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User-Centered Design (UCD) Process Description

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ADMINISTRATIVE INFORMATION

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EXECUTIVE SUMMARY

OBJECTIVE AND APPROACH

This report describes the Space and Naval Warfare Systems Center Pacific's (SSC Pacific) user-centered design (UCD) process. UCD employs scientifically proven methodologies of the behavioral and cognitive sciences to optimize the design of the human–machine interface. UCD begins with agile sessions that consider user's knowledge, skills, capabilities, and limitations. UCD focuses on the human work to be performed, which is the key to optimizing the relation between end-users and system operation/maintenance. Work is articulated starting with card storming and sticky note sessions that evolve into explicit models of work flow where critical tasks and decision points are identified. From here, paper wireframe storyboards are sketched and then validated with cognitive walkthroughs. Low-fidelity prototypes are created and checked against essential story scenarios, eventually leading to the development of high-fidelity mockups and prototypes.

CONCLUSIONS AND RECOMMENDATIONS

UCD provides guidance for improving total system performance by considering the real-world human work for operation, maintenance, and support of command and control equipment. Employment of UCD during command and control product development will yield systems with more capability with fewer equipment operators/maintainers, optimizing total system cost. It is recommended that UCD be a required system engineering element for Space and Naval Warfare Systems Command acquisition programs.

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BACKGROUND

The User-Centered Design & Engineering (UCD&E) team advises Space and Naval Warfare Systems Center Pacific (SSC Pacific) programs of records (PORs) on all issues related to human factors engineering (HFE) in the design and development of command and control (C2) systems. HFE is the domain within human systems integration (HSI) that is most relevant to the system engineering (SE) process, and ironically, is often misunderstood, dismissed, or omitted entirely from SE architectures.

Effective HSI planning for C2 relies heavily on the HFE domain for identifying human–system interactions related to the development of situational awareness and executing appropriate courses of action. HFE focuses on designing human system interfaces to optimize user performance and reduce the likelihood of user errors. The goal of HFE is the development of an effective system that requires minimal training for the user, prioritizes information necessary for the decision making process, and provides interfaces that effectively manage and simplify operator workload, are intuitive to use, and provide for user customization where feasible.

Here, we describe the user-centered design (UCD) engineering process as a method to design, develop, and build sensible graphical user interfaces (GUIs) for C2 equipment. UCD is a SSC Pacific best practice within HFE domain of HSI to optimize the design of the C2 human–machine interface (HMI) by reducing the equipment operator's cognitive burden of assimilating and acting upon disparate C2 information. The UCD process follows an analytical HFE design methodology that involves direct user engagement sessions to construct cognitive models of command situational awareness, workflows, use cases, and other artifacts to directly support rapid and agile prototyping.

Artifacts from the UCD process will focus and guide the hardware and software integration efforts and will support systems engineering goals to achieve total system performance. The objective here is the development of an intuitive HMI, which minimizes cognitive workload and inherently reduces training for the user. The UCD process will generate salient GUI layouts that make relevant information and functions available, easy to find, and actionable so equipment operators can do their jobs.

The UCD process has two main components:

- Defining user activities: The tasks and subtasks for each activity are derived from the system's functional requirements, operator duties, and job workflows. Subtasks, tasks, and activities are validated for activating system functions to achieve mission goals. Our design goal is to align C2 system functionality with real-world work patterns so that the C2 system operator is processing warfighting tasks, not just activating functions.
- Create specific interface layouts that support user activities: UCD offers a repeatable process that iteratively evolves the design and layout of the interface by continuously engaging the end-users and other subject-matter experts (SMEs).

PROCESS DESCRIPTION

User-centered design is an SSC Pacific best practice within the human factors engineering domain of human system integration. UCD employs scientifically proven methodologies of human sciences [1, 2, and 3] to optimize the designs of human–machine interfaces and teaming systems to improve performance and proficiency. UCD, as depicted in Figure 1, begins with agile sessions that consider the user's knowledge, skills, capabilities and limitations. UCD focuses on the user first and foremost, and on the work to be performed, which is the key to optimizing this relation between end-users and system operation and maintenance. The human work is described starting with card storming and sticky note sessions that evolve in to explicit models of the work flow where critical tasks and decision points are identified. From here, paper wireframe storyboards are sketched and then validated with cognitive walk-throughs. Low-fidelity prototypes are then created and checked against essential story scenarios, eventually leading to the development of high-fidelity mockups and prototypes.

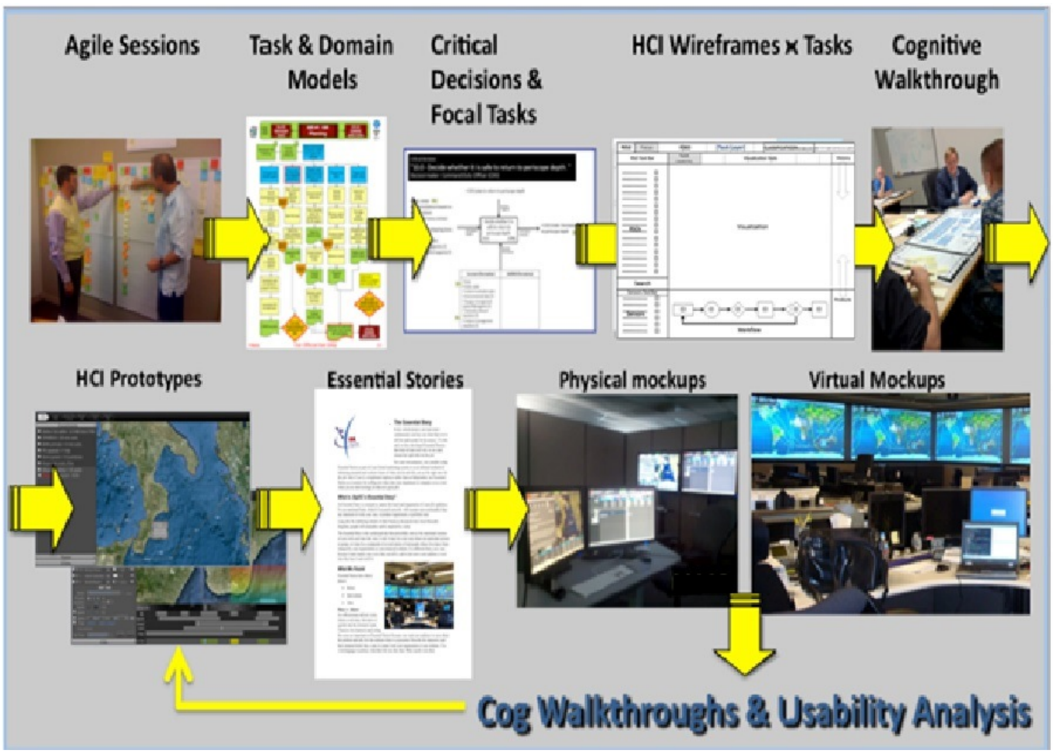

Figure 1. User-centered design (UCD) overview.

The result of the UCD process provides consumers with human–machine interfaces (HMIs) that lack the visual absence of every system function and result in a task-based structure. Function-based HMIs are the result of a data-centric systems engineering process that squanders the concept of human task goals and task needs, while only satisfying the engineering goals for functional flow. In contrast, task-based systems are characteristic of software/hardware development efforts that have utilized the human engineering practices of user-centric or work-centered approaches. While systems certainly require function-based presentation layers, most commercial multimedia devices now protect the consumer on the top layer from the complexity and details of the software programming.

UCD focuses on human interface design principles that are based on the human mental and physical requirements for a given set of tasks, and is not focused on the functional capabilities of the system. Most smart phones and tablets provide a modern example of user-centric design; these devices provide a consistent and simplistic user experience (UX) by not requiring consumers to think about how the phone or tablets works. You do not have to understand the machine functions to make the machine work. The consumer can simply use the phone or tablet by following easy-to-find affordances or recognizing simple metaphors.

UCD is a multistage agile problem-solving approach that allows end-users, stakeholders, and operational leadership to design the human interface, testing the validity of their assumptions, using a rapid prototyping process. The UCD process produces HMI layouts that will improve total system performance and which, in turn, will provide the end-users with more rapid situational awareness. User-centered design is an approach for design that optimizes the relative synergy of human and machine with GUIs that are optimized for human capabilities and limitations. UCD has been able [3] to build display layers to optimize human performance to conduct mission operations while balancing task load between machine capability and operator needs.

UCD also considers the levels of situational awareness (SA) as described by Mica Endsley in reference [4], as lying "at the heart of all human decision making and performance" and are directly attributable to individual and team performance:

Level 1 SA: Perception of the elements in the environment within a volume of time and space.

Level 2 SA: Comprehension of their meaning.

Level 3 SA: Projection of their status in the near future.

Legacy systems are data centric: Data drives the workflow and requires the operator to make sense of the information and determine the next action. This legacy approach requires the end-users to establish and maintain their own mental models and heuristics of the command environment as described below:

<u>Today - Struggle for Level 1 SA</u>

Models and heuristics - system focused

Systems and procedures - reliant upon user cognition and recall

Trigger - human observation, limited automation

Orient - search, aggregation across disparate sources

Decide - no decision support systems. Raw data presented

Produce - outputs are manually produced by hand or verbally

Deliver - many manual tasks

Confirm - often poor feedback; no tracking of tasks

Transition - no user help

UCD provides operators with leveled and layered information relevant to mission tasking, aligning to CONOPS (concept of operations). This user-centric approach will drive the workflow based on operator needs and provide intuitive HMI layouts that make better sense of the information to processes required to achieve a mission task or action. The user-centered approach for Pre-Milestone A development will provide consumers with the right top layer of information specific to their mission tasking supporting better awareness of command connectivity:

<u>UCD - Level 2 and Level 3 SA</u>

Models and heuristics - user focused

Systems and procedures - captured in user interface and presented in proper layer

Trigger - automation assists in all major mission tasks

Orient - brings information to war fighter in concise formats

Decide - provides evidence & explanation

Produce - provides for review of draft outputs

Deliver - simplifies delivery and execution

Confirm - thorough feedback for current, past and future tasks planned

Transition - orient toward critical activities needing attention

UCD can optimize manpower and achieve more capability at less cost. UCD can generate the "correct" watch floor structure and workload balance to ensure operational success while gaining significant reductions in initial and sustainment training. The prime benefit from UCD is the increased operational SA from user interfaces developed with a repeatable and iterative methodology. Operational displays are derived from prototyped HMI concepts that ensure operational primacy and workload reduction for manned and monitored systems. This also realizes significant reduction in life-cycle constraints and significant savings to integrated logistics support (ILS) and integrated logistics environment (ILE).

The design methodology and procedure for the creation and modification of the HMI is an iterative process that relies on three pillars: Operator feedback, domain expertise, and human factors best practices. The design process for the HMI will fit the structure of the sprint/scrum, service pack, and incremental delivery schedule, and is adaptable to support evolving operations and user goals, as well as potential cost and schedule changes in the program. The process for design begins with requirements analysis to understand the upcoming development needs and toolsets required for the acquisition. Next, legacy tools are evaluated to identify processes and products essential to current operations. Then, technical interchange is established among the HMI designers, mission application providers, and SMEs to prove a conceptual design and create a development roadmap. The HMI team then creates an initial design that will be utilized to engage users and elicit initial feedback to concepts created by the team. Once this feedback is integrated back to the development team, development iterations of capability occur. These iterations also include additional user and SME engagement as capabilities become tangible. The capabilities and service packs are deployed and fixes are made according to the program's evaluation of user change requests, testing bugs, and operations acceptance needs. Throughout this process, iterative user feedback incorporated into the design significantly reduces inefficiencies and facilitates current operations.

Persistent throughout the procedure for Milestone A and B design and development is the need for embedded human factors and cognitive science expertise. This expertise will be utilized in the design of the HMI to aid in the decomposition of requirements, in concert with SME support, and must be specially applied in cases where capability developers do not have such expertise. Human factors (HF) best practices are also applied to the user engagement processes to ensure the highest quality of user feedback and translation into development tasks and requirements. HF engineering will then be applied iteratively as part of the development cycle, including but not limited to the initial screen design, user engagement iterations, and HMI design patterns. HF expertise will also then be embedded in the test and fix cycle to ensure efficient understanding of user change requirements and test findings and their fixes for successful integration into the service pack baseline. Also, HF expertise will be utilized to customize and tailor HMI documents and capabilities to specific mission requirements and seat positions within the system enterprise.

The process of designing the HMI begins with the analysis of requirements from the applicable documentation including the System Requirements Specification (SRS), Application Requirements Document (ARD), Functional Requirements Document (FRD), and the Capability Development Document (CDD) when a higher level context is needed. In the case of the increment delivery schedule, work breakdown structure documents and the SRS are utilized to specify the time and scope for delivery of components. From the requirements analysis phase, the HMI team expects to have clear guidance on mission applications, tools, and capabilities that will be delivered per sprint or service pack. The HMI team should be able to create a very high-level architecture based on knowledge elicited from analysis of requirement documentation and work patterns found during the UCD process.

The discovery and capture of specific artifacts produced by the user community during user engagement events is essential to the design process for the HMI. The origin of such artifacts, including the overall data flow (inputs, processes, and outputs), must be captured before the HMI can be fully designed. Input files and data, specific legacy applications, output formats, and delivery vectors must be identified and codified to accurately associate their creation and delivery, and also to facilitate better productivity and process flow.

Legacy applications used to create outputs or complete work must be carefully analyzed by those with applicable C2 expertise. The legacy system architectures must be fully vetted for process controls and potential areas of improvement and analyzed in the context of program requirements to aid in the satisfaction those that are legacy-related or focused.

Also, design personnel must fully encapsulate patterns of interaction from high levels (e.g., use of tabular data and interactive graphing components) down to terminally specific implementations of data, such as specific step-by-step procedures necessitated by the underlying command and control computations and the variables assigned to each piece of data. User engagement will facilitate both the determination of these existing steps, and should also elicit shortcomings, stopgaps, and areas for process improvement for HMI implementation.

Once existing technologies, procedures, and outputs have been identified to prototype a high fidelity HMI, UCD identified replacement applications and technologies must be assessed for data flow, interaction patterns, infrastructure design, and data service availability. Technical interchange meetings are a valuable method for determining the lowest level of detail regarding mission application inputs and outputs, infrastructure capabilities (such as the availability of Web services for data passage, synchronicity, etc.), and potential HMI display technologies. New or parallel development for mission applications, infrastructure, and HMI must be discussed and fleshed out as a part of this process. Any shortcomings in planned services or applications will be identified early in the development process and will allow the development teams to close any critical gaps that are found.

After interfacing with domain experts, end-users, and potential mission partners, an initial design of the HMI will be created. This design is very high level and includes an overall infrastructure-interaction plan, mission application interfacing plan, and first-cut HMI sketching in the form of wireframes, toolsets, and demonstration screenshots. This design utilizes many guiding concepts, including the software development kit (SDK) design patterns and style guide, C2 expertise, and customer support requirements. Once this design has been created, user engagement is necessary to validate the interface design and interaction components. Initial design can be validated against functional requirements, job task analyses, and workflows. The user community should examine the design, interaction patterns, and output creation processes at a high level with the SMEs to address proposed interaction and elicit shortcomings with the design prior to implementation.

Using the results of the initial design and user engagements, the lead HMI designer will consolidate the design into actionable components and interact with technical staff on the development strategy for the components that have been designed. Development will occur via the sprint/scrum or service pack process. Iterations of development will occur on specified intervals, with the HMI design team specifically integrated in the development process prior to delivery of code for integration.

The development, iteration, and user engagement process will ensure that the HMI is built in accordance with data elicited and knowledge gained from all the previous steps in this process. It will also provide the consumers with possible new or improved capabilities, and provide feedback and guidance on the design and implementation of potential new mission applications.

After service pack delivery, it is expected that user change requests (UCRs) for the HMI may be submitted during the formal integrated test cycle. Program management leadership and the program office will evaluate and prioritize UCRs during the period prior to the update and redeployment of technologies. As part of this process, the HMI team will utilize the results from this evaluation to formally analyze and implement changes required for the fixing of bugs, user satisfaction, and ultimately operational acceptance of the final product.

BENEFITS OF USER-CENTERED DESIGN

UCD is a practice within HFE. Most of today's systems are data-centric: Users must make sense of the information and processes to act. UCD provides C2 operators and maintainers leveled and layered information designed from tasking, aligning with "Lines of Operation" (LOO). This user-centric modeling will drive the workflow based upon the user's needs and provide intuitive HMIs that make better sense of the information and processes required to achieve a task or action for the LOO and appropriate layer for the level of war.

Layer 1. Quick-look always available or one-key popup. *Team and individual*

Layer 2. Information summaries and assessments. *User configurable, team and individual*

Layer 3. Detailed toolsets and analysis work domains. *User selectable, individual*

UCD provides an approach to design that optimizes the relative synergy of human and machine through an innovative design approach that focuses on the tactical needs of the warfighter. This approach results in a simple human–computer interface construct that is both understandable and repeatable, and is relevant and responsive to the dynamic battle space environment.

A shift towards user centric modeling described here can achieve the enhanced SA required to support the anticipated C2 human workload increases. Modeling the workflow of the operators and maintainers who will operationally employ the capability provides opportunities to reduce the cognitive workload and interpersonal communications required in maintaining SA. Moreover, governance and guidance documents have mandated the program manager accountable to the task of employing HSI to achieve total system performance established within established in DoD 5000-series.

By identifying specific mission-related human performance metrics, quantitative models of human operators/maintainers tasks and workflow are factored into the system engineering and design requirements. The establishment and inclusion of such requirements are communicated and stressed throughout the design process to ensure compliance. The resultant product is an optimized system design improving total product performance, reduced life-cycle cost within schedule parameters of the acquisition process, and a system built to accommodate the characteristics of the user population that will operate, maintain, and support the C2 system. UCD provide C2 PORs with a specialized focus to implement product designs that achieve more capability with fewer equipment operators and maintainers, optimizing total system cost and performance.

REFERENCES

1. M. B. Cowen and J. L. Kaiwi. 2010. "Key Human System Integration Plan Elements for Command & Control Acquisition." *Proceedings of the Command and Control Research & Technology Symposium*. June 22–24, Santa Monica, CA. Available online at http://www.dodccrp.org/events/15th_iccrts_2010/papers/033.pdf. Accessed 11/25/2014.

2. A. G. Lemon and M. B. Cowen. 2012. "A Task-based Design Guide for Command and Control." *Proceedings of the Command and Control Research & Technology Symposium*. June 19-21, Washington, DC. Available online at http://www.dodccrp.org/events/17th_iccrts_2012/post_conference/papers/032.pdf. Accessed 11/25/2014.

3. G. Osga, K. Shobe, D. Kellmeyer, J. Waters, G. Ramstrum, and B. Croft. 2009. "Optimizing Performance for Mine Warfare: A Case of Task-Centered Design." *Proceedings of the Human Systems Integration Symposium*. March 17–19, Annapolis, MD. Available online at http://www.navalengineers.org/SiteCollectionDocuments/2009%20Proceedings%20Documents/HSIS%202009/Papers/Osga_Shobe_Kellmeyer_Waters_Ramstrum_Croft.pdf. Accessed 11/25/2014.

4. Mica Endsley. 1999. "Situation Awareness and Human Error: Designing to Support Human Performance." Available online at http://209.238.175.8/Papers/pdf/Sandia99-safety.pdf . Accessed 11/25/2014.

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14. ABSTRACT

In this report, human factors engineers from Space and Naval Warfare Systems Center Pacific (SSC Pacific) describe the user-centered design (UCD) engineering process as a method to design, develop, and build sensible graphical user interfaces (GUIs) for command and control (C2) equipment. UCD is an SSC Pacific best practice within the human factors engineering (HFE) domain of human systems integration to optimize the design of the C2 human–machine interface by reducing the equipment operator's cognitive burden of assimilating and acting upon disparate C2 information. The UCD process follows an analytical HFE design methodology that involves direct user engagement sessions to construct cognitive models of command situational awareness, workflows, use cases, and other artifacts to directly support rapid and agile prototyping.

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