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Collaborative Engineering as an Efficient Tool for Coordination among Stakeholders in Aerospace Industry

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Abstract

This paper analyzes the impacts and effectiveness of collaborative engineering, for overcoming coordination barriers and elevate management efficiency among stakeholders in aerospace industry. A case study about Boeing Co. is presented to analyze the collaborative engineering approach and describe an innovation project conducted within the aerospace industry. Three specific methodologies of collaborative engineering are listed to elaborate how recent advances in platform simplification, statistic mapping, experiential scenario design, are becoming the key enablers of next generation systems engineering and systems engineering languages.

Keywords: Collaborative engineering; efficiency; coordination; aerospace industry.

1. Introduction

Nowadays, most enterprises increasingly involve active participation from stakeholder groups that are geographically displaced across the globe. In the professional work environment, group projects and design teams are often put together to design products and to develop business solutions.

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However, many professional terms and languages employ highly technical notation that prevents stakeholders who are not engineers from contributing to system design and validation in upfront engineering. Besides, the clarity of knowledge expression inside various complicated systems has become harder to be comprehended due to the increased information load, as well as the problems associated with geographic boundaries, organizational boundaries, and departmental boundaries. Thus, a more advanced methodology needs to be constructed to help aid the stakeholders of a collaborative environment.

Thus, in light of the foregoing, there calls for an extended engineering languages in a manner that makes them comprehensible to all stakeholders. Successfully addressing this challenge is key to allowing all stakeholders to provide valuable and timely inputs into upfront systems engineering when change is both possible and affordable.

2. Background

2.1 What is Collaborative engineering

Collaboration engineering is the new discipline of designing reoccurring processes that are transferred to client groups for self-sustaining, repeatable work in these processes. Said another way Collaborative engineering is the creation and modeling of techniques and technologies into structured collaboration processes that support the execution of high-value organizational tasks and can be transferred to self-sustaining groups.

Collaboration engineering first appeared in the Summer of 2001 when the leading researchers, Dr. Gert-Jan de Vreede of the University of Nebraska and Dr. Robert O. Briggs first came together to document what their original concept. Dr. de Vreede describes Collaborative engineering as a field that “models and deploys repeatable collaboration processes for recurring high value collaborative tasks for execution by the practitioners themselves” [1]. As technology and society developed, such an approach is particularly emerging due to the modern challenges in engineering and design: market globalization, short delivery times, rapid evolution of customer requirements, and complex industrial chain creation. As a consequence, new flexible organizations arise to satisfy the design and manufacturing needs and face the novel industrial scenario. Indeed, working groups must be organized in a new way to cooperatively act in distributed teams and allow a dynamic team configuration according to the specific objectives. At the same time, traditional tools may not properly support such collaborative teamwork in distributed spaces and new technologies must be adopted.

The goal in Collaborative engineering is to create simple, effective processes, built on tools and techniques of collaboration that can have some predictable success. These processes are designed in such a way that a client’s group can use them without the help of professional facilitators for reoccurring tasks. According to researchers, reoccurring collaborative tasks include strategy formulation, operational risk management, crisis response, requirements engineering, document review and feedback gathering.

After long term experiments and practices, Collaborative engineering has been proved to optimize engineering processes with objectives for better product quality, shorter lead-time, more competitive cost and higher customer satisfaction”. It has also been widely applied to product design, manufacturing, construction, enterprise-level collaboration and supply chain management.

2.2 Effect of Internet on Collaborative Engineering

Before the development of electronic communications networks, stakeholders of a system were required to work in the same room in order to collaborate on projects. In the 1980's, the process of numerous stakeholders collaborating on different aspects of a project at one location was known as concurrent engineering [2]. By the early 1990's, as local area networks developed into wide area networks and finally into the World Wide Web, it became possible for stakeholders to utilize the communication and dissemination capabilities of networks encompassing large geographic areas. The majority of the projects that were developed around this time were designed as communication facilitation tools, and very few of these projects involved a knowledge representation of the collaborative environment or the eliciting of knowledge from stakeholders involved.

Speed and connectivity are arguably the Internet's greatest contributions to collaborative engineering. The fact that the Internet is accessible via computer from any location, anytime, and with very little third party assistance, allows for it to serve as a conduit for a generalized tool for knowledge acquisition, knowledge analysis, and knowledge dissemination. With the increasing globalization of businesses and engineering endeavors, key stakeholders of businesses or engineering processes can rarely be found at the same location at the same time. The World Wide Web offers tremendous potential for collaborative information sharing amongst stakeholders who may be geographically displaced in both time and space. Steady growth in telecommuting and electronic communications, such as email or online messaging, has served to facilitate communication between participants [3]. As technology continues to improve, the capabilities of telecommuting become more advanced, moving from asynchronous processes such as email and fax to interactive processes such as video conferencing.

Since the late 1990's, as use of the Internet has become increasingly prevalent, distance collaboration using teleconferencing and shared media has become a significant area of research and development. Examples of early research prototypes that utilize the Internet are Media Space project at Xerox PARC, Cruiser and Touring machine projects at Bellcore, Argo system at DEC, and the Ontario Telepresence Project [4]. These projects typically involved the use of proprietary systems and analog video to support interaction among stakeholders.

Nowadays, web-based collaboration no longer revolves solely on the transferring of design files over the Internet, but now encompasses systems that can offer interactive, real-time design review and mark-up through the Internet. Technology has come a long way from participants using the Internet to send text messages, to audio/video conferencing, and now to full-blown collaborative tools.

2.3 Development of Collaborative Engineering Tools

As Internet use became more prevalent in the mid-1990's, small collaborative engineering processes that utilized the Internet began to be packaged together as specific collaborative tools.

Many recently developed tools focus on the development of a collaborative CAD framework in which all stakeholders of a design are able to access a particular CAD design. Other general knowledge management and design tools focus more on the overall high-level understanding of a project rather than on the technical specifications [5]. These higher level collaboration tools are the type of tools that will be later discussed in this thesis.

Collaborative engineering tools support two main functions: knowledge retention and knowledge discovery. Knowledge retention encompasses the capture and archiving of knowledge of past design decision rationale and stakeholder preferences, as part of the evolving knowledge representations of the collaborative environment. Knowledge discovery encompasses the creation of new knowledge and ideas through the analysis of past decision rationale and stakeholder preferences [6].

The recent incorporation of knowledge-based systems and other artificial intelligence techniques into the basic knowledge management framework allows for the creation of more intelligent systems. The new era of knowledge-based collaborative tools will allow designers to better manage the evolution of products and services. Because of this trend of incorporating knowledge-based properties, more collaborative engineering tools will begin to support knowledge discovery functionalities.

3. Case study & Collaborative Tools in Use in Boeing

Aerospace engineering typically involves a complicated system design with a large number of stakeholders due to the highly complex and large systems that are developed. These properties of aerospace design make the industry an ideal candidate for collaborative engineering tools.

The aerospace industry does not have a standard collaboration tool which all aerospace corporations utilize. Instead, corporations employ various collaboration tools which may even vary within a single company.

This paragraph dives into the application of collaborative engineering approach and describes how the analysis of stakeholder relationships to various knowledge representations can provide vital information of the design process. By chaining the pathways of knowledge flow between the two original tools, stakeholders can better understand how design decisions made at any level of the engineering design process will impact the overall collaborative endeavor. Through this process, stakeholders gain unprecedented insights into historical information and thereby become better equipped to make educated decisions regarding future design directions.

3.1 Concept Design Center

The Boeing Company is the world's largest aerospace company. The company itself incorporates numerous collaborative engineering tools, including an in-house collaboration tool known as the Concept Design Center.

The Concept Design Center is a networking tool that was designed to assist in the preliminary design process. The tool facilitates collaboration in a common location by functioning as a central knowledge repository that archives all system specifications designed and edited by the design team. Nicola Nelson, a Principal Engineer at The Aerospace Corporation, emphasized that the most valuable insight to successful collaborative engineering is a clear understanding of all stakeholder preferences in a system [7]. She expressed interest in using a collaborative tool that could clearly elicit and analyze stakeholder preferences in a design system.

It also provides functionalities that address the claims for a clear representation of stakeholder preferences. In addition to this, the knowledge discovery of Concept Design Center creates a dynamic understanding of the causal effects that design changes have on stakeholder utility and expense values. This functionality of relational analysis is not commonly found in current commercial collaborative tools.

3.2 ICEMaker

The Boeing Satellite Systems group has used the ICEMaker tool since the winter of 2002 to help assist in collaboration of design systems. In addition to ICEMaker, the Boeing Satellite Systems group is looking to acquire an additional collaboration tool. The two commercial tools being considered are Oculus and Phoenix Integration [8]. Both tools integrate and automate various software tools, allow for geographic distribution of stakeholders, and accommodate different computing platforms into a cohesive environment for systems design.

Regarding the topic of knowledge retention of past design knowledge, Stephen Sichi, a Chief Engineer at Boeing, commented that the design cycles of a few aerospace systems are very short, in the ballpark of 5 years. At times, he mentioned, it may be cheaper to maintain an iteration of a current engineering design for 5 years, and after the 5 years has elapsed, to start from scratch on the new generation of the design. He attributed such a short design cycle to advances in either development tools or aerospace technologies that result in enough design change over 5 years that the re-engineering of the system is a more practical solution [7]. However, during the 5 year period that the design iterations are maintained for, a system that is able to support knowledge retention, knowledge capture, and knowledge discovery would be useful in pushing forward design initiatives. The issue to keep in mind though is that the design cycles for most systems typically are longer than 5 years. This means that typically, knowledge retention for design iterations is even more important and must be adequately handled.

ICEMaker addresses the issue of knowledge retention by incorporating archiving functionalities that capture design state knowledge for future review. It can also archive the knowledge from expert engineers through the stakeholder interview process through its variable history functionality. Sichi also mentioned that knowledge retention of employee expertise is slowly becoming more of a problem as the engineering generation responsible for many advancements such as rocket propulsion are slowly reaching the retirement age. In the case of rocket propulsion, in the 1960's, that generation of engineers were responsible for the majority of the research conducted on rocket design, and in the past few decades, much funding for rocket research has been cut resulting in fewer new engineers becoming experts in the field [9].

To conclude, it is well recognized that one of the most important added benefits of collaborative engineering tool is the ability for stakeholders to stay involved in the engineering design process throughout the entire endeavor. Chad McFarland, a Engineering Design Manager at Boeing, recognized the importance of stakeholder involvement throughout the engineering design process, and he understood that with the use of a tool such as ICEMaker, stakeholders could continuously be involved in the design process. This valuable functionality would be most useful in allowing the customer stakeholder to maintain a consistent voice throughout the engineering design project to develop a more complete design that fits all of the customer's preferences.

4. Discussion

In the following paragraphs, three specific methodologies are discussed to extend the understanding of next generation systems engineering and systems engineering languages.

4.1 Platform simplification to centralize specifications and goals

Across the aerospace industry, most corporations employ varying types of collaboration tools ranging in diversity of functionalities. Avidyne Corporation, an aerospace corporation based out of Lincoln, Massachusetts, is an example of employing collaboration tools to assist in the collaborative design process.

Avidyne is a leading provider of integrated flight deck systems for the next generation of light aircraft. The corporation employs the collaboration tool DOORS to help assist in the CAD development and knowledge management process through the facilitation of communication between stakeholders [10]. DOORS, which is developed by Telelogic, is a requirements management tool that enhances communication, collaboration, and validation across a particular enterprise through the creation of a repository of system knowledge and basic forums for discussion and validation.

With the integration of DOORS to assist in the communication and dissemination process of collaborative design, all stakeholders of a design system are able to centrally access the current design specifications and goals. The DOORS tool does not add value as a knowledge discovery tool, but the ease of use and facilitation of communication does ease the burden of collaborative design.

4.2 Experiential scenario design to provide elevated experience

Air craft divert scenario, an illustrative scenario used to demonstrate the development of technical stories, comprises both sunny day and rainy day versions, revolves around an airplane that takes off, and experiences a malfunction, that requires making a decision about whether or not to divert the aircraft. The scenario employs an airplane that in one case is equipped with an Aircraft Health Management (AHM) system, and in the other case is not.

With the AHM, the airplane is expected to have fewer diverts because of up-to-the-minute information about aircraft health and availability of potential landing sites. However, today the full value of the AHM is not always realized because many stakeholders arc not conversant with AHM usage.

A key purpose of AHM is to allow all stakeholders to “experience” working with the system within scenario-based stories that unfold in virtual worlds. Stakeholders that experience the design in this fashion arc also able to collaborate effectively with each other, and provide useful and timely feedback on system design to systems engineers during upfront system engineering.

4.3 Statistic mapping to reduce statistic complexity

System engineers prefer to formal, structured diagrams as the starting point for developing system models, such as representative operational scenarios (use cases) and activity diagrams, to collaborate with subject matter experts and non-technical stakeholders. It is common that operational scenarios are documented primarily in prose form in operational scenario documents. These documents tend to be subject to inconsistencies, ambiguities, and gaps.

However, most subject matter experts and non-technical stakeholders tend to be unfamiliar with systems engineering methods and formal modeling notations. Also, it is important to note that the virtual world of knowledge systems is a domain-limited yet verifiable representation of the system of interest, which requires interfaces to investigate how the system behaves in a variety of situations. Verification of the system representation is conducted collaboratively by all stakeholders in terms of the ability of the virtual world representation to support the different use cases of interest and to answer questions posed by stakeholders from their respective perspectives [2].

Thus, an innovative method, named statistic mapping, has been elicited between systems engineers, subject matter experts, and other non-technical stakeholders for more efficient collaboration. This method has been providing the impetus for adding an experiential perspective to the current system modeling methods, which can be derived from storytelling in virtual worlds. As to its functions, it builds up a story to enact within virtual worlds, dramatically enhancing collaboration among all stakeholders. Then, a relatively straightforward bidirectional mapping can be constructed between system models and the story space.

5. Conclusion

As collaborative endeavors become more popular from the engineering domain to the commercial and academic domains, the need for tools to assist in communication and knowledge management will continue to be a major focal point in collaborative environment research.

The major challenge in collaborative environments is the efficient coordination and maintenance of communication amongst stakeholders of a system. Due to the increased amount of information and the problems associated with geographic boundaries, organizational boundaries, and departmental boundaries, there tends to be an increasing need in Collaborative Engineering and affiliated design iterations. What also worth noticing is that as collaboration becomes much more important in all facets of life, supporting tools will become even more essential to help facilitate such environments.

In aerospace industry, collaborative engineering tools have been adopted and developed to work complementarily to act as a combined tool that facilitates communication and comprehension across the entire spectrum of design representations. Tools such as Concept design house and ICEMaker employ new methodologies to elicit knowledge from the collaborative environment in approaches and techniques that have not been currently utilized by other engineering tools.

Through the chaining of the pathways of knowledge flow of the collaborative systems from system specifications to design properties to design attributes to stakeholder preferences, this combined tool develops an innovative approach to better understanding design system relationships. By linking all of these different facets of design representation, the combined system is able to conduct analyses on the entire knowledge pathway by relating various different representations of the system in order to discover how changes in one aspect of design can affect the entire collaborative environment.

Collaborative Engineering is the practical application of collaboration sciences to the engineering domain [11], which harnesses efforts in companies worldwide, and sustainability issues have raised concerns in society, collaboration is increasingly needed from inception throughout the disposal of a product. In the future, it is essential that the coordinated use of collaborative engineering tools will undoubtedly simplify collaboration complexity and provides a new methodology using elicitation of system knowledge to better understand relationships between multiple design representations.

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