ENGINEERING AND PRODUCT DESIGN EDUCATION CONFERENCE
7-8 SEPTEMBER 2006, SALZBURG UNIVERSITY OF APPLIED SCIENCES, SALZBURG, AUSTRIA

A SYSTEMS ENGINEERING WEBTOOL FOR NASA: A CASE STUDY IN INFORMATION DESIGN

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ABSTRACT

This paper describes an ongoing research project that seeks to create a reference tool leveraging web technology and visual communication strategies that will enable NASA technical and managerial staff to access the content of the *NASA Systems Engineering Handbook*. The new tool will serve as both a reference and learning tool for newly hired or newly promoted personnel, and will use interactive media to overcome the deficiencies of the text version.

Keywords: information design, visual literacy, user–centered design

1 INTRODUCTION

The National Aeronautics and Space Administration (NASA) is an organization that encompasses ten semi–independent Centers, each of which is dedicated to a different area of specialization, including: propulsion and communication technologies, flight and aviation research, space observation, robotic exploration, human space exploration, and operations. The Centers share common goals but each has a different structure, budget and organizational practices, with its own standards, procedures and documents.

The NASA *Systems Engineering Handbook* is a key reference tool used throughout the Agency by engineers, technicians, and managers who are engaged in designing and fabricating complex systems. The *Handbook "…represents some of the best thinking from across NASA and furnishes a good overview of NASA–wide systems engineering practices"* [1]. The *Handbook* is intended to be an educational guide written from a NASA perspective. The primary audience for the document are individuals who take systems engineering courses, and working professionals who require a guidebook to NASA systems engineering. Since its inception, interest in the *Handbook* has gone far beyond NASA. It has been used as an example of best practices in systems engineering by several organizations and in academia.

However, the *Handbook* as it is currently configured poses several problems for its users. Seen from the viewpoint of a design professional, it deals with very complex, hierarchical information that is inherently non–linear ('non–linear information' refers to processes and activities that occur simultaneously and/or non–sequentially). The typical user confronted with this document, even someone with considerable NASA experience, has difficulty formulating a clear mental map of the processes and procedures described. This is primarily due to two factors: First, printed media is not best suited to display dynamic information. The tasks, design reviews, documents, and

gates that a project must generate as it moves from pre–proposal through launch and operation are not always sequential; the "book" format obscures the information, forcing the user to navigate in a linear path.

The second factor is the design of the book itself: there is no clear visual hierarchy in the information structure, visual composition or page layout design. The charts and diagrams tend to be exceptionally dense matrices of actions, agents, technical reviews, documents and acronyms, which are displayed simultaneously, overwhelming the reader. The complexity of the data is inherent to the subject, but the information structure, visual composition and page layout do not support the user in extracting the information as needed.

The content of the book is of great value to the engineering community, but the format and delivery of the content present a great challenge to design professionals. The use of design principles can support and clarify the information without reducing the quality of the details. Alternative delivery systems such as Web technology can effectively assist the learning experience. This paper discusses the process of developing a prototype that can demonstrate the benefits of:

- developing a clear visual hierarchy,
- using web technology to deal with complex information
- allowing the user to seek information as it is needed.

All three of these dimensions directly impact the learning experience for both the novice and the experienced user.

2 THE CURRENT STATE

The NASA *Systems Engineering Handbook* in its current printed format is ten years old. It was conceived as the best way to encompass the entire NASA systems engineering process and to support personnel training. The document contains a broad definition of systems engineering, a broad process outline, and typical tools and procedures. The *Handbook* was intended to accompany formal NASA training courses on systems engineering, not to be a stand-alone, comprehensive view of NASA systems engineering [1].

The printed *Handbook* approaches systems engineering from a systems perspective, starting at mission needs and conceptual studies and continuing through operations and disposal. Because it deals with complex material that is inherently non–linear, the strictly text–based document makes this material even more difficult to understand. In part, this is due to the fact that written text is linear, and forces the information into a narrative form, which is unsuited to the tasks of systems analysis and systems design. Systems are complex structures in which functions and events typically occur simultaneously at many different levels. Events may occur synchronously or not, and events at one level typically impact events at several other levels in the system. Attempting to create a printed, text–based document that can accurately reflect the state of a system is an exercise in futility, due to the fact that printed text forces events to unfold sequentially, regardless of how the events actually evolve in time.

A second problem that confronts the reader of the current *Systems Engineering Handbook* is the segmented information in the major diagrams, particularly the *Program/Process Life Cycle* diagram and *Program/Process Life Cycle Process Flow* diagram. The original diagrams displayed detailed information simultaneously. They contained rich data in a comparative context. (See Figure 1)

These diagrams are powerful information displays but unfortunately, in order to be distributed in a letter sized printed document, they were poorly segmented into three pages losing readability and context. When a new user of the Handbook encounters the NASA *Program/Process Life Cycle* diagram for the first time, the initial reaction is that of being overwhelmed by the level of detail presented without context.

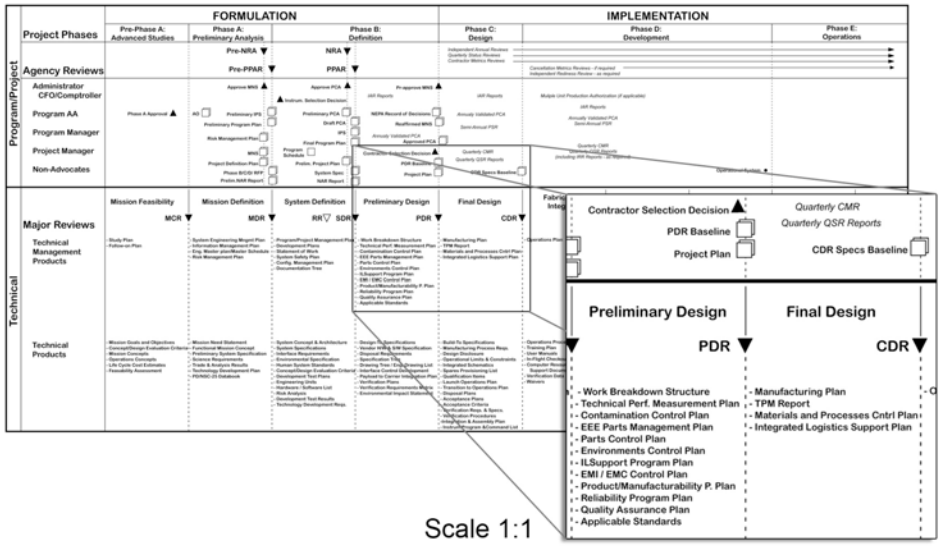

Figure 1. Program/Process Life Cycle Diagram

The problem is not the quality or the amount of information contained in the diagram. Micro and macro designs enforce both local and global comparisons and, at the same time, avoid the disruption of context switching [2]. In this case, the information was compromised by the delivery medium. There is a discrepancy in the scale, alignment and orientation of the three pages, not to mention the severed paragraphs.

A third problem with the handbook is a result of the difficulties of effectively organizing and displaying the information. The issue is not the density of the data or even the viewer's lack of understanding. Confusion and clutter are failures of design, not attributes of information [2]. The challenge is to find Visual Communication design strategies that clearly reveal the details, particularly at the time the user seeks them. The design solutions should allow the user to view, select, compare and extract the data to meet their individual needs. As Knowles has explained, adults are task or problem–centered in their orientation to learning, so there is a need to provide flexibility for self–inquiry [3].

3. DESIGN OPPORTUNITIES

For the printed document there are several design opportunities for development, such as leveraging principles of layering and separation in order to retain a high level of detail while allowing flexibility of readings [2]. The visual relationships in diagrams and charts can be clarified by the use of basic design principles in order to support the user's task.

Because we have concluded that several of the problems have derived from the printed media and the need for dissemination of the document, the search for alternatives led us to Web technology as a solution. Web technology offers interactivity and supports a visual representation of vast amount of data and processes in a way that printed media cannot. At the same time, it supports the learning experience by allowing the user to navigate at his own pace, allowing access to multiple users at different times, facilitating revisions, reviews and updates.

Using the Web provides the design development team with the ability to extend the scope of the project from a single document to a larger on–line information resource. The Handbook is one document among several that present similar challenges. There is an opportunity to apply the concepts and design strategies developed for this project across key documents throughout the Agency, initiating an effort towards a full visual design system, rather than solutions particular to individual documents or to the different Centers.

4 CURRENT DEVELOPMENT

This effort is still in a prototype stage, but we have developed an application that addresses the *Systems Engineering Handbook* in a parallel function as its printed version: a reference tool (Figure 2). The difference is that our application uses web technology to translate the *Handbook* into an interactive diagram that displays information at a macro and micro levels, offering a clear mental model.

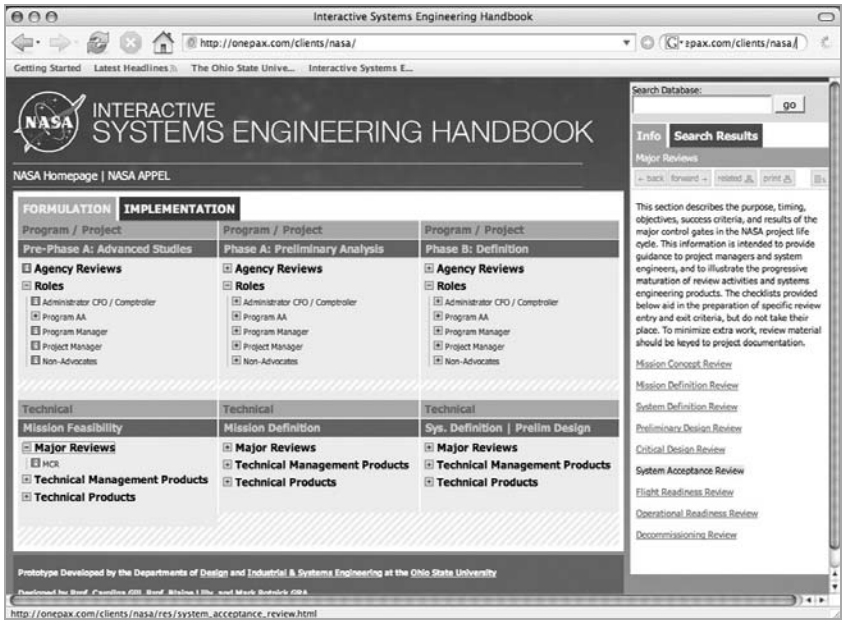

Figure 2. Interactive Systems Engineering Handbook

The major advantage this tool has over its paper counterpart is the ability to hide secondary information from view until the user needs it. We call this progressive disclosure. Primary information, such as the labels for Phase or Review, is at the top level in the hierarchy of the diagram and is always displayed. Secondary information such as the individual roles within phases or the products of the reviews is hidden until

the user clicks on them. Tertiary information is hidden until the user feels the need to access it. It also has the flexibility to allow the user to display documents and data simultaneously on command and to dictate the sequence of accessing the content layers. The *Interactive Systems Engineering Handbook*, is an attempt to take the cumbersome and complex documentation of NASA's *System Engineering Handbook* and distill it into a clear interactive reference tool. Essentially, the goal is to create an application that allows the user to navigate through an organized, visual representation of the *Project/Program Life Cycle*, based on the original chart from the printed handbook. (Figure 1)

The benefits for a user of such a proposed system include increased speed of finding relevant information, forms and templates, and the ability to dictate the inquiry and make comparisons. Essentially, instead of leafing through a heavy booklet the user can browse through all of the necessary information wrapped in a concise, easy to use electronic "chart." The separate stages of the development process, as well as their components, are described in progressive detail: The top level information is always displayed up front, and the further in the user chooses to go, the more information is revealed.

Understanding the importance of user–centered design, we kept three distinct types of users in mind as we created the tool. The first type of user would be someone who is new to NASA, and just beginning to understand how complex projects and programs are managed. This person typically would have no prior exposure to acronyms, nor to the sequence of documents and reviews necessary for a project to come to life. The second user is an outside contractor who has been hired to teach courses in systems engineering to NASA personnel. This person would have a better understanding of the project life cycle, having taught similar courses in the past, but would not have been through the process first–hand. For this user, the interactive handbook would be most useful as a tool that students could refer to on their own, following a class in systems engineering. The third type of user is an experienced NASA project or program manager who is responsible for training new NASA employees – in effect, the supervisor for the first user above. This person needs a tool that he or she can refer the new employee to when questions arise regarding procedures, documents, etc.

5 CONCLUSIONS AND FUTURE OUTLOOK

The Interactive Systems Engineering prototype has proven successful in introducing NASA managers to the insights a designer can bring to the development of on-line documents and manuals. To quote a NASA systems engineering manager, *"What you have produced is the "kernel" and the systems engineering application is just one example of how this can be utilized by NASA"*. [4]

With the advent of new leadership within the Agency, developing centralized databases with up–to–date material has been identified as a priority. Additional efforts towards training personnel in Systems Engineering are also under development, so the timing and relevance of this project have opened the doors for further design applications in the future. We are currently seeking additional funding to continue the project expanding its scope from a single document to an on-line library resource information system. This endeavor aims to work with NASA managers in designing a tool that will provide all program and project managers and their teams with the current policies, requirements, support tools and training needed to manage successfully.

The original focus of the funding was a database of case studies in engineering design for the NASA Engineering Training (NET) program. Because of the shift in training

priorities for NET, along with the subsequent reassignments in NASA personnel, we were asked to focus our efforts into Systems Engineering so the project evolved into this particular application. The current prototype was developed without direct access to users. It has been successful in demonstrating good use of technology and design and was also successful in "selling the idea" to managers. We believe there is room for improvement since it is primarily an information–driven website. If successful in securing additional funding, we will have the opportunity to access both users and developers in order to shift the focus from the data to the user's needs and thus create a user experience rather than simply another on-line document.

NASA is an engineering driven organization characterized by a task–oriented approach coupled with an engineering mindset. It has been quite difficult to persuade NASA management to consider the design perspective. Without an internal champion, we would have faced an impossible task in selling our idea within the organization. As outsiders, we needed an agent of change, someone who could clearly see the benefits of our work, and who was able to network with those key players, thereby opening the door for us and working to promote acceptance of our ideas.

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