Verification & Validation; An inconvenient truth

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Abstract. This paper addresses several inconveniences regarding the proper use of Verification and Validation. The inconvenient truth is addressed by discussing reality in projects and domains, versus the widely accepted definition of Verification & 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 & Validation, 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 [1] and ISO 15288 [2]). In 2011 James Armstrong presented a paper [3], identifying the multiple definitions of both terms.
We identify several inconveniences regarding Verification and Validation. One well known inconvenient truth is that testing does never improve a specific existing product. It's like a bottle of wine; tasting the first glass doesn't 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 & Coherence: a Recipe for Disaster
- Subjective V&V: a blessing in disguise
- V&V Incentives: a core problem in infrastructure projects

Aside of identifying the inconveniences, a set of potential solutions are given for each topic addressed.

Poor Integrity and Coherence; a Recipe for Disaster

Throughout all life-cycle 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 Verification & Validation creates a gap

Verification & Validation are different activities*:* In theory, Verification and Validation are different subjects [4] and it s 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 has shown to lead to an explosion of plans and reports for proving compliance with each (derived) requirement. Especially in the Dutch Infrastructure domain, this is the 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 compliancy 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 J.Armstrong [3]. 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 it will 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-up of Verification and Validation activities between the supplier and contractor will most likely result in bureaucracy and lost of sight 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 Verification & Validation

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 [6], the principal mostly does not differentiate between the development System Breakdown Structure and the Contract Breakdown Structure. This hinders optimised Verification and Validation 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 industry each contractor is generally specialised in one discipline only, e.g. civil construction, installation, electro-mechanical, etc.. 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, etc.) tend to be scattered throughout all contracts;
2. Contracts are based on a preferred static situation and do not cover scenario’s that affect multiple disciplines;
3. Verification and Validation regarding the end-to-end system performance is completely made a principal’s responsibility.

Rijkswaterstaat, the infrastructure manager for the Dutch water and roadways, has chosen to contract some of its integral systems, based on the Design, Build, Finance & Maintain (DBFM) principle. However, consortia that have won the contract subdivide the contract into the classical, discipline based, parts. Each party covered the activities related to it’s 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 phase. Among other reasons, this has resulted in excessive delays in delivery and in proving compliance of multiple tunnel projects [12].

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 surely 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 be integrated 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’s 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 & characteristics of the integral system and a lack of incentive to create a system architecture).

However, a project like the Millau bridge in Southern-France is an example of a well managed project, where system coherence was a constant factor and where both verification & validation were on the consortium mind throughout all phases of the project. This definitely contributed to the fact that this bridge was delivered in time, within budget and meeting the required quality [7].

Figure 1: Millau bridge, France

Scope of V&V is N^{-1}

To make sure the system works according to specification and the intended use, it needs to be verified and validated. However, V&V needs to be performed not only to the systems itself, but also in interaction with its direct environment (politics, public, users, etc.).

System Context: The V&V effort is often related 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.

Figure 2: Bijlmer station trolley enclosed by support beam.

As an example of the need to consider the project scope N-1, we take a look at the cleaning facility of the Bijlmer railway station [8]. 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 of the cleaning facility for the glass/metal structure of the outer walls. The picture on the right 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 cleaning facility was ignored. Even worse, during integration of the cleaning facility the installer did not check whether the equipment was fit for use, since the trolley can only be moved 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 by other parts of the system.

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

Subjective V&V: a blessing in disguise?

Both ISO-9000 [1] and ISO-15288 [2] define Verification and Validation as activities that take place against well pre-defined requirements and provide objective evidence. However to what extent V&V can be or should 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 to what costs of 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 chooses for 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 then 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 Standis-1994 [9], Lewis-2003 [10] and Ellis-2008 [11] 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 even 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 [5]. Though there are probably many causes why project execution does not improve, one of the reasons is lack of a learning curve. Verification & Validation contributes to closing the loop for the learning curve inside projects.
An example of the potential value of Verification and Validation 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 from 1968, definite plans (2002) indicated a budget of 1,5 billion euro. Start of operation was estimated to take place in 2011. Nowadays after many disappointments, settlement problems with houses, evaluations and political interventions, the costs are increased to 3,1 billion euro and a delivery date in 2017. Complex projects have many reasons to fail. Among the major conclusions in a for failure are several V&V related conclusions [12]:

- 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 check & 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 (e.g. political ambition versus a negative business case)

- early failures (e.g. 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 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 verification & validation of the business case at major milestones
2. Explicit V&V of all stakeholder requirements. Stakeholders have to sign off 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 [13]. In the practice of the Dutch construction sector some anomalies reoccur again and again. More then 50 reviews of specifications in de 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, e.g. Planguage (see also T. Gilb [13]). Once a specification has been finalised, the addition of pass-fail-criteria per requirement improves the V&V-ability of the specification.

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

The figure to the left 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'. Needless to say, this solution surely doesn't fulfil the user's needs.

Craftsmanship

In quite 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 principals 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 type of subjective V&V should be avoided. 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 SOI 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 life cycle. Sometimes certain incentives of these organization's seem to conflict with the incentives to perform V&V. In this section, some insights are shared that cause the inconvenient truth to perform thorough V&V, especially in the infrastructural domain.

V&V is the next phase's problem, again and again

Over decades studies have shown that investing in V&V leads to lower life cycle costs (T. Gilb,[14]), 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 (Barry Boehm,[19]). So how does this reflect on infrastructural projects?

Let us examine a typical large infrastructural project from initial ideas until the first contractor has been hired. The time 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 time 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 the project has been agreed by politics. The project is being investigated and stopped, over and over again, until the project is finally agreed by politics.

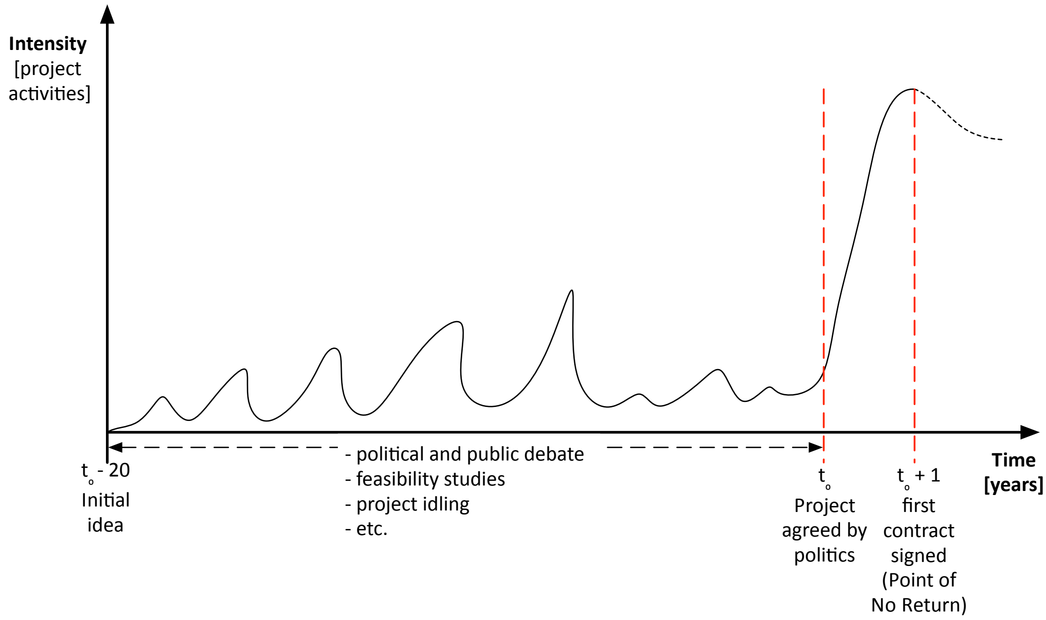

Figure 4: Typical (infrastructure) project intensity of activities as a function of time

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's 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 here defined as the moment where the first (main) contractor has been 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 principals 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's 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 towards the next phases. This is as described by Elich et al for an infrastucture PPP project [15]

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, processes and tools need to be designed[1] and it's clear there's a large risk that faults and many changes 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 time 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, [16]),
  - Dutch Parliament agrees the plan: 1994 (Commissie Infrastructuurproj. [17]).
- The railway tunnel project "Spoorzone Delft".
  - Initial ideas: 1988 (Spoorzone Delft, [18]),
  - Dutch Parliament agrees the plan: 2004 (Spoorzone Delft, [18])
- The Amsterdam underground metro project "The Noord-Zuid Lijn", to create a connection from north to south.
  - Initial ideas: 1968, (Investigation committee Noord/Zuidlijn, [12]).
  - Dutch Parliament agrees the plan: 2002, (Investigation committee Noord/Zuidlijn, [12]).

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 crystal clear,
   c. a system architecture is available and has been verified,
   d. risks are analyzed and acceptable.
3. Using the time period between initial idea and t_0 more efficiently to realize the products as requested in 2.a – 2.d.

European public tender (f)law limits V&V

There is another important reason why V&V is postponed as 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'. But does this policy allow applying of adequate Verification and Validation in early project phases?

The Consolidated Directive on Public Procurement (2004/18/EC) [19] permits a principal to involve contractors in an early project phase by two means:

1. Competitive dialogue (Art 29: *'In the case of particularly complex contracts,*

[1] Due to the lover level of SE maturity in the Dutch construction sector, processes and tooling applied are defined and reinvented for each project.

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 verification & validation purposes in early project phases.

V&V: the penny wise / pound foolish approach in tendering

Let's examine the effects of a principal's strategy in tendering on the quality of V&V that is delivered by the contractors. Despite initiatives from principals to stimulate creativity (Design and Construct contracts), sustainability and life cycle costs (Most Economically Advantageous Tender) and rewarding CO2 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 work has been rewarded, 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 be sold. Developing competitive products leads in general to higher profit margins.

Since in tendering the contract is leading, the contract quality is crucial. Two important aspects that determine the contract quality are discussed here:

1. The quality of the requirements (the specification) in relation to the customer' needs,
2. The quality of the Verification & Validation 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 represents the stakeholder's 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 by reaching the point of no return 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 doesn't have to create a V&V plan in the pre award phase, what can a principal reasonably expect from a contractor's 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, etc. So, if a principal is serious about the value of V&V, the activities need to be made explicit (up to a certain extend) during tendering.

One solution to this problem would be to prescribe V&V procedures in the contract for those requirements which 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 don't 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 extend are principals willing to pay for V&V activities? And 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 life cycle costs and can be used to 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's 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 again. If management only focuses on planning and budget, there's 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. But 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 are dealt with as soon as they pop up.

So it's absolutely essential to make V&V progress explicit in the entire product chain, just like planning and budget, in order to steer on it and to find the balance between time, budget and project result.

Conclusions

Verification & Validation suffer form several inconveniences. Inconveniences arise from a scattered system 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.
- Don't treat V&V as just a means of book keeping
- Clearly identify independent V&V activities by stakeholders, e.g. for the business case.
- Make V&V part of the management reporting and incentives. Link V&V to the payment schedule

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Biography

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.

Erik Elich is an independent consultant in change and engineering management. Apart from the public sector he gathered his knowledge and experience in the electronics, defence, medical, banking, and IT industry. Erik holds a Master of Science in Electrical Engineering (1984, Delft University of Technology). He started with the application of Systems Engineering in 1984 when introducing Just In Time production principles within factory automation. In 1991 he founded Monto and held various project management and consultancy positions, lately within the transportation and civil construction industry.

Erik is fascinated by the "suspense of old and new, between now and endurance ". His device is balance in change.

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 is the Associate Director for Events.