V&V Assessment Package Instantiation in ICT-based Manufacturing
Experiences from Ten Industrial Use Cases

Outi KETTUNEN[1], Kim JANSSON[1], Iris KARVONEN[1], Stefano PERINI[2],
Giacomo TAVOLA[2], Chiara GALBUSERA[2], Marco TAISCH[2]

[1]*VTT Technical Research Centre of Finland, B.O. Box 1000, VTT, 02044, Finland*
Tel: +358 40 7601843, Fax: +358 20 7227604, Email: outi.kettunen@vtt.fi
[2]*Politecnico di Milano - Department of Management, Economics and Industrial*
Engineering, via R. Lambruschini, 4/b, Milan, 20156, Italy
Tel: +390223994080, Email: stefano.perini@polimi.it

Abstract: This paper describes the instantiation process of a Verification & Validation (V&V) method developed for evaluating the implementation of Future Internet components in a multi-sectorial environment. ICT systems represent a key competitive factor for enterprises, and new application development paradigms are emerging with e.g. a modular approach based on standard, open and cloud-based components. The utilization of modules coming from different sources emphasizes the need for a sound V&V approach in order to ensure that the final solution is of quality, accords to the existing standard and at the same time addresses the original business needs. The proposed approach is based on a standard V&V methodology characterized by a structured assessment of the software quality at different levels and a reduced set of business indicators able to evaluate the business impact of the integrated solution; all of these are deployed via a configurable V&V Package based on a web interface. At the end of the paper the practical experiences and lessons learned from our work are also described.

1. Introduction

Manufacturing industry is characterized by emerging trends such as increasing production system complexity and the need for continuous improvement and innovation of products and processes. For this reason, internet technologies are gaining increasing importance as the main enablers to adapt processes according to these phenomena. In order to enable Factories of the Future, new smart solutions in the field of ICT are required.

In particular, this paper focuses on the area of Verification and Validation (V&V) of software solutions in industrial environments, developed using modular and open source software components, shared on a common platform. The main purpose of these components is to allow European factories to increase their business process effectiveness by enabling and accelerating the use of Future Internet technologies in facing emerging needs. For these reasons, the main aim of this work is to describe the process of development and especially deployment of a generic V&V assessment package proposed so as to perform the activities of V&V, and its implementation in ten use case trials in the ICT-based manufacturing domain.

2. Objectives

There has hitherto been no process to define a simple and user-friendly method and a set of tools to perform assessment of V&V activities in a complex multi-sectorial environment. Therefore, the goal of this paper is to describe the definition and instantiation of the V&V

Assessment Package, the evaluation of the quality of the software components and of the whole integrated solution from a technical perspective, as well as the definition of the impact from a business perspective. The work has entailed the creation of a simple yet reliable V&V method in a multi-sectorial environment implementing future internet components, and the creation of a process for instantiating the method into the trials in an efficient way. First results and users experiences have been then collected and described.

3. FITMAN Project – the Framework of the Study

The study has been performed within an EU-project FITMAN [1]. FITMAN has 36 partners from industry, research and universities. It aims to provide the FI PPP programme [2,3,4,5] with ten industry-led use case trials in several manufacturing sectors, which all are included also in the work of this paper: automotive / PLM ramp-up for reduced time to market and safe & healthy workplace; aeronautics / training services for blue collar workers; white goods / mobile workforce; furniture / mass customised production; textile/clothing / cloud manufacturing; LED lighting / collaborative production; plastic / collaboration valorisation; construction / as-designed vs. as-built interoperability; and manufacturing assets management: networked business innovation. In particular, the purpose of FITMAN is to test and assess the suitability, openness and flexibility of FI-WARE [4] Generic Enablers (GE) FI components designed for EU manufacturing industries. FITMAN is also developing its own set of software assets, specific enables (SE).

4. Methodology

4.1 Development Process of V&V Assessment Package

The development of a generic V&V Assessment Package is achieved through a process of three main phases: defining and identifying the methodology, customizing it according to the actual operational environment and then defining the most appropriate techniques to collect the results of the assessment. In greater detail, defining the methodology means clarifying the main steps that have to be followed in the assessment procedure. Due to the complexity of the solution and the different purposes of the evaluation, the different steps can be focused on different units of analysis: for example, the code testing has to be carried out at software component level and, on the other hand, the business impact has to consider the whole solution. The deployment activity implies the definition and set-up of technological tools used to perform each methodological step through the selected technique, that is defining the stakeholders, scheduling the assessment in each use case and the possible temporal evolution of the assessment system, and providing a training section to support them in the V&V process and in the use of the developed tool kit.

4.2 FITMAN V&V Methodology Overview

The developed FITMAN Verification & Validation (V&V) methodology introduces an innovative means of performing V&V activities in various ways by:
- Bringing together and getting the best out of agile software engineering philosophies.
- Infusing a crowd assessment mentality within the V&V activities, under each methodological step from code verification to business validation.
- Balancing and bridging the business and technical perspectives in an effort to assess the software and the "fit for purpose" requirements and evaluate the added value of the overall software.
   The background methods provided as inputs to the FITMAN V&V process are represented by two main concepts, 1) the FITMAN V&V methodology [6,7,8,9,10] and 2)

the simplified ECOGRAI methodology [11,12,13,14,15,16]. The former defines a general logical procedure for verification and validation, while the latter provides a model to identify and measure the business performances of a given system.

5. V&V Assessment Package

The V&V methodology and the measuring system described have been integrated into a unique framework managed by a set of technological tools needed for the collection of data and its subsequent elaboration and assessment. However, both the V&V methodology and the measuring system should be considered to be the underlying elements of a general approach, of which the set up will be described in detail. Hence the V&V Assessment Package definition will be first addressed and then its instantiation will be presented.

5.1 V&V Assessment Package Definition

The definition of the V&V assessment package [17] follows three main phases, as depicted in Fig.1:
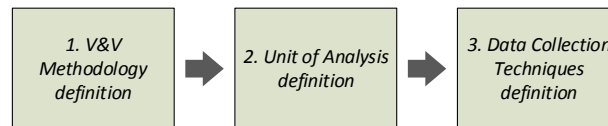

Figure 1 V&V Assessment Package Definition Process

The first phase is represented by the definition of the proper V&V methodology, which identifies in detail the steps needed for the verification and validation process. The second phase implies the definition of the units of analysis, i.e. the objects to be considered for each of the steps previously identified. For instance, a unit of analysis could be a single software component rather than the whole integrated solution (Fig.2):
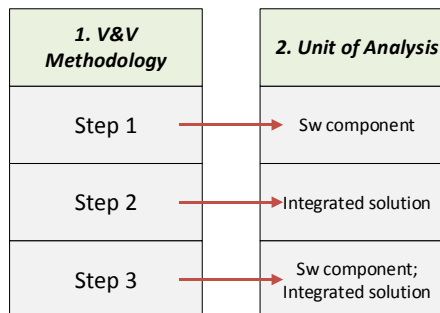

Figure 2 Example of V&V Unit of Analysis definition

The third and last phase aims at defining the data collection techniques to be associated with each step and each unit of analysis. The potential data collection techniques could be several (e.g. code verification tests, performance indicators). Hence the choice mainly depends on how consistently the data can be associated with the specific unit of analysis:
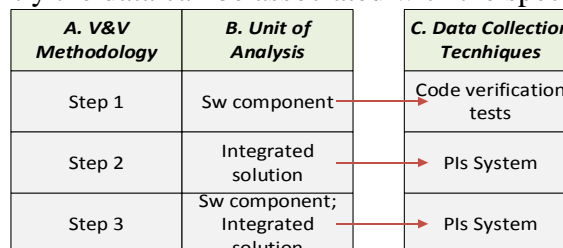

Figure 3 Example of V&V Data Collection Techniques definition

This three-phase process allows the final definition of the conceptual framework including all the methods for data to be collected. This result represents the first part of the

V&V assessment package, called the data collection section. A further area, i.e. the communication section, will be then used as a support in terms of information and instructions needed to drive the use of the techniques and technological tools defined. The resulting V&V assessment package framework is depicted in fig.4 below:
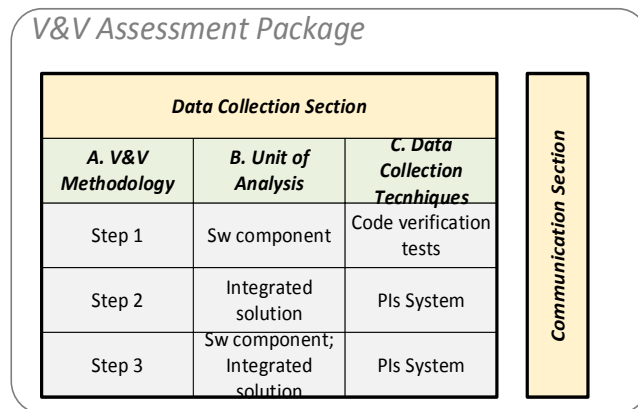

Figure 4 V&V Assessment Package framework

5.2 V&V Assessment Package Instantiation

After the definition of the V&V assessment package framework, instantiation [18] should be performed. Within FITMAN, instantiation has meant specifying and adapting the generic V&V assessment package for each of the ten trials, starting from the previously mentioned FITMAN V&V methodology and FITMAN V&V measuring system. Therefore, each trial has defined the final objectives of V&V assessment, selected the business performance indicators to be evaluated, selected the people to be involved in the assessment, and identified the proper sources of data for the indicators. As a result of the instantiation, the FITMAN V&V assessment package can be presented as composed of three different scopes (Fig. 5):

- Business performance indicators system, specific to each trial, assessed by the end users, through "as-is", "to-be" and target values; they refer to the step T2 of the FITMAN V&V methodology.
- Two groups of technical indicators, i.e. five indicators for the whole trial solution, implemented as community-based collection of users' opinions, and three Indicators for the software components, implemented as evaluation through a scale of different values; they refer to the P5-T1 steps of the FITMAN V&V methodology.
- V&V tests: after the development of SEs and TSCs (trial specific components), each of them tested by the software development partner; it is allowed to use its own methods, reporting results through a self-certification mechanism; they refer to the P1-P5 steps of the FITMAN V&V methodology.
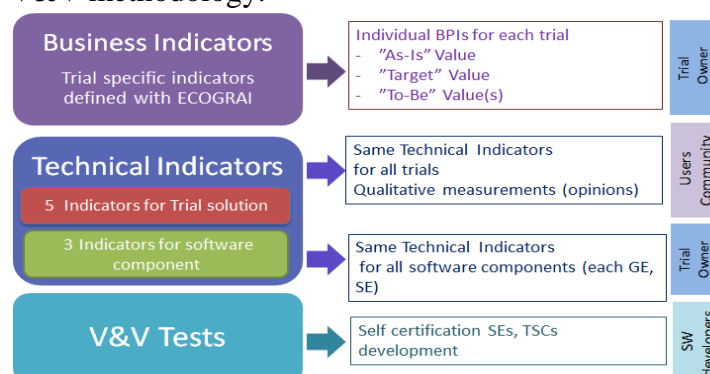

Figure 5 FITMAN V&V Assessment Package overview

Within FITMAN, it has been decided to implement all the data collection techniques of the V&V assessment package by means of a web-based system able to integrate different types of forms according to their functions. The choice of a web-based system has been made mainly because of its high scalability, modularity, level of automation and ease of use. In particular, SurveyMonkey software has been selected for the implementation [19]. The final result has been the definition of a set of web-based forms organized in three main macro-areas according to whom it is addressed; in particular: General Forms, Community-based Forms and Self-Certification Forms, represented in Fig.6 and described below.
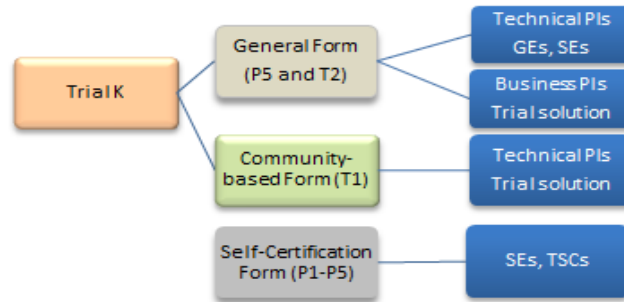

Figure 6 FITMAN V&V Assessment Package – Data Collection Forms

General Form is addressed to the trial owner who is responsible for completing it; it includes:

- Technical indicators forms (step P5 of the FITMAN V&V methodology) (Fig.7) that are related to each software component (i.e. GEs, SEs), where the indicators are replicated for each form and the value assignment can be carried out within a scale of different levels;

Figure 7 Example of Technical Indicators Form

- Business indicators forms (step T2 of the FITMAN V&V methodology) (Fig.8) that are related to the whole trial solution. Business indicators are closely linked to the objectives of the trial itself. TO-BE and target values are expressed as the percentage (i.e. ratio) which represents the increment/reduction of the related current value. This choice has been made in order to allow trials to by-pass the confidentiality issues faced during data collection:

Figure 8 Example of Business Indicators Form

Community-based Form (Step T1 of the FITMAN V&V methodology) requires crowd engagement because it aims to collect the "community-based" assessment, e.g. opinions and subjective perceptions in using the solution; therefore, it has to be completed by all the users of the trial team. The unit of analysis is the whole integrated solution and the value is assigned within a scale of four level of agreement according to a given statement:

Figure 9 Example of Community-based Form

Self-certification Form (Steps P1-P5 of the FITMAN V&V methodology) is designed for the software component developers, because it aims at assessing the results of the specific V&V tests applied to each of them during their development. The self-certification process, unlike the previous ones, is specifically designed for each software component (i.e. SEs, TSCs) independently of the different trials in which they have subsequently been implemented:

Figure 10 Example of Self-Certification Form

Finally, the FITMAN Communication Section of the V&V assessment package has been implemented in practice on the FITMAN website. The information has been organized in four main areas, as depicted in Fig.11 below:
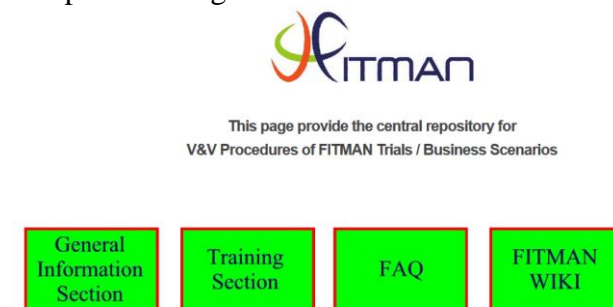

Figure 11 FITMAN V&V Assessment Package – Communication Section

In order to simplify the future consolidation and elaboration of the outcomes of the different technical indicators and V&V tests, a univocal codification has been developed. This system will enable the automatic identification of the measures and the consequent analysis of the results. On the other hand, the business indicators are specific to each trial. Therefore, only clustering activities according to the four categories, productivity, lead time, cost and quality, will be performed.

5.3 V&V Assessment Package Instantiation Experiences

The instantiation of the V&V Assessment Package into the trials was as a whole an interactive and iterative process. During the process we encountered some challenges, which are described in the following table:

Table 1:

The challenges	Addressing the challenges
Timing issues. The trials have their own schedules, and the timing of instantiating and performing the V&V has to be defined separately for each trial.	The simplified ECOGRAI method takes the different timing needs into account by supporting the definition of timing for the measurement of *to be-values* for business indicators.
There is a large variety of different use cases in a multi-sectorial environment, and yet they need to be assessed with the same method. The method also needs to enable cross-trial assessment at the end of the project.	The technical assessment was aligned down to just a few indicators which apply to every use case. In this way, cross-trial assessment will also be possible. Concerning the business indicators, the differences of the trials were accepted, and the business indicators are all trial-specific and derived from the objectives of the trials.
Lack of time in the trials, as they are busy with the actual work setting up and running the trials.	Using the V&V method was made as easy as possible. Key issues were: simplifying the method, efficient communication and support.
Confidentiality requirements	In general, numerical values were encouraged. In cases where the confidentiality was essential, values were given in percentages.

We were able to collect feedback from the trials in face-to-face discussions in the instantiation phase, in general meetings of FITMAN, in training sessions and in conference calls. In addition, the trials will complete a trial journal where they have the opportunity to write down their experiences and observations concerning the V&V. In general, we received positive feedback concerning the training events and guidance in using the FITMAN V&V method. In the instantiation process, close interaction with the trials was essential, as well as face to face possibilities for the trials to bring their issues into discussion. We learned that the method has to be quite simple in order for the trials to adopt it properly.

6. Results and Business Benefits

In this work we have created an efficient, flexible and easy to use V&V method for assessing deployment of Future Internet tools in various use cases in smart, digital and virtual trials. We created a process for defining the V&V, and a process for instantiating the V&V into the trials. We also collected valuable experiences on the instantiation process. The experiences include both our own observations and feedback from the trials. The benefits of this work are three-fold. European industry and the IT sector can utilize the method developed; EU projects can adopt the method for future projects in order to obtain valuable data on the project impacts; and third, the research community has gone one step further in defining a process for instantiating a V&V method suitable for a multi-sectorial environment. We will pay particular attention for dissemination in order to be able to

capture full potential of utilization of the method, including the instantiation phase, outside the project.

7. Conclusions and Next Steps

The characteristics surrounding the work of developing and instantiating the V&V method described in this paper expose the success of the work for some specific risks. These characteristics include the facts that the work is part of an EU project with an exceptionally short timeframe and large amount of partners, as well as the multi-sectorial nature of the trials. The identified risks for the success of the work are:

- The timing differences between the trials set challenges for the organization of assessment as well as for cross trial assessment during the project.
- The tight schedule of the project sets challenges for successful instantiation and proper use of the method in the trials, due to e.g. lack of time of people working in the trials.
- The developed V&V method can be seen as too difficult to use by the trials. Yet the method had to be able to cover several different aspects due to differences in the trials.
- On the other hand, due to the need of simplifying the method and the assessment package, there is a risk of it being too generic for all different purposes.
- Risk of failing to define proper business indicators in trials.
- Risk of cutting down the selection of technical indicators too much, so that they might not the most appropriate for all trials.

After the development and the deployment of the FITMAN V&V Assessment Package, some key findings and critical issues have been highlighted. These also help to minimize the risks mentioned above. Our key findings and critical issues are:

a) In order to apply a V&V method in ten heterogeneous trials it is important to ensure that the trial groups clearly understand what is needed, and which stakeholder/role is responsible for which task. To support this, six V&V training events for the trials were organized, including hands-on training.
b) The simplified ECOGRAI process for business indicators definition has to be carried out in close interaction with the trials.
c) "Background noise" has to be considered in collecting and evaluating results. We define "background noise" as variation in the operational performance of the analysed process, independent of the solution implementation.
d) The time dimension (frequency, intervals) of the assessment is an important aspect to consider, as the definition of the measurement frequency is a fundamental aspect in terms of significance.
e) Identifying the approach used to aggregate the results reported is fundamental and strongly affects the definition of the target value that the company wants to achieve.
f) The method has to be simple in order to be adopted properly by the trials.

The paper aimed at providing the process of development and deployment of a generic V&V Assessment Package, and at describing the implementation and validation of it into a set of use case trials in the context of an EU Project. First results from the implementation of the package have been collected, but the assessment is still ongoing; therefore, the next step is to collect more user experiences, consolidate them and benchmark (where possible) the different trial results. After this, the FITMAN V&V method will be updated.

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