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Integration of agility in a MBSE methodology for multidisciplinary systems design

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Abstract—The multidisciplinary collaboration can be efficiently supported by the Model-Based Systems Engineering (MBSE) approach. However, even if the MBSE approach presents a brilliant method of development of complete architectures, this approach does not avoid system defects during or after the development process. In this paper, we describe the benefits to integrate agile methods into MBSE approaches and we propose in particular to introduce the Agile Scrum method in a MBSE design methodology for multidisciplinary systems.

Keywords—Multidisciplinary design, Agile, Scrum, Systems Engineering, MBSE approach.

I. INTRODUCTION

Current traditional design processes need to adapt to new challenges. Indeed, due to the rapid evolution of technology and the corresponding complexity of systems, current industry, especially in the field of mechatronics, needs to design and develop ever more innovative products while reducing time-to-market, in order to keep a competitive advantage. Yet, fully specifying a multidisciplinary system from the beginning is hardly ever possible, as users'/customers' requirements frequently change before the design/concept is sufficiently advanced (i.e. until a first prototype is done). As late changes during the embodiment and detailed design phases cause a dramatic increase of design costs and time, these changes require more flexibility during the design process.

Another issue concerns the limitations of written communication, as this mode of communication does not offer direct interactions to verify that messages being carried between interactors are understood. Finally, in traditional cascading projects, the specifications related actors may be numerous and various (i.e. the customers' specification writer, the general functional specifications writer, the detailed functional specifications writer, the developer, testing team, etc.). On long projects with high turnover, it can even happen that these

different actors never meet. How to guarantee a good design covering the set of needs in these cases?

A new design approach that seems more appropriate and has already proved its success in the design of software systems is called the agile approach. It aims at limiting the rigidity of the specifications, interfaces and organization and at involving the various stakeholders, customers, specifiers, partners in a more flexible way. In particular, the Scrum method has become the most used method because of its adaptability and reliability. Indeed, contrary to traditional methods, agile methods are compatible with the continuous evolution of needs requested by current companies.

Focusing on the multidisciplinary system design process, the traditional design cycles models (such as the waterfall model [1], the spiral model [2] or the V-cycle model [3]) can support the design process at a very macroscopic level, but do not support either the usual collaboration required between different designers from different disciplines, nor the multi-domain integration, such as hardware-software integration [4]. Then, the agile methods could be a suitable means to address previous issues thanks to their main benefits: the lead time between two deliverables is fixed and unchangeable; the high frequency of iterations leading to deliveries allows a reduction in "time to market" while improving the quality of the product delivered; finally, the waste minimization by iterative and incremental work allows the development teams to faster reach significant productivity levels.

In this paper, we propose to study how agile methods (and notably the Scrum one) can be integrated in system engineering (SE) approach, and particularly in a MBSE design methodology for multidisciplinary systems. The paper is organized as follows. Section 2 presents the state of the art regarding the agile Scrum method and the agile methods adoption for multidisciplinary systems design. Section 3 describes our proposal in which we

propose to introduce the Scrum agile method in a MBSE design methodology. Finally, the section 4 summarizes our proposal and presents future work.

II. STATE OF THE ART

A. The Agile Scrum method

Agile approaches are a set of iterative and incremental software development practices, based on short development cycles, to quickly design solutions that are valuable to the customer [5]. In fact, the first agile approach, named Iterative Development Project Management approach dates back to 1986. Then, the Scrum method is currently the most widely used, documented and proven current agile method since its first implementation in 1993, with 52% of cases in user organizations [6]. Takeuchi and Nonaka, as developers of the Scrum method, claim that flexibility is one of the most important factors in the development process, and they underline the importance for the development team to work as one unit towards a common goal [7].

Scrum is in many ways different from traditional project management approaches, where people try to have all information needed for design right from the start and minimize any later changes. The Scrum method (Fig. 1.) is composed of three main roles: the *Product Owner* (PO), the *Scrum Master* (SM) and the *development team*. In this method the PO defines the *Product Backlog* which is a list of features that corresponds to the list of customer requirements in order of priority. Then the team meets in order to have the *Sprint Planning Meeting* and then define the *Sprint backlog*. The *Sprint backlog* is a list of tasks addressing a subset of the requirements and that the development team must perform during an iteration called *Sprint* (which lasts from one to four weeks). At the end of each sprint, a *Prototype* is achieved; it corresponds to a partial product marketable and is improved after each sprint. When changing requirements or adapting to customer's needs, the method is flexible and adapts to change by updating the product backlog. Finally, as the requirements are progressively handled in order of priority, with regular verification and exchange phases with the client, the Scrum method can generate high quality products while taking into account the changing needs of customers.



Fig. 1. The Scrum method process [8].

Still, even if agile methods and notably the Scrum one have made significant progress in recent years; they can be more complex when applied to hardware systems and especially to multidisciplinary ones.

B. Agile methods for multidisciplinary system design

Although, the concepts of agility have initially been mainly applied to software development projects, some examples in the literature demonstrate the use of agile methods in non-software design projects.

Indeed, Suss asserts that following a development process like Scrum, with intermediate outcomes well-defined and short feedback and review cycles helps to improve coordination and to focus in the development project, leading to reduced iterations and design rework, whatever the product kind [9]. Then, Suss has described in an agile mode a stochastic model executable of the product development process and concludes that an agile approach like Scrum is beneficial for all types of design and product development projects, and is not strictly limited to software development. In the same way, as the agile Scrum software development defines no software-specific activities, Abrahamsson et al. underline that it can be used for any engineering project [10]. Cooke et al. explain how agile software methods have been implemented to support the study of a bicycle stability test bench. By adapting the Scrum method, they describe how to apply a new approach called Scrum-Milestone to a multidisciplinary project, and then demonstrate that it is possible to adapt Scrum to some complex multidisciplinary systems [11].

Another example of agile approach applications addresses the aviation industry, which works on the development of new and revolutionary aircraft concepts. In general, the task of developing new aircraft is risky and extremely complex. Therefore, aircraft manufacturers seek to control this complexity by adopting an evolutionary approach. Glas and Ziemer discuss the use of agile methods for the development of large systems in the aeronautical industry [12]. They describe how to apply the principles of the agile approach to the aircraft development process to better manage process disturbances and product complexity. In the same way, Esposito et al. explain why the agile principles are as usable for the development of the aircraft as for the software development, and claim that the agile development methods are promising instruments to reduce error risks during the development process [13].

Finally, there are few studies about agile methods for engineering and especially in the multidisciplinary context of the mechatronic design and are for now limited to the educational context [14, 15]. As multidisciplinary systems design is suitably supported by SE/MBSE approaches, we propose to couple them with agile methods and notably the most known and used agile method: the Scrum method.

III. OUR PROPOSAL

A. Agile Methods As A Support for System Engineering

Even if SE has been often considered as a one-pass process (like in the V-model) with few iterations, all design steps can be iterative within an integrated systems engineering and development cycle. In line with Turner, who explains how

agility can be successful in many domains and can especially support the systems engineering [16], we propose here to study the benefits of introducing “agility” in SE approach.

Typically in traditional SE approaches, the requirements and architectures may contain significant errors that will be identified too belatedly. Indeed, one of the main failures of projects is that we cannot easily see the defects until the system components are fully integrated. These defects are then identified too late and lead to with very expensive and important delays, as they will require downstream identification, rework, and reverification. This is very time and cost consuming and usually happens at a time when the project should usually be done. Still, an iterative process agile method can avoid these defects and rework.

Agile method can also be very useful for systems engineering and more specifically for the integration,

verification and validation phases (IVV). With an agile method, the integration tests are applied incrementally as the system is being built. This continuous integration of the system elements ensures a progressive evaluation, through the verification and validation (V&V) plan [17], and thus significantly reduces the failure risk before the final integration of the system.

B. Modeling of A Scrum Agile-based MBSE Methodology for Multidisciplinary Design

We propose here to introduce the Scrum agile method in a MBSE design methodology (Fig. 2) for mechatronic systems [18], even if integrating an agile process in a MBSE design methodology to make it more robust and adaptable, can be a challenging task due to the multidisciplinary nature, systems complexity, uncertainties of the conceptual design, and dependencies between the different aspects of the process.

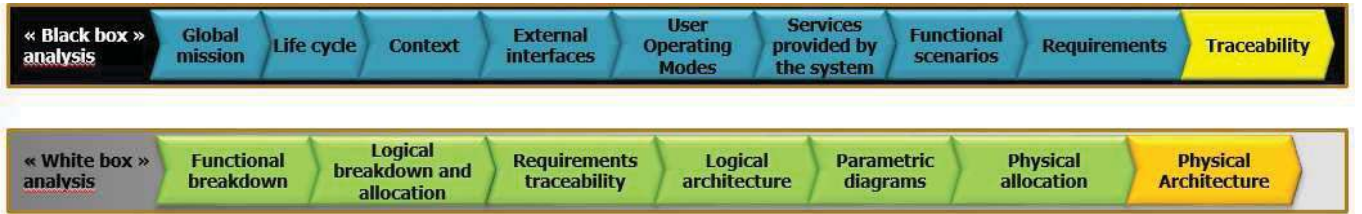


Fig. 2. Initial MBSE design methodology for mechatronic systems[18].

The black box analysis consists in building a complete and coherent set of requirements by exploring all the system viewpoint in line with the customers, in order to limit expensive further requirements changes. This is done through a sequence of steps. First, the main purpose and mission of the system are determined. Then, its life cycle is identified. For each phase of the system lifecycle, the system context, including the interactions between the system and its environment, must be taken into account. Then the external interfaces that support these interactions are defined. The external behavior of the system is described through the user's operating modes, use cases and functional scenarios. Finally, the corresponding requirements are collected during all these steps and traced to the elements of the model, in order to contribute to their identification and rationale.

The white box analysis aims at building a physical architecture of the system; this architecture is gradually identified by starting with a hierarchical model of system functions that is established from the black box analysis. Then, depending on the functional model, logical components are assigned to aggregated functions to synthesize the candidate logical architectures. A logical architecture is based on general classes of components. Finally, alternative physical architectures can be defined by allocating the physical (specific) components to the logical components. Based on some performances simulation evaluations, trade-offs allow to choose the final physical architecture. The validation process is made at the end, by tracing the components to all the derived requirements generated in the black box analysis.

The first modification of this methodology we propose to make it agile (based on the Scrum method), occurs between the

black box analysis and the white box one (Fig. 3). Based on the set of complete and consistent requirements at the end of the black box analysis, which represents the *Product backlog* list of the Scrum method, a subset of these derived requirements which are the most critical is chosen (defining the *Sprint backlog*). Then a *sprint*, in the Scrum mode, is launched by performing the white box analysis in a well-defined iteration in duration, with tasks distributed to the multidisciplinary team, in order to have at the end a part of the final physical architecture that corresponds to this subset of requirements.

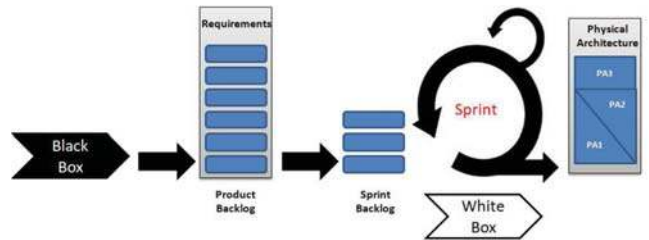


Fig. 3. The Scrum method process in MBSE Methodology

A new step added to the initial methodology is the physical prototype realization at the end of each sprint. The verification of the partial system *prototype* can be done through the evaluation of the components traceability to the derived requirements selected, and notably regarding the components interface specifications. Then it can also be partially validated in accordance with the corresponding customers' needs (based on the related use cases and functional scenarios). This first V&V (also named the “Review” step in the Scrum method) allows avoiding unexpected integration defects. At this stage,

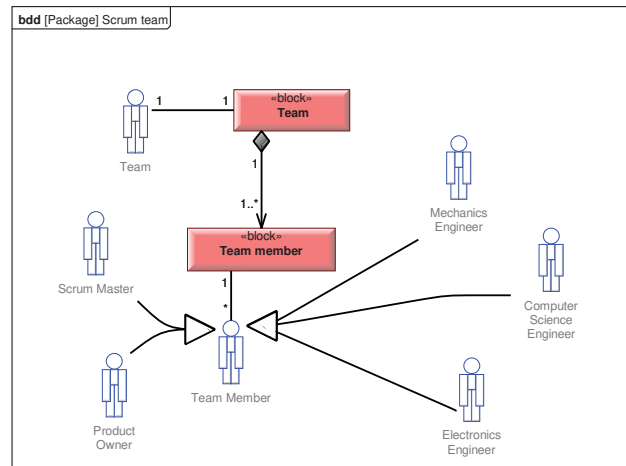
The choice of some components for this first prototype architecture can generate new “induced requirements”, which have to be added to the requirements specification. These new requirements generated at the end of a sprint are in line with the Scrum method, which updates the backlog, based on customers’ changes but also on the feedbacks of previous sprints. Then, based on this updated “*Product backlog*”, a second set of requirements can be selected to be addressed in another sprint. A particular attention, if applicable, has to be paid on the integration step of the new generated prototypes, as they have to fulfill induced interface requirements imposed by previous developments.

The diagram illustrates the relationship between Black Box and White Box testing in the context of requirements and traceability. It features two main horizontal components: a top 'Black Box' section and a bottom 'White Box' section.

The **Black Box** section is represented by a large black arrow pointing to the right. Inside this arrow, the text 'Requirements (Product Back log)' is centered, and 'Traceability' is written towards the right end. Above the Black Box, the text 'New requirements' has a blue arrow pointing down into the start of the Black Box arrow. Below the Black Box, the text 'V&V' has a blue arrow pointing up into the start of the Black Box arrow. A blue arrow also points down from the center of the Black Box arrow to the top of the White Box arrow.

The **White Box** section is represented by a large white arrow pointing to the right, located below the Black Box arrow. The text 'White Box' is centered below this arrow.

Another adaptation brought by the Scrum method addresses the organizational aspect of the designers' team. Indeed, the Scrum method requires formalizing a multidisciplinary team to cover the multi-domain field of mechatronic design (Fig. 5). This also supposes to take into account the skills and knowledge of each one. These two aspects were not considered in the initial methodology, but such human factors are critical in the success of the design process and then have to be now dealt with.



C. Discussions

At the architecture level, the Scrum method provides the expected suitable architecture, thanks to an incrementally development. Indeed, at the end of each iteration (sprint), a partial physical architecture is delivered, verified and validated. Thus in contrast to a classical design method, this progressive process limits the integration issues between the partial architectures and ensures the development continuity of the final architecture, while avoiding the accumulation of defects and then improving the quality of the final product.

IV. CONCLUSIONS AND FUTURE WORK

In this paper, the Scrum agile method is discussed and adapted to be integrated in a MBSE methodology for mechatronic design. We have presented how agility can be useful in MBSE approaches and notably thanks to its iterative and collaborative aspects. Its introduction in a MBSE

methodology for multidisciplinary design can then have significant gains in time and cost.

Although this new MBSE design methodology integrating the Scrum method seems applicable to support multidisciplinary system design and to make it more efficient, it has to be validated on various mechatronic designs case studies, since for each project, each team can evolve in a different context. Then, our future work will first address the validation of this agile method for the design of different mechatronic systems from different sectors. Secondly, this preliminary work on the Scrum method will be followed by the analysis and comparison of other agile methods, before to propose new customized agile design methods adapted to different mechatronic design contexts. Finally, another future work will be to study how to capitalize effective design changes during these agile-enhanced MBSE design processes.

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REFERENCES

- [1] Royce, W.W., 1970, Managing the development of large software systems, in: Proceedings of IEEE Western Electronic Show and Convention (WesCon), Los Angeles, (USA), pp. 1–9.
- [2] Boehm, B.W., 1988, 'A spiral model of software development and enhancement', Computer, 21 (5), 61–72.
- [3] Forsberg, K., Mooz, H., 1992, 'The relationship of system engineering to the project cycle', Engineering Management Journal 4 (3), 36–43.
- [4] Bricogne-Cuignières, M., 2015, 'Méthode Agile pour la conception collaborative multidisciplinaire de systèmes intégrés: application à la Mécatronique', PhD thesis, University of Technology of Compiègne.
- [5] Proulx, J-F and Robert, J-M., 2010, 'Intégrer une approche de conception centrée utilisateur à une approche agile de développement logiciel', Proceedings of the 22nd Conference on Interaction Homme-Machine, 125-128.
- [6] Sverrisdottir, H. S., Ingason, H. T., Jonasson, H. I., 2014, 'The role of the product owner in scrum-comparison between theory and practices', Procedia-Social and Behavioral Sciences, Elsevier, 119, 257-267.
- [7] Takeuchi, H. and Nonaka, I., 1986, 'The new new product development game', Harvard Business Review, 64(1), 137–146.
- [8] Coursedroid. (2018). *Agile development methodology for BI Applications*. [online] Available at: [1] <http://coursedroid.com/agile-development-methodology-for-bi-applications/> [Accessed 21 May 2018].
- [9] Suss, S., 2011, 'Coordination in complex product development', PhD thesis, McGill University Canada.
- [10] Abrahamsson, P., Salo, O., Ronkainen, J. & Warsta, J., 2002, *Agile software development methods: Review and analysis*, VTT publication 478, Espoo, Finland, 107p.
- [11] Cooke, A., Bonnema, G. M., Poelman, W., 2012, 'Agile development for a multi-disciplinary bicycle stability test bench', Trauner Verlag.
- [12] Glas, M., Ziemer, S., 2009, 'Challenges for agile development of large systems in the aviation industry', Proceedings of the 24th ACM SIGPLAN conference companion on Object oriented programming systems languages and applications, 901-908.
- [13] Esposito, E., Raffa, L., 2006, 'Evolution of the supply chain in the aircraft industry', Proceedings of the Ipsera Conference.
- [14] Klein, T. P., Drescher, B., & Reinhart, G. (2016, June). *Agile engineering in mechatronic education: Interdisciplinary development of a mechatronic system using Scrum*. In Mechatronics (MECATRONICS)/17th International Conference on Research and Education in Mechatronics (REM), 2016 11th France-Japan & 9th Europe-Asia Congress on (pp. 020-025). IEEE.
- [15] Grimheden, M. E. (2013). Can agile methods enhance mechatronics design education?. Mechatronics, 23(8), 967-973.
- [16] Turner, R., 2007, 'Toward Agile systems engineering processes', Cross Talk, The Journal of Defense Software Engineering.
- [17] Douglass, Bruce Powel-Agile Systems Engineering-Morgan Kaufmann (2016)
- [18] Mhenni, F., Choley, J.-Y., Penas, O., Plateaux, R. & Hammadi, M. A SysML-based methodology for mechatronic systems architectural design *Advanced Engineering Informatics, Elsevier*, 2014, 28, 218-231