three very negative results of this approach are:

1. Aspect-systems (safety, transfer between modalities, comfort, and more) tend to be scattered throughout all contracts.
2. Contracts are based on a preferred static situation and do not cover scenarios that affect multiple disciplines.



Figure 1. Millau Viaduct, France

3. V&V regarding the end-to-end system performance is completely the principal's responsibility.

Rijkswaterstaat, the infrastructure manager for the Dutch water and road ways, chose to contract some of its integral systems, based on the design, build, finance, and maintain (DBFM) principle. However, consortia that won the contract subdivided the contract into the classical, discipline-based parts. Each party covered the activities related to their own expertise. Since parties suffer from limited knowledge of managing the integral system, these projects encounter serious problems during the design, realisation, and especially the transition phases. Among other reasons, this resulted in excessive delays in delivery and in proving compliance of multiple tunnel projects (Limmen 2009).

Here, the solution is to organize overall system V&V throughout the system development and realization. It is for the principal to assure that V&V activities are being covered by all parties involved. Generating a V&V management plan for each system of interest forces parties to define what is to be expected.

#### *Responsibility for System Architecture is Missing in Most Infrastructural Projects*

In order to specify all subsystems and to make sure the subsystems can integrate to form the integral system, the responsible company for the system requires the architecture role. In many industries, these responsible companies have the knowledge to create their system architecture (that is their core business). In infrastructural projects however, where the project team is responsible for the entire system, an accurate architecture is often missing (due to complexity, lack of knowledge in the behaviour and characteristics of the integral system, and a lack of incentive to create a system architecture).

However, a project like the Millau Viaduct in southern France is an example of a well managed project, where system coherence was a constant factor and where both V&V were on the consortium mind throughout all phases of the project. This definitely contributed to the fact that this viaduct was delivered in time, within budget, and met the required quality (Millau Viaduct 2004).

#### *Scope of V&V is N-1*

To make sure the system works according to specification and the intended use, it requires V&V. However, V&V must not only happen on the system itself, but also in the interaction with its direct environment (politics, public, users, and other).

**System Context:** The V&V effort often relates to contractual obligations between principal and contractor, at whatever level. There is always a system of interest more or less sharply defined. The V&V effort tends to focus just on the contracted system of interest. However the success of the system, and especially the validated system, is dependent on looking at least one-level-up, taking into account the context of the system under evaluation.

As an example of the need to consider the project scope N-1, we take a look at the cleaning design of the Bijlmer railway station (Lamper 2011). The detailed design and construction of the upgrade for the Bijlmer railway station was contracted to a consortium. Many activities were subcontracted. One of the contracts comprised the design for a cleaning trolley system for the glass/metal structure of the outer walls. The picture in Figure 2 clearly shows that the trolley design was implemented, but that at integration it was positioned in a corner and next to a support beam. What happened is that during design it became clear that additional support beams were needed on the outer walls. At that point the impact on the design for the cleaning trolley system was ignored. Even worse,





Figure 2. Bijlmer station window-cleaning trolley enclosed by support beam

during integration of the cleaning trolley system the installer did not check whether the equipment was fit for use, since the trolley can only move vertically where it also should be able to move horizontally. The trolley supplier failed to validate whether the solution was fit for use to clean the windows, where the designer of the glass-wall construction failed to validate its redesign to the use of other parts of the system.

The solution for this matter lies in the fact that during all phases of the development and realisation of a project the context of the system of interest is to be evaluated and proven by V&V activities, thus properly managing the system integrity.

#### SUBJECTIVE V&V: A BLESSING IN DISGUISE?

Both ISO-9000 (2005) and ISO-15288 (2008) define V&V as activities that take place against well pre-defined requirements and provide objective evidence. However to what extent can/should V&V be objective? It is a general belief that subjective V&V should be avoided. In practice, subjective V&V can be a blessing in disguise. There are four reasons to challenge objective V&V:

1. Objective V&V contributes to TRANSPARENCY, which is required for implementing corporate social responsibility. "Corporate social responsibility is the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large"

(World Business Council for Sustainable Development). We must be able to explain sustainability: what happened, why it happened or did not happen, and at what costs to society. But what level of transparency is desired or even accepted?

2. The PUBLIC OPINION is the ultimate example of subjective V&V. The public opinion is the final judgement whether a product becomes a true valuable and appreciated product or not. The perceived quality overrules the intrinsic quality of a system. The specifications of the Philips Video 2000 system were generally believed to be superior. However, the public opinion finally chose the VHS-system. V&V is not only about requirements, but also how requirements are perceived, weighed, and communicated.
3. The ISO definitions assume a perfect world of neatly pre-defined requirements, which in the real world is seldom true. Many projects suffer from INACCURATE REQUIREMENTS.
4. The whole process of V&V is more than checking the box. V&V requires skilled staff with a certain CRAFTSMANSHIP. To what extent do we rely on craftsmanship?

#### Transparency

Transparency is the buzzword among politicians and members of the board of directors. But do we really understand the consequences of transparency? According to Standish Group (1994), Lewis (2003), and Ellis (2008), 70-80% of projects fail

to deliver on time, within budget and according to the scope or a combination of them. Apart from discussions on the definition of project failure, it seems as if the project success does not increase over the years. We learn too little from mistakes. USP Marketing consultancy reports for the Dutch construction sector show an increase in failure costs over the last 10 years: total failure costs as percentage of the project costs increased from 6% (2001) to 11% (2010). Major reason is a lack of communication and checking a realistic design: too little V&V is incorporated to close the loop (Rijt 2009). Though there are probably many causes why project execution does not improve, one of the reasons is lack of a learning curve. V&V contributes to closing the loop for the learning curve inside projects.

An example of the potential value of V&V for transparency in a real life project is the Noord/Zuidlijn (North-South metro line) in Amsterdam (Netherlands). The Noord/Zuidlijn is an extension of the Amsterdam subway of 9.7 km right under the historic centre of the city. Though the first ideas originated in 1968, definite plans (2002) indicated a budget of 1.5 billion euro. Start of operation was estimated to take place in 2011. After many disappointments, settlement problems with houses, evaluations and political interventions, the costs are now 3.1 billion euro, and a delivery date in 2017. Complex projects have many reasons to fail. Among the major conclusions in a failure are several V&V related conclusions (Limmen 2009):

- Limited V&V of the intended use of appropriate technology
- No transparent V&V on design/project changes
- Insufficient V&V on the business case
- V&V of the market consultation results have been denied
- No appropriate V&V on contracts and risk approach
- Too little checks & balances.

The above case illustrates that it is very difficult to maintain transparency for projects with conflicting interests.

As a consequence transparency may reveal:

- hidden interests (political ambition versus a negative business case)
- early failures (technology risks for settlements)
- lack of progress
- value trade-offs
- risk profiles.

The (social, economical, political) context of the project and the attitude of the



Figure 3. Street light installed at the center of the intersection

management involved, determines to what extent these types of consequences can be handled. Hence the level of transparency is as good as the accepted level of transparency.

To improve the transparency one may think of the following measures:

1. Independent V&V of the business case at major milestones.
2. Explicit V&V of all stakeholder requirements. Stakeholders have to sign off on the V&V report.
3. Dedicate organization for V&V in the initial stages of the project both with the principal as well with the project organization itself.

#### Public opinion

The perceived quality is defined as the consumer's opinion of a product's (or a brand's) ability to fulfil his or her expectations. It may have little or nothing to do with the actual excellence of the product. The perceived quality is based on the firm's (or brand's) current public image, consumer's experience with the firm's other products, and the influence of the opinion leaders, consumer's peer group, and others. Hence demonstrating that a system fulfils its intended pre-defined requirements with objective evidence is no guarantee that the consumer or end-user agrees with this objective conclusion. The Apple iPhone is perceived as a superior product, not withstanding the technical problems with battery life and signal-strength.

This phenomenon requires a link between the marketing, communication strategy, and V&V activities: how to communicate V&V results apart from the formal project reporting mechanism.

#### Inaccurate requirements

Specifying requirements and specifying systems is an extremely difficult job. Relying 100% on correct specifications is dangerous, though a risk based approach might triple your chances for project success (Wheatcraft 2011). In the practice of the Dutch construction sector some anomalies reoccur again and again. More than 50 reviews of specifications in the principal and contractor domain, during the last three years, demonstrate the following top-3:

- Non SMART requirements, open to multiple interpretations.
- Derived requirements without any design decision, replacing the upper requirements. As a consequence, the end-to-end performance of the system and the relations among requirements are lost.
- Requirements unnecessarily prescribing design solutions.

Above anomalies originate from lack of transparency, limited competencies, and strongly separated requirements engineers and design engineers. A common sense sanity check should always be part of a serious V&V effort. V&V contributes to solve these anomalies in two ways. Formal requirement reviews reveal early improvement opportunities and increases the awareness of writing good requirements. These formal reviews can be based on a clear reference, such as, Planguage (Gilb 2004). Once a specification has been finalised, the addition of pass-fail-criteria per requirement improves the V&V-ability of the specification.

Figure 3 is a real-life example of obvious mistakes initiated in requirements/guidelines, being implemented in design and

even during construction, without somebody 'ringing a bell.' This solution surely does not fulfil the users' needs.

#### Craftsmanship

In some cases, documents are reviewed on an informal basis. Mr Jones, who is an expert on control systems, evaluates the design documents of a contractor for tunnel control systems. Mr Jones provides his comments based on his expert opinion. Mr Jones is not familiar with the contract or the original principal's requirements. The contractor starts discussions on his comments, claims rework. In the worst case, a third opinion of an even more expert guru should solve the problem.

As soon as V&V tends to be a personal belief, it only creates turbulence. This is the type of subjective V&V to avoid. Most times this type of subjective V&V occurs in discipline-oriented teams without adequate communication between specialists, project management, and contract management.

However, applying V&V without any craftsmanship is likely to fail. This type of V&V will result in checking all boxes, while the final system in the real world does not work properly.

Competency profiles are required to differentiate between (certified) craftsmanship and objective V&V. Competency profiles also are required to establish balanced review teams.

#### V&V INCENTIVES: A CORE PROBLEM IN INFRASTRUCTURAL PROJECTS

One of the main goals of V&V is to detect design faults and integration problems, preferably in an early stage. Furthermore, V&V acts as a proof that the system of interest will work as the stakeholders intended it. Although the value of V&V is well-known in the era of systems engineering, in practice V&V is not always desired or considered important by the organizations involved in the system development lifecycle. Sometimes certain incentives of these organization's seem to conflict with the incentives to perform V&V. In this section, we share some insights that cause the inconvenient truth preventing the performance of thorough V&V, especially in the infrastructural domain.

#### V&V is the Next Phase's Problem, Again and Again

Over decades, studies show that investing in V&V leads to lower lifecycle costs (Gilb 2004), especially when systems become complex. Studies also show that V&V performed in an early stage is more cost effective than in a later stage (Boehm 1981). So how does this reflect on infrastructural projects?



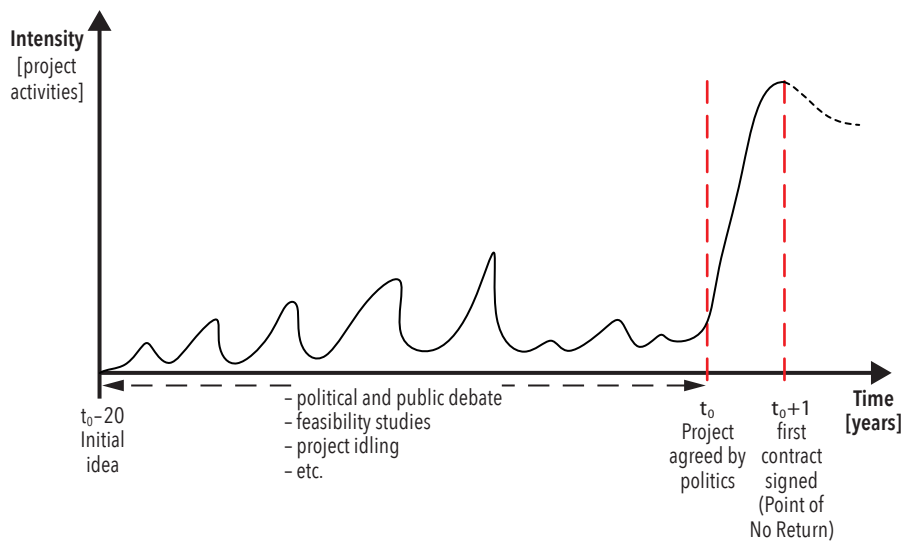


Figure 4. Typical (infrastructure) project intensity of activities as a function of time

Let us examine a typical large infrastructural project from initial ideas until the first contractor hire. The period between the first ideas and the final agreement to officially realize the large (infrastructural) project can sometimes take years or even decades. This is often due to complexity and the large investments involved, as well as the political disagreement between parties about the project degree of importance. This period is indicated in the figure below between  $t_0 - 20$  and  $t_0$ , where the intensity of project activities is depicted as a function of time. In this example, it takes 20 years from initial idea until project agreement due to politics. The project is investigated and stopped, over and over again, until the project is finally agreed to by politicians.

During this long time period, there is plenty of time to perform feasibility studies, problem analyses, conceptual design, and V&V activities. However, during this time period there are 3 important drawbacks:

1. The customer requirements are often not really clear yet.
2. Resources are limited because there is no official project yet and therefore only a small budget is available.
3. V&V activities are not officially demanded yet. Therefore V&V activities are postponed to later (when the project really starts).

When the government finally decides to start the project at time  $t_0$ , the principal wants to reach the point of no return (PNR) as soon as possible, especially if it took a long time to come to this decision. The PNR is the moment where the first (main) contractor is contracted. Especially in large infrastructural projects, there will always remain a risk that the government will withdraw its decision (driven by politics, for instance during election). In

our example, the PNR is set at  $t_0 + 1$  year. From  $t_0$  until the PNR, all project effort is required to create the contractual specification. However, in practice it turns out that at that time, the principal's requirements are often not clear yet and a well thought out and verified systems architecture is also missing.

Here lies our inconvenient truth: due to the external time pressure to reach the PNR by hiring a contractor as soon as possible, there is often not enough time at  $t_0$  anymore to create a new systems architecture, to make all customer requirements clear, to review specifications, and to perform thorough V&V activities. A contract is put out to the market based on many assumptions and without proper V&V activities against customer requirements and a system architecture. The V&V activities are again postponed to the next phases. This is as described by Elich et al. for an infrastructure public-private partnership (PPP) project (Elich 2008).

Combine this with the fact that between  $t_0$  and the PNR the project organization is in the middle of its start-up phase where people need to be hired, and processes and tools need to be (re) designed (due to the lower level of systems engineering maturity in the Dutch construction sector, processes and tooling applied are defined and reinvented for each project). From this, it becomes clear there is a large risk that faults and many changes may arise in the specification during a later phase, often resulting in high additional costs.

Well-known large infrastructural projects in the Netherlands confirm such a long period to come to a project agreement:

- The railway project “Betuwe Route” for goods transportation from the port of Rotterdam to the hinterland towards Germany

- Initial idea: 1985 (Poeth en Van Dongen 1985)
- Dutch Parliament agrees the plan: 1994 (Commissie Infrastructuurproj 2004)
- The railway tunnel project “Spoorzone Delft”
  - Initial ideas: 1988 (Spoorzone Delft 2004)
  - Dutch Parliament agrees the plan: 2004 (Spoorzone Delft 2004)
- The Amsterdam underground metro project “The Noord-Zuid Lijn”, to create a connection from north to south
  - Initial ideas: 1968, (Investigation committee Noord/Zuidlijn 2009)
  - Dutch Parliament agrees the plan: 2002, (Investigation committee Noord/Zuidlijn 2009).

A solution to this problem can be sought in:

1. Standardization of proven system architectures and specifications. By using more standardization, the time span between  $t_0$  and the PNR can become less critical since standards are available.
2. Using the GO/NO-GO moment at  $t_0$  to explicitly verify that:
  - a) the business case has been verified independently from the principal
  - b) all customer requirements are clear
  - c) a verified system architecture is available
  - d) risks are analysed and acceptable.
3. Using the period between initial idea and  $t_0$  more efficiently to realize the products as requested in 2. a)–d).

#### European Public Tender (F)law Limits V&V

There is another important reason why V&V gets postponed and becomes the ‘next phase’s problem.’ European Union (EU) law. EU law on public procurement aims to increase competition and transparency in the European economy. Modernising and opening up procurement markets across borders mean more opportunities for businesses and better value and higher quality services for the taxpayer. EU law intends to create a ‘level playing field.’ Nevertheless, does this policy allow application of adequate V&V in early project phases?

The Consolidated Directive on Public Procurement (2004) permits a principal to involve contractors in an early project phase by two means:

1. Competitive dialogue (Article 29: ‘In the case of particularly complex contracts, Member States (of the EU) may provide that where contracting authorities consider that the use of the open or

*restricted procedure will not allow the award of the contract, the latter may make use of the competitive dialogue in accordance with this Article....')*

2. Market consultation (as long as the results are available for all suppliers).

The inconvenience is that a contractor is not willing to expose his competitive edge in an early phase of the project, since this information (must) become public to preserve the 'level playing field'. The jurisdiction in this area is ambiguous. Principals are hesitating to make extended use of the above-mentioned opportunities.

In fact, the ambition of a 'level playing field' limits the use of sophisticated realization knowledge for V&V purposes in early project phases.

#### *V&V: the Penny Wise/Pound Foolish Approach in Tendering*

Let us examine the effects of a principal's strategy in tendering on the quality of V&V delivered by the contractors. Despite initiatives from principals to stimulate creativity (design and construct contracts), sustainability and lifecycle costs (most economically advantageous tender), and rewarding CO<sub>2</sub> reduction, practice turns out that the contractor with the lowest price will often receive the work from the principal. The lowest price remains the leading motive.

After the award, the contract with its price is leading. The contractor's incentive is to develop and realize the work at a low as possible cost with a quality still meeting the requirements of the contract. In this way, the contractor can potentially make a profit. This is in contrast with commercial products where the end user is leading because products need to be competitive in order to sell. Developing competitive products leads in general to higher profit margins.

Since in tendering the contract is leading, the contract quality is crucial. We discuss two important aspects that determine the contract quality here:

1. The quality of the requirements (the specification) in relation to the customer's needs,
2. The quality of the V&V activities.

Since a contractor will deliver according to the contract (compliance is enough), the principal needs to make sure that the requirements as stated in the contract represent the stakeholders' needs. As described earlier (under "craftsmanship"), too often it's seen that Mr Jones (the final user or client) reviews the product without using the specification. To avoid mismatches between stakeholders needs and the contract, the principal has to make sure that:

- stakeholders needs aren't missing in the contract
- requirements in the contract represent exactly the stakeholders needs.

This means that the V&V feedback loop from contract specification to stakeholder needs must be checked thoroughly. However, this feedback loop costs some time and can be in contrast to reaching the PNR quickly.

Another important aspect is that the "quality and performance bar" must be set accurately. This means that the requested quality and performance must be made explicit. If one aims for a procurement benefit by keeping the quality and performance vague, what kind of performance and quality can we reasonably expect? A principal cannot expect a better product than requested in its contract, unless the principal is willing to pay more (which in practice leads to changes in requirements). So this short-term procurement benefit can in the end be a penny-wise/pound-foolish approach.

One could reason that we have to specify more accurately. Although this would help, we all know that perfect contracts do not exist. Besides writing good quality requirements, the quality and effort in V&V activities is also crucial.

Since V&V activities will cost some money, the contractor must be able to estimate these activities or it needs to make explicit what kind of V&V activities it will perform during the project. If the principal does not prescribe its desired V&V activities for the requirements in the contract and the contractors do not have to create a V&V plan in the pre-award phase, what can a principal reasonably expect from a contractor concerning its V&V activities? If the V&V activities are vague during tendering, this will lead to discussion afterwards about how to verify the requirements, in what phase, and more. So, if a principal is serious about the value of V&V, the activities need to be made explicit (up to a certain extent) during tendering.

One solution to this problem would be to prescribe V&V procedures in the contract for those requirements that are absolutely critical and costly. This seems a fair solution because these activities can also be estimated by the potential contractors during the tender phase and can then be included in the price. Some principals do not do this because they are afraid to raise the price during the tender phase (they aim for a procurement benefit).

Another solution would be to request a V&V plan during tendering and to take the quality of the suggested V&V activities of the contractors into account in the award

criteria.

Both solutions raise the question to what extent are principals willing to pay for V&V activities? In addition, do principals realize the importance and value of V&V executed by the contractor? Principals and contractors need to become aware that investing in V&V wisely can reduce the total lifecycle costs and can iteratively design a better product, which in return leads to satisfied users and customers.

#### *The Importance of Managing V&V and Dedicating Resources to It*

The benefits of V&V are acknowledged widely. But why is it so difficult to implement V&V in project organizations and dedicate resources to V&V? An answer might be the primary project incentives allocated to the responsible managers: time, money, and number of project staff. How many managers report on the compliance of requirements?

If time and money are the dominant factor (for instance reaching the PNR at all cost) this can go at the expense of V&V. How often does one see that there is no time and money to do things right the first time, but in the end, additional time and money is required to do things over. If management only focuses on planning and budget, there is a risk that rework is required which results in delays and/or budget overruns.

So, the triangle between time, money, and project result must be in balance. In order to find this balance, the three variables must be measured and analysed: time by planning, money by budgets, project result by V&V. However, a problem arises if an organization does not have to report compliance of requirements to the management. In those cases, management will steer on planning and budget solely because only these variables are available. This short-term vision creates the risk that problems in compliance (product quality or performance) remain undetected and then are dealt with as they pop up.

So it is essential to make V&V progress explicit in the entire product chain, just like planning and budget, in order to let it be a guide and to find the balance between time, budget, and project result.

#### CONCLUSIONS

V&V suffer from several inconveniences. Inconveniences arise from a scattered systems approach, conflicting interests, limiting rules, missing incentives, and inadequate organisation of V&V. As a consequence, theory and practice disperse. The power of V&V, how to improve systems, and how to demonstrate the 'fit for use' is lost.

Some critical improvements measures are:

- Organise V&V explicitly from the very first beginning.
- Establish one V&V management plan for each party's system of interest.
- Always consider the system in its

context.

- Do not treat V&V as just a means of book keeping.
- Clearly identify independent V&V activities by stakeholders, such as for the business case.

Make V&V part of the management reporting and incentives and link V&V to the payment schedule. ■

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Maarten Vullings holds a master of science degree in mechanical engineering. In the Systems Engineering Group at Eindhoven University of Technology, he conducted research in container terminal planning, supply chain management and the engineering of manufacturing networks. In 2009 Maarten started as a systems engineer at ProRail B.V. (the Dutch railway infrastructure company), where he is currently involved in an inner city railway tunnel project in Delft (The Netherlands). Maarten is an INCOSE member since 2010.

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Paul Schreinemakers holds a bachelor's degree in fine mechanics and is a master of science in engineering product design. Paul has over 20 years experience in developing products for space, defence, and road & rail industries. In 2003 Paul founded his own consultancy company, called SEPIAdvies. Together with Erik Elich, he teaches the application of systems engineering at How2SE, a co-owned company founded in 2010. Many of the projects he was involved in consisted of multi-lingual and multi-cultural project teams. Paul became actively involved in INCOSE in 2000, and has served for 3.5 years on the board of directors of the Dutch chapter, of which he now is a former president. He was the general chair of the IS2008 host committee and since 2009, the Associate Director for Events. (*Editor's Note: Paul served INCOSE as Deputy Technical Director 2013-2014 and Technical Director 2015-2016.*)