Implementing Digital Enterprise Technologies for Agile Design in the virtual enterprise

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Digital Enterprise Technology (DET) is defined as a synthesis of digital and physical systems across the product lifecycle which can be exploited for two main benefits: risk mitigation through consistent and seamless data standards; and reduction in product development times through improved access to the most accurate project data at any time, from anywhere, by anyone. Agility is defined as responsiveness to unpredictability, particularly unpredictable events in the environment external to a process. The general need for agile response in turbulent environments is well documented and has been analysed at the manufacture phase.

This paper introduces a framework for an agile response to these turbulent environments during the design stages of product development. The Agile Design Framework is based on the founding principles described as DET, with the added benefit of reduced reaction time and therefore greater agility in the face of unpredicted external events. A 4 level classification scheme for event impact is discussed and a common toolbox of Digital Enterprise Technologies (Core Tools) for agile design is introduced. The paper proposes the implementation of the DET-based Core Tools during a meta-design stage, for maximum benefit from the synergies of the many systems.

1. INTRODUCTION

The benefits of agility in the manufacture of products is well documented. [Jiang et al, 2003, Kara et al 2001] Recent research has also explored the application of agile methodologies from the manufacturing process to other aspects of the product development cycle [Matthews et al, 2005]. This paper builds on the Agile Design Framework [Armoutis et al 2003], an extension of the Digital Enterprise Technology methodology, previously defined by the authors to propose a meta-design stage of the design process, during which the Core Tools of the Agile Design Framework are defined and configured. This meta-design stage is undertaken once the initial requirements gathering has been completed and the collaborative design team begins to come together, usually under the direction of a prime contractor or system integrator.

The remainder of this paper is structured as follows: Section 2 describes the background research activities of the team in the area of agile design, and introduces

the Agile Design Framework in the context of Digital Enterprise Technologies. Section 3 presents the Core Tools of the Agile Design Framework while Section 4 presents the arguments for a meta-design stage and the proposed benefits of introducing an additional stage in to the design process, with a view to reducing the overall process time. Section 5 discusses the findings with regard to the theoretical benefits of Digital Enterprise Technologies for Agile Design while Section 6 concludes the paper and proposes the next steps in Agile Design research.

2. BACKGROUND

In order to concentrate on unique core competences, there is a trend towards multiple smaller companies collaborating on a short-term basis to acquire all the necessary competencies to complete a project, without having to each maintain the excess competences during projects for which they are not required [Lomas et al, 2005]. This allows *Virtual Enterprises* to have the knowledge of a large organisation without the overheads associated with one. Companies are selected on the basis of their expertise [Lomas et al, 2005]. The Virtual Enterprise forms the basis of the Agile Design Framework, which seeks to define what happens when a design project, decomposed into multiple distributed components, is interrupted by an Unpredictable External Event (UEE).

The level of impact of a UEE has been categorised into 4 levels of severity [Maropoulos, 2003], and each can be dealt with in a different manner. *Trivial* events can be resolved completely at the local level, incurring a small penalty, represented as time. This could be a requirements change due to government legislation, but crucially, the existing agent is still able to satisfy the requirements and deliver its part of the design. *Minor* events require the agent to seek external assistance, or redeploy a part of the work to another partner. For example specialist knowledge in a particular field will now be needed, so another partner with the necessary competence is brought into the project team to assist. A *major* UEE cannot be resolved by the agent or another member of the virtual enterprise. The redeployment of work to a new team member and initiation of the new member to the project incurs a serious time penalty. Finally a *fatal* UEE cannot be resolved by the agent, and there exists no external agent that can provide support. Effectively, the design is fundamentally flawed and is not realisable.

Each UEE has an impact (normally negative) on the percentage of work remaining for that stage, which can be translated into a time penalty. If the task is on the critical path, then the time penalty is transferred to a global time penalty for the project.

The goal of an agile system, in this case a design process, is to have the ability to respond quickly to unpredicted changes in the environment. The nature of the events have been discussed here, in terms of there causes and the level of impact they impose on a project. In order to respond to these events, the Digital Enterprise Technology (DET) Framework [Maropoulos, 2003] presents an initial template on which we can build a set of *Core Tools* comprising the Agile Design Framework.

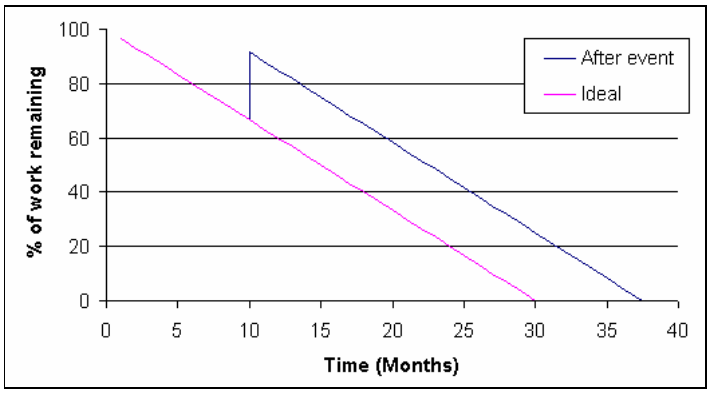

Figure 1. Time penalty caused by a UEE

The Agile Design framework is aligned to the DET framework (Figure 2) through a common distributed and collaborative environment. Agile Design builds on the 4 cornerstones of DET to identify specific Digital and associated tools. The main focus of exploiting the synthesis between digital tools across the product lifecycle has been risk mitigation through eliminating conversions between partners and software systems, and to allow more seamless access to data across the Product Lifecycle.

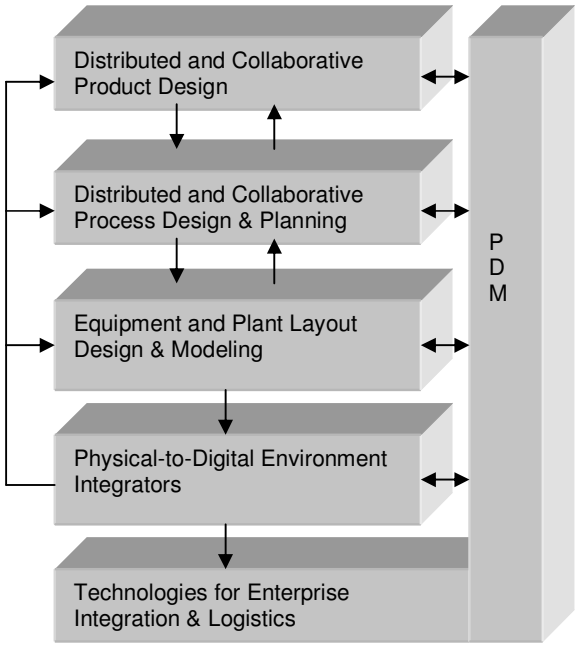

Figure 2. The 4 cornerstones of Digital Enterprise Technology

The aim of the Agile Design Framework is to develop this methodology in order to reduce not only the conventional product development time, but also use the Digital environment and the physical to digital integrators to reduce the penalty (time, economic or quality) caused by unpredictable external events.

3. CORE TOOLS FOR AGILE DESIGN

3.1 Competence Profiling

In the event of a minor or major level of UEE, there exists a requirement for external intervention, either in assisting an existing agent of the project, or in replacing a failed agent. This process of identifying alternative agents has been shown to delay projects' progress, due to a lack of direction in the search for new agents and a lack of information about their capabilities and competencies being available [Lomas et al, 2005]. During this process no direct work is completed on the project and a time penalty can be incurred. Competence Profiling is one tool which can be used to respond more rapidly when a new agent is needed. Companies complete an on-line form relating to their core competences, as well as other information such as geographical locations, international awards obtained and current customers. This database can then be searched for one or more competences in a single search, and a company or group of companies will be scored and recommended based on their performance against the search criteria. The Competence Profiling system then provides a full company report on any companies that could be investigated further to meet the requirements. In this way, the process of finding companies to assist or replace existing agents is greatly speeded up.

3.2 Design for Assembly

In the cases of minor and major events, where external companies are brought into a project part-way through, it is important that they can be integrated as easily as possible in order to minimize the delay caused by their inexperience with the project. Design for manufacture principles such as the use of early defined and standard interfaces between components/sub-assemblies, can help this. This principle is also referred to as de-coupling tasks [Ulrich et al, 2005] and Modular Architecture [Gu et al, 2004].

3.3 International Standards

International Standards such as SI units and terminology can play a vital role in how seamlessly a company can integrate into a project part way through. While some standards may be obvious, such as SI units, it is important to stipulate from the outset the standards, languages and terminology that will be used for a collaborative project. One example of the importance of this is the use of CAD data. In a distributed and collaborative project where the same CAD packages are used, there appears no need to use neutral file formats such as STEP for the exchange of data between partners. However, if an unexpected event requires that a new agent must be introduced to the project, then it is important that their CAD package does not

become an obstacle and cause further delay, because they cannot easily share files with other agents. The trial carried out by Durham and Oregon State Universities clearly showed the negative impact of using different CAD systems for a distributed collaborative design project [Arnold et al, 2004].

3.4 Web-based Product Data Management

Product Data Management (PDM) systems have been around for a number of years, and recently have migrated to web-based systems. The benefits of this development to an agile design process are significant, and related to the previous two tools. Once a UEE occurs during a project and the level of that UEE has been identified, there may exist a need to introduce new partners to the project. Without the use of a web-based PDM system, the process of integrating that new partner or partners becomes more complex. PDM systems do not only offer access to the majority, if not all, of the information a new agent would need, but also the project history through discussion boards and document revision control. This insight into the progress of the project so far, the reasons behind decisions made and importantly, any failures which might have caused their involvement, will mean that any new agent can more quickly become effective within the project than if they were entering 'blind'. The web-based nature of modern PDM systems can allow a new agent to gain access to this information simply with a username and password, rather than having to speak to each of the other affected agents individually. There is also a guarantee that the new agents obtain the most up-to-date information.

Although there exist many other tools which could further increase the agility of the response to unpredictable events, these tools have been identified by the authors as Core Tools, that is they can have significant effect on the response time, and are readily available.

4. META-DESIGN

The Agile Design Framework described in the previous section builds on the DET framework to define a set of Core Tools to enhance the benefits into dealing with UEEs, therefore creating an agile process.

As discussed, the way in which product development projects are carried out has changed over the last ten to twenty years, and now adopts a more collaborative, distributed model. However there is little evidence of the product development process changing to reflect this trend.

Meta-Design is proposed as 'designing the design process'. In order to maximize the benefits of the core tools it is proposed that all members of the virtual enterprise must be familiar with them and committed to their use. Therefore, the introduction of these tools must be well planned in order to maximize the cumulative benefit.

The traditional product development process follows a staged process as shown in Figure 33.

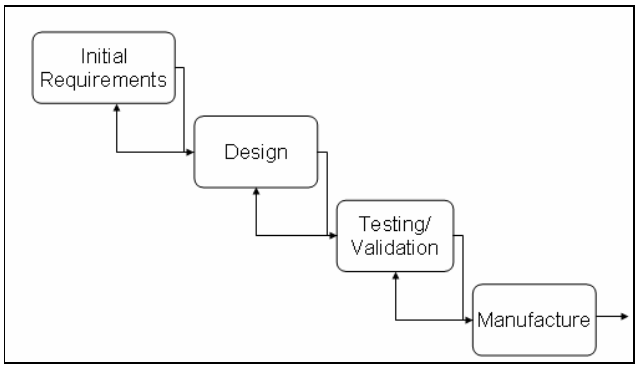

Figure 3. Traditional Staged Product Development Process

Through the introduction of a meta-design stage the virtual enterprise is preparing itself for the design process. Therefore, the impact of an Unexpected External Event can be limited through the use of procedures and tools already introduced and agreed.

One example might be the development of a new technology which means that welding airplane wings is possible, rather than the traditional riveting. The Agile Design Framework proposes Competence Profiling as a method of identifying specialist collaborators who could be introduced to the virtual enterprise to assist with this particular change in requirements and reduce the impact of the UEE. If, during a meta-design stage, the existing partners have agreed on Competence Profiling via a particular system, then the process of identifying new partners is greatly reduced because training has already taken place on a tool which has been agreed and tested. Furthermore, Web-based Product Data Management is a Core Tool of the Agile Design Framework. By introducing the web-based PDM during a meta-design stage and training administrators, a new company such as that discussed could easily be added to the PDM system and gain access to the relevant project data more quickly.

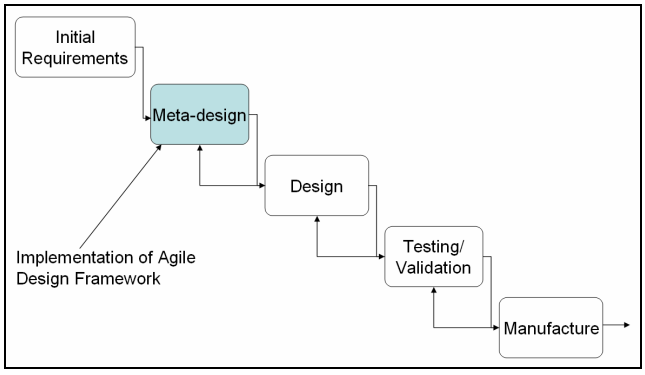

Figure 4. Meta-design stage for definition of Core Tools

The meta-design stage is best placed in-between Initial Requirements gathering and Design to allow the overall integrators of the project to identify the make-up of the virtual enterprise. Competence Profiling may be used to match the initial requirements to interested companies to form the project team. Preliminary discussions will then allow an initial team to form the virtual enterprise, whose first task should be to develop the customer requirements into concepts. At this stage of design concepts the issues of data sharing procedures, international standards, software standards for sharing digital files and many more become relevant. Therefore meta-design, for defining these processes and standards before they become problems, must precede the conceptual design work, and therefore sits well between requirements gathering and design.

The meta-design should be lead by the integrator or manager of the project, and all participating collaborators should be in agreement. At this stage it may be appropriate for training to take place.

It is also proposed that a part of the meta-design process, in addition to the agreement of procedures and tools, should include scenarios to allow partners to appreciate the benefits of the Core Tools and procedures, and also enhance understanding of the way in which they may be used to limit the negative impact of any UEEs. This use of scenarios can help to overcome the cultural resistances to operating in such an open and collaborative environment.

Essentially the Meta-Design process facilitates three purposes:

- Definition of Core Tools
    - Web-based PDM
    - Competence Profiling
    - International Standards
    - Design for Assembly/Manufacture
- Training
- Scenario Planning

5. DISCUSSION

The Agile Design Framework discussed relates specifically to collaborative design projects in a virtual enterprise. The main focus of research in this area has been on tools which may be of benefit to the collaborative effort through improved data-sharing. The proposed meta-design stage of the product development process allows a virtual enterprise the opportunity to use these and other tools (the Core Tools) for maximum agility. This is achieved through the definition of tools and procedures, and appropriate training, prior to any design work being undertaken, as soon as the initial partners of the team are identified.

6. CONCLUSIONS

This paper has introduced the Agile Design Framework as a development of the Digital Enterprise Technology methodology for product lifecycle management. The

Agile Design Framework seeks to exploit the synergies between digital technologies in collaborating and distributed organisations to not only mitigate risk, but to enhance their ability to respond to Unpredictable External Events. This is achieved in a number of ways: Definition of a set of Core Tools used across the virtual enterprise for identifying new partners and managing communications within the project team; Early definition of the Core Tools during a meta-design stage which is lead by the project integrator and defines the tools and procedures for use throughout the project by all members; The use of scenarios to illustrate the benefits of the Core Tools and overcome any resistance. In this way the Digital Technologies employed will be more effective because of early definition and planning, enabling a faster response to Unexpected Events and a reduced product development cycle.

Future work will include lab-based experiments to demonstrate the benefits of early implementation of the Agile Design Framework. This will be followed by retrospective industrial case analysis and implementation of this methodology in industry.

7. ACKNOWLEDGEMENTS

The authors would like to thank The Virtual Research Laboratory for a Knowledge Community in Production (VRL-KCiP) for their support in funding this research.

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