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Introduction

The increasing demand for testing and quality assurance in the railway industry implied by the recent introduction of modern development standards, causes the railway rolling stock designers and manufacturers to seek cost- and time-optimal methods of software verification and validation. From the historical perspective, one of the milestones in this regard was the introduction of the EN 50128 standard. After the standard was published, key railway industry players quickly realized that the verification and validation methods, which had been in common use over the past several decades (like careful manual testing of pre-production rolling stock specimens directly on the test tracks), would not meet the requirements of either the desired testing effectivity level or the project time-frame. Those methods turned out to be simply too time-consuming and too expensive to allow those companies to successfully compete on the railway market which is undergoing a transformation. Taking into account several important factors like: increasing amount of vehicle functions implemented in software rather than hardware, high software reliability requirements, especially on higher software integrity levels (SIL2, SIL4), and increasing costs of performing tests on a real test track – both because of the cost of test track itself and because of the risk of damage – the leading rolling stock manufacturers have begun turning to techniques previously developed within the automotive and/or aerospace industry. One of the testing methods which seemed particularly appealing was the HiL (Hardware-In-the-Loop) , where the physical controller is connected to a simulated plant in the laboratory in the identical way as it is connected to the real plant, allowing the tester to exercise functionalities of the control software even before it is applied in an actual vehicle, thus allowing to find errors quicker and with less effort.

The railway-specific issue with HiL

Although first attempts of adopting a classic HiL solution to a railway vehicle control software development process seemed fairly successful, some industry-specific considerations started to play an important role in the cost and flexibility of the development process. Unlike the automotive industry, where the vehicles are manufactured in large, repeatable series, the railway vehicles are usually built in much smaller batches. This difference is also visible in the overall project budget, and in turn it makes the cost of the HIL solution, and its simulation system in particular, a significant chunk of the overall project's cost. Moreover, such simulation systems present in the market turned out to be not quite as flexible as expected, and also relatively expensive to maintain. As a result, a demand for a different approach, which would fit the specific needs of the rolling stock vehicle development process, has risen among the railway manufacturers.

The solution: not just a HiL System, but a XiL Platform.

As the rolling stock control software development processes evolve to leverage more and more modern techniques, the verification and validation part of the classic V-model also needs to be re-adjusted to include those new measures and to take maximum advantage of the development products in terms of verification and validation as early as possible.

Since a standard HiL system turned out not to be quite up to that task, Tritem turned to another concept used previously within automotive control software development: a platform capable of testing the product of software development at whatever stage the software is, even before it is actually written or generated and exists only in form of a model. This is often referred to as: XiL.

The letter "X" in the term "XiL" indicates a "variable parameter" which can be set to either M – for Model, S – for Software or H - for Hardware -in-the-loop. Let's take a look at what are they about:

a_Model in the loop (MiL)

It has become quite common for complex control software developers to first model the behavior of the software, and then generate the code out of such model, or manually write the code that reflects the functionality of the model. A good example of a tool often used for this purpose is MATLAB Simulink.
Putting this kind of a model in a testing loop together with the plant simulation at such an early stage provides benefits for both the developers and testers. The developers get to know how the software performs against test cases derived from the actual requirements. Software testers can start working on their test cases very early, and they can discover and fix any potential misconceptions in the system design specification or requirements engineering and address them accordingly.

The sooner this kind of issues are clarified and cleaned up, the more beneficial it is for all the parties involved in the development process, and the less compromised the project timeline is.

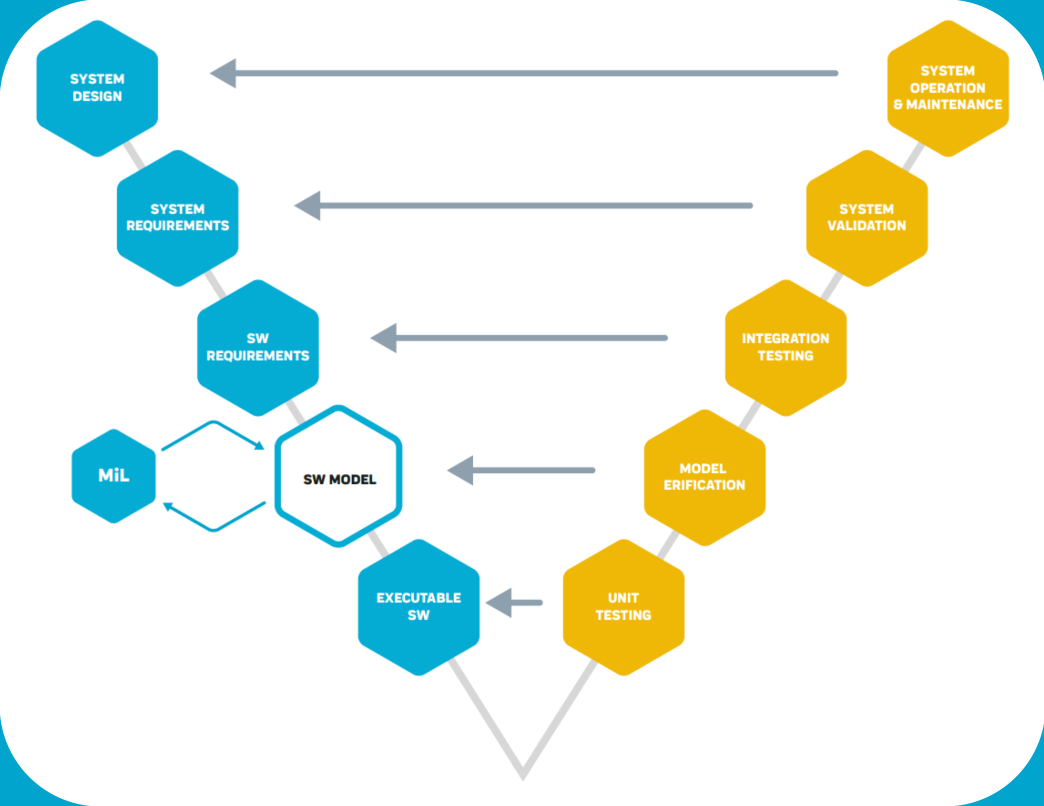

Fig. 1 Model in the loop in the context of the V-model

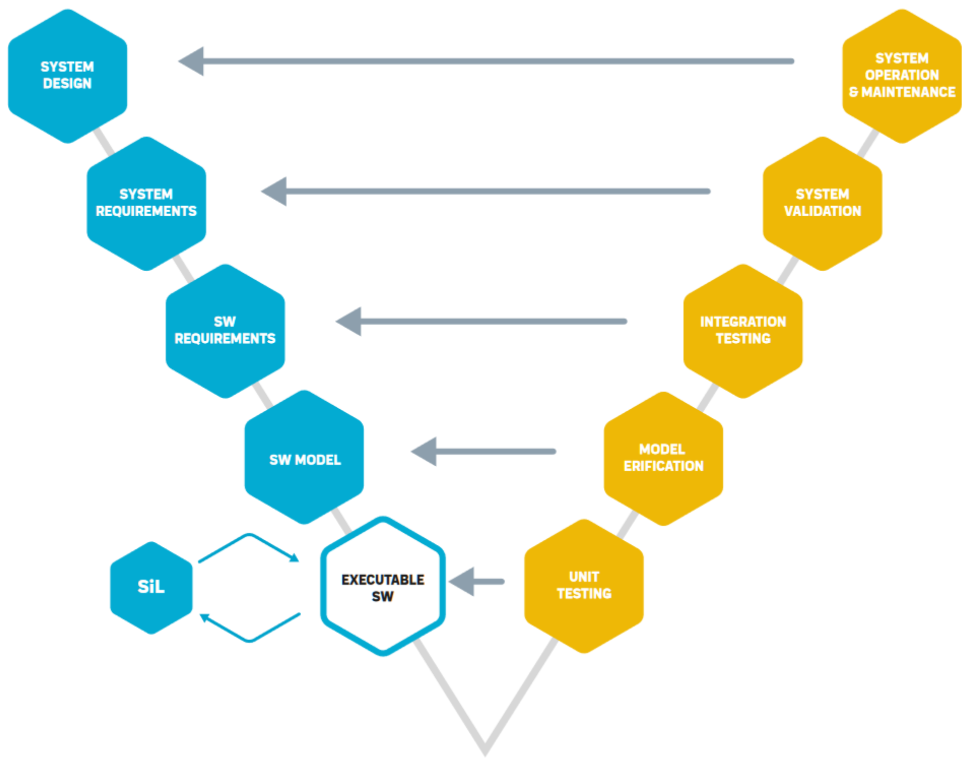

Fig. 2 *Software in the loop in the context of the V-model*

b_Software in the loop (SiL)

The executable software is sometimes written or generated even before the hardware which it is supposed to run on actually exists, or there is a shortage thereof. In such situations, the software can be run in an emulated environment.

In the SiL set-up, such an emulated environment becomes a part of the automated testing system. Emulating the controller usually means that the hardware communication layers (like BUSes and direct I/Os) can be replaced by higher software layers of abstraction, thus making the simulation coupled closer to the control software, and runnable on a standard piece of PC hardware. This in turn makes it much easier to debug, and allows the simulation to be developed substantially quicker.

c_Hardware in the loop (HiL)

A HiL System is used when the control software and the hardware it runs on are both already in place. Such a HiL system can consist, in its simplest form, of a sole hardware controller operating in a simulated environment. However, there often is a good reason to include additional hardware components like bus gateways, power supplies, I/Os etc, or even complete physical parts of the target system. In case of the railway domain it is not uncommon to include real radio or real ETCS components in the HiL set-up, but it depends on the actual scope of testing to be performed.

All those three set-ups have one important thing in common and that is: the simulated plant. A truly flexible XiL has to be able to morph from SiL through MiL to HiL without the need for changing the simulated plant in any significant way.

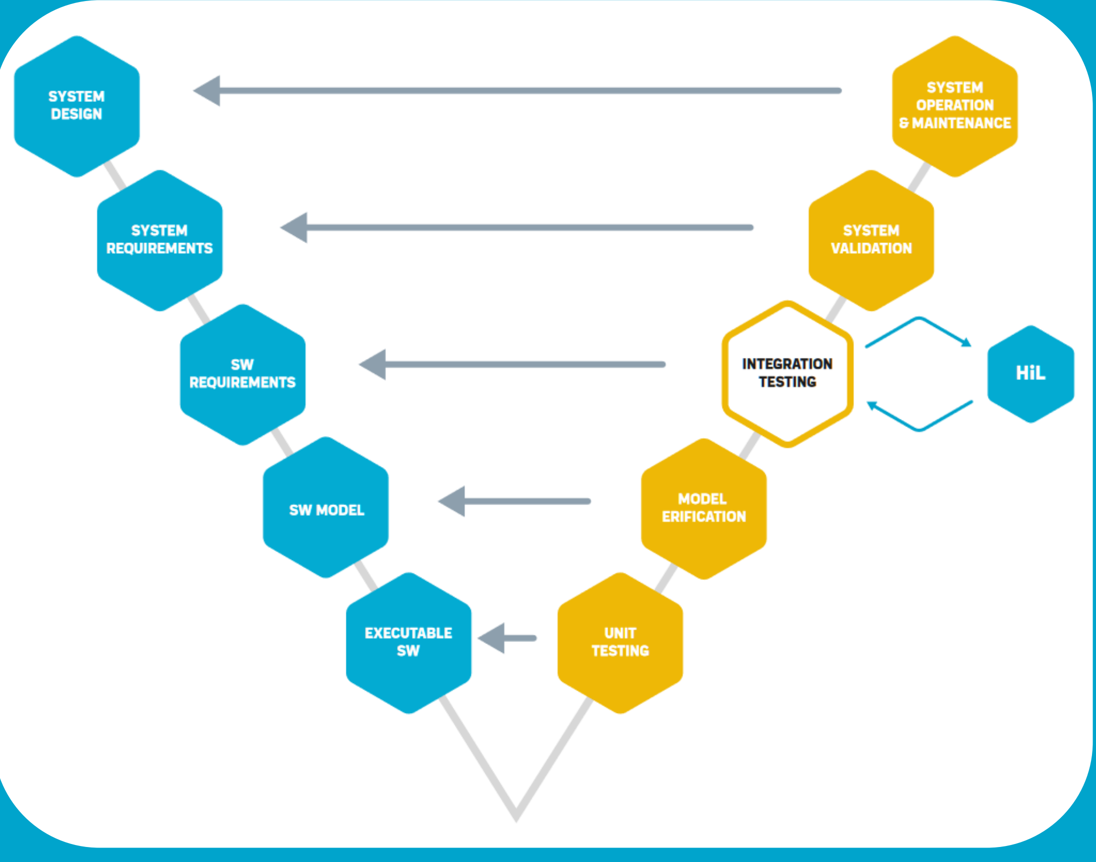

Fig. 3 Hardware in the loop in the context of the V-model

Tri-XiL – The XiL platform with one-of-a-kind simulation engine

The Tri-XiL platform emerged as a result of Tritem's years of experience in providing its customers with HiL-like systems and supporting them with problems related to their application on a daily basis. It comes in three different trims, but the general principle can be described with a following graph:

Three core elements of the Tri-XiL platform are: the simulation, the test framework and platform management facilities.

Tri-XiL is based on Tritem's unique simulation engine called ELMo, which reflects just as much of the system as is necessary to test effectively, but not more. At the same time, ELMo is able to automatically reconfigure itself in response to changes in the system being developed which happen over the course of time.

If any sort of the input data changes, the ELMo Simulation reconfigures itself to reflect the current state of the simulated plant for the Tri-XiL platform.

When necessary, ELMo's simulation can run in Real Time, but the engine is efficient enough to be successfully deployed to and used on a standard Windows PC.

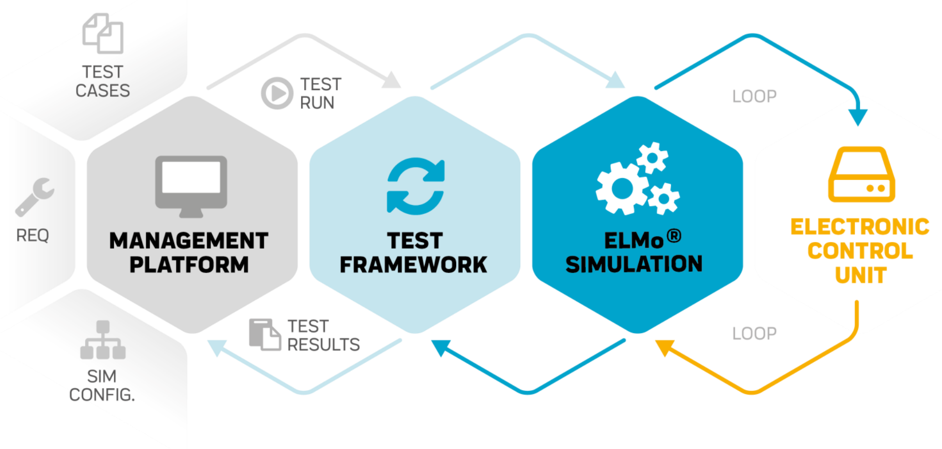

Fig. 4 Tri-XiL platform at a glance in HiL flavour

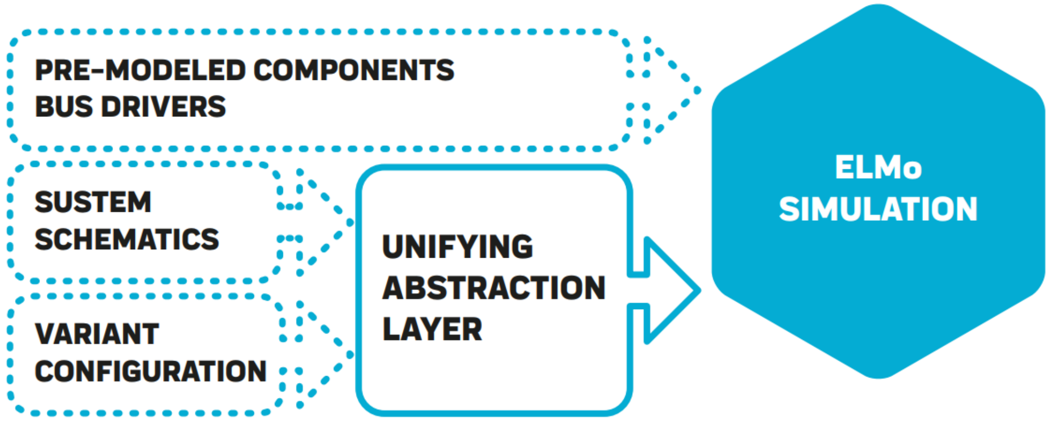

Fig. 5 ELMo Simulation with input data

As the technology advances and companies become more inclined to start introducing novel solutions for their product development (like IoT or Industry 4.0), ELMo is able to demonstrate its flexibility once again: not only is it a foundation for the Tri-XiL platform (covering MiL, SiL and HiL scenarios described above), but it is also capable of being used as a backbone of a Digital Twin, which, when paired with third-party cloud-based solutions, opens up a whole set of new possibilities for the companies that have already invested in Tritem's technologies. Once again this turns out for them to be money very well spent.

Summary

Domain-specific considerations play a significant role in the applicability of techniques widely considered as appropriate for solving the problems which at first glance appear to be common to a couple of different branches of technology. When faced with a challenge of adopting an existing technique or measure to their environment, many companies just accept the overly high costs of those solutions and the fact that the system they have now will not be of much use in a near future – when a vendor of a certain subsystem changes or when a new variant is ordered.

Thankfully it does not always have to be the case: with a XiL-type solution built on a firm foundation of a truly flexible simulation engine (ELMo), such as the Tritem's Tri -XiL platform, companies can make sure that those money are well spent, and that in the long run they can treat it rather as an investment than a particular project's cost.

Over the years of successful cooperation with some of the biggest players in the world railway industry market, Tritem has proven that its verification and validation platform is worth the investment, and that it can return itself many times while being a solid foundation for the incoming projects.

NI TECHNOLOGY

The Tri-XiL platform is built basing on solutions provided by National Instruments, including LabVIEW and NI Veristand. This gives Tritem a firm and stable technological backup, and to its customers it means confidence in the quality of the solutions and a guaranteed worldwide access to technical support. In 2018, Tritem has been awarded the "LabVIEW center of excellence" title by NI.

Michał Krześlak
Testing Group Leader

A graduate of the Silesian University of Technology in Gliwice, Faculty of Automation and Robotics. He also holds a Ph.D. in biocybernetics.

At Tritem, the competence center for Tritem company, he manages a team of specialists dealing with software testing engineering as well as with R & D of methods and techniques connected with this field. As he emphasizes himself, the specialists in his team can be called triathlonists: they are programmers, first users and of course testers.

Piotr Łuczak
Software Team Leader

A graduate of the Silesian University of Technology in Gliwice with the specialization in Computer Control Systems.

At Tritem, the competence center for Tritem company, he manages the team responsible for software engineering, controller programming and integration of the company platform with systems used by clients..

Jerzy Kocerka
Simulation Group Leader

A graduate of the Warsaw University of Technology; passionately keen on NI LabVIEW system-design software and National Instruments technology.

At Tritem, the competence center for Tritem company, he manages a team of technicians who develop Hardware-In-the-Loop systems, simulations and software used to support testing processes.