SPAWAR
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San Diego

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A Human–Computer Interface Vision for Naval Transformation

Nancy Campbell
Glenn Osga
David Kellmeyer
Daniel Lulue
Earl Williams

SSC San Diego

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SPAWAR
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SSC San Diego
San Diego, CA 92152-5001

SSC SAN DIEGO
San Diego, California 92152-5001

T. V. Flynn, CAPT, USN
Commanding Officer

R. F. Smith
Executive Director

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Released by
G. Osga
User-Center Design
Business Area Manager

Under authority of
J. Martin, Head
Simulation and Human Systems
Technology Division

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CONTENTS

Figures

Tables

1. INTRODUCTION

A transformation is needed in Human–Computer Interface (HCI) to accommodate transformations in information availability, computing power, and changing warfighter roles. The HCI paradigm should be transformed from system-centric to mission-centric, and the HCI should be decoupled from individual weapon/sensor/command and control (C^2) systems to span across multiple systems to accomplish mission goals. A mission-centered design (MCD) approach can achieve the needed revolution in HCI via transformations in three areas: (1) HCI Design (how the HCI supports the warfighter); (2) HCI Design Process; and (3) HCI Software and Information Management Infrastructure.

A Mission-Centered Design Consortium (MCDC) should be created to advance each of these transformations through the creation of open standards and the development/description of best practices.

2. WHY TRANSFORM HCI?

"The United States is transitioning from an industrial age to an information age military. This transition requires transformation in warfighting and the way we organize to support the warfighter." (Department of Defense [DoD] Transformation Planning Guidance, April 2003). This transformation is necessary to maintain our overwhelming military advantage by exploiting information age technology at a rate faster than our future adversaries. A key point is that warfighters exploit the information advantages, not be overwhelmed by them. One lesson learned by the G2 of the 1st Marine Division during Operation Iraqi Freedom was the inundation of information and data that "had little bearing on their mission or Intelligence requirements. Information was not disseminated based on a proactive evaluation of what supported commanders needed, it was just disseminated. There seemed to be little thought to tailoring information to specific MSCs [Military Sealift Command] or develop products that directly anticipated an MSC requirement." (report attached to memo from Commanding General, 1st Marine Division, dated 29 May 2003).

Coupled with the transition from platform-centric to network-centric warfighting is a budgetary demand to decrease military costs, including costs related to crew size. Any reduction in personnel cannot be made at the expense of mission performance. HCI design plays a critical role in enabling warfighter performance, reducing training time, while accommodating increases in data quantity and complexity across a broad range of weapon and sensor systems. When done effectively using standards and protocols, HCI design supports inter-service and multi-national interoperability.

HCI transformation is timely because of the current shift toward network-centric warfare, with changes and upgrades to legacy systems and with new system innovations. HCI is as much about *design* as it is *process*. The following specific requirements demand that a transformation in HCI occur:

- <u>Need for multi-tasking</u>: With a decrease in the number of warfighters, yet an increase in the number of weapon/sensor/C^2 systems, the remaining warfighters of the future will manage more systems concurrently. No longer can the military afford a 1:1 correspondence of warfighter to each mission component system.
- <u>Need for increased mission cognizance</u>: The warfighter is no longer dedicated to a single system. He/she must maintain a higher level of cognizance and focus on mission goals that may use several systems. The rapidity of warfare requires cognizance at all levels of command authority in appropriate detail.

- Need for supervisory control of systems: There will be an increasing reliance on computer systems to perform procedural functions to offload the remaining warfighters. With increasing automation, the role of the human changes from a data collector/analyzer to a decision maker working in cooperation with automation.

These new warfighter roles require significant changes to HCI design to ensure increased efficiency (short response time, no errors, and minimal training time). The multi-tasked supervisor of automated systems must maintain a higher level of awareness across several systems. His/her job is to achieve an operational goal that may span the information and capabilities of several systems. When the operational goal is well defined, the HCI must assist the warfighter by maintaining his/her focus on accomplishing the individual tasks to achieve these goals. The warfighter's primary interaction with multiple weapon/sensor/C^2 systems cannot be at the individual system level; it must be at the operational mission goal level. Therefore, the primary HCI must span across systems yet be focused on the user's mission goals. The warfighter must not be forced to interact with multiple disparate HCIs from each individual system.

An efficient military HCI then is one that seamlessly buffers the warfighter from the idiosyncrasies of individual weapon/sensor/C^2 systems, and assists him/her in focusing on the mission goals. There can no longer be disparate, inconsistent, stove-piped HCIs that force the warfighter to interact with each system separately. The HCI can no longer belong to the individual weapon/sensor/C^2 systems. The HCI of the future is a system of its own dedicated to assisting the warfighter in accomplishing his operational goals in the minimum of time, with minimal errors, and requiring minimal training.

Other advantages of a common HCI infrastructure include:

- Consistent HCI: Display styles and system control methods are reused.
- Evolvable: Isolating the HCI from the weapon/sensor/C^2 systems allows a separation of growth with minimal repercussions.
- Reusable HCI components: Frequently used HCI components (e.g., maps, symbols, report formats, decision aids) can be maintained in a software library. These components can be tailored for each specific task or as defined by the weapon/sensor/C^2 system, but the basic template is reusable.
- Reusable watchstations: Specialized watchstations will become less common. The common HCI system will reside on more generic watchstations that can accommodate multiple operational goals and tasks.

Recent advancements in technology make this separate HCI system possible:

- Open systems: A single HCI system depends on its ability to perform data input/output for the weapon/sensor/C^2 systems. The data therefore must be readily available to all systems that need it.
- Standard architectures: Several standardized architectures to accommodate open systems have been developed, e.g., Sun J2EE® (Java 2 Platform, Enterprise Edition), Microsoft® .NET, and open-source, web-based architectures.
- Computing power: Enormous quantities of data become available when weapon/sensor/C^2 systems open up their data to the HCI system. These data must be intelligently filtered to avoid overloading the warfighter. When the warfighter's mission is known, the HCI system can intelligently filter the data to focus on assisting the warfighter in accomplishing his/her goal.

We must continuously evaluate emerging requirements, coupled with advancements in technology, to apply smart innovation that will reap rewards in improved performance and cost savings. FORCEnet is one such concept meant to revolutionize Navy system interconnectivity. The time is right for a revolution in HCI as well. An HCI system overarching across multiple weapon/sensor/C^2 systems using the interconnectivity provided by FORCEnet is a perfect match for this vision of future Navy capability.

In this document, we discuss the means to achieve these requirements, which then forms the basis for transformation in performance and operations. HCI alone cannot achieve transformation; but when done poorly or without regard to human capabilities and limitations, it can become a block to other technology or process advances. We present the notion that MCD for HCI, when coupled with a process that works in DoD design and procurement, together with cost-cutting and enabling software methods, enables a jump from today to a transformed Navy human–system capability.

3. HCI TRANSFORMATION GOALS

HCI transformation is about design requirements and results, together with a process for engineering development that includes legacy and innovative system components. The HCI design paradigm should be transformed from system-centric to mission-centric, and the HCI should be separated from individual weapon/sensor/C^2 systems to span across multiple systems to accomplish mission goals. An MCD approach can achieve the needed revolution in HCI via transformations in three areas:

- HCI Design and Requirements (how the HCI supports the warfighter)
- HCI Design Process
- HCI Software and Information Management Infrastructure

3.1 MISSION-CENTERED HCI DESIGN

HCI encompasses not only display format, but content, context, management, and delivery. Today's design is most often data driven and function centered. Designers place data into windows by data type—tactical maps, tabular data, multitudes of status displays. In recent research (Osga et al., 2002), we have defined key cognitive requirements for warfighter support throughout the entire decision process and across a multitude of tasks. Mission tasks require analysis, synthesis, and combination of data types to provide for mission task solutions. Designers leave much of the manual labor to the warfighters at all levels of tactical and operational levels. Key facets of an MCD in comparison to today's approach are shown in Table 1. The reader is referred to other papers for further details on these design qualities (Osga 2003a, 2003b).

An MCD approach to HCI centers on supporting the mission goals and interim mission products that the human and system must produce. This approach provides *explicit* mission and task visualization, increases support for all cognitive task phases, visually links information across tactical maps and mission plans and solutions, and focuses software and design to prepare high-quality mission task products. Products may be as broad as a coordinated strike plan or as focused as an individual air defense track update report. The warfighter is then "freed" from complex manual labor at all levels and can become a strategic thinker, planner, and manager of mission tasks—the desired roles for warfighters in a transformed Navy. The HCI design directly focuses on the tasks that must be accomplished to achieve a mission goal, rather than on an individual system's functions. The entire mission is supported via a Mission-Specific Presentation Layer common across multiple systems. All phases of the warfighter's cognitive and visual work are supported by the HCI software: initiation, orientation, decision, product development and delivery, confirmation, and transition.

Table 1. Comparison of future HCI goals with today's capabilities.

MCD HCI Transformation Goals	Comparison with Today
Explicit mission and task visualization.	Mission process visualization ignored in design.
Support all cognitive task phases: initiation, orientation, decision, execution, confirmation, transition.	Support missing for task initiation, often with poor orientation, complex execution, poor confirmation, and no support for transition.
Support work management.	Support is non-existent – relies on training community and missing in design.
Visually link information.	Limited visual linking – not in a task context.
Prepare high quality mission task products.	Data dumps in windows by data types – not product oriented.
Build for evolution over time	Hard-wired, stove-piped individual HCI for every subsystem with costly evolution.

An HCI produced through MCD provides explicit mission and task support, intelligently pulling task-relevant information from multiple sources. The HCI and supporting infrastructure anticipate the needs of the warfighter, presenting only relevant information to support his/her task, while also presenting options and product candidates for the warfighter to chose from. The warfighter remains the decision maker; the software becomes his/her executive assistant performing the menial tasks that computers do well. The warfighter maintains the flexibility to bypass the recommendations made by the assistant and to deviate from preconceived software-assisted tasks that may not fit unanticipated situations. But for all mission tasks that can be anticipated, the HCI and supporting infrastructure are fine-tuned to minimize warfighter workload and errors while maximizing decision speed and quality.

MCD HCI also crosses the boundaries of multiple systems and mission phases. The emphasis is on the integration of warfighter and mission(s), working in harmony and synchronization from pre-planning, through planning and execution, from tactical through operational to strategic mission goals. This approach is in contrast to working from sensors to databases and networks ending up with reams of data dumped into windows with a huge training and warfighter workload burden to turn these incomplete results into mission products. The methodology exists in structured scientific methods within the domain of Human Factors Engineering, using a Cognitive Work Analysis (Vincente, 1999, 2002), which focuses system requirements on supporting the warfighter by performing a Work Domain Analysis (WDA), leading to high-quality requirements and design that is developed and tested using structured prototyping and usability testing.

This MCD approach has been successfully demonstrated within the Air Defense Warfare mission domain (Osga et al., 2002) and is currently being applied to Land Attack Warfare (Kellmeyer et al 2002) and the DD(X) program.

3.2 HCI DESIGN PROCESS

MCD requires careful analysis of mission processes and workflows. VADM Albert Konetzni, Deputy Commander and Chief of Staff for the Atlantic Fleet, has stated that the military "has largely abandoned operations analysis….A better path would be one in which proposals for innovation are studied analytically and developed with a 'complete plan'—including concept of operations, training, and maintenance—before we throw these things on our ships" (speech to the Armed Forces Communications & Electronics Association (AFCEA) Transformation TechNet 2003 conference, 13 May 2003). An HCI design process must not only perform the up-front cognitive work analysis needed to ensure support for the warfighter, but must include expert warfighters early and continuously throughout the analysis, design, and development of the HCI.

The products from a representative MCD process are shown in Figure 1. There are four basic phases in the MCD process: Analysis, Design, Implementation, and Development. Each box in Figure 1 represents a product produced during one phase of the process and is color-coded to signify which process phase produced it.

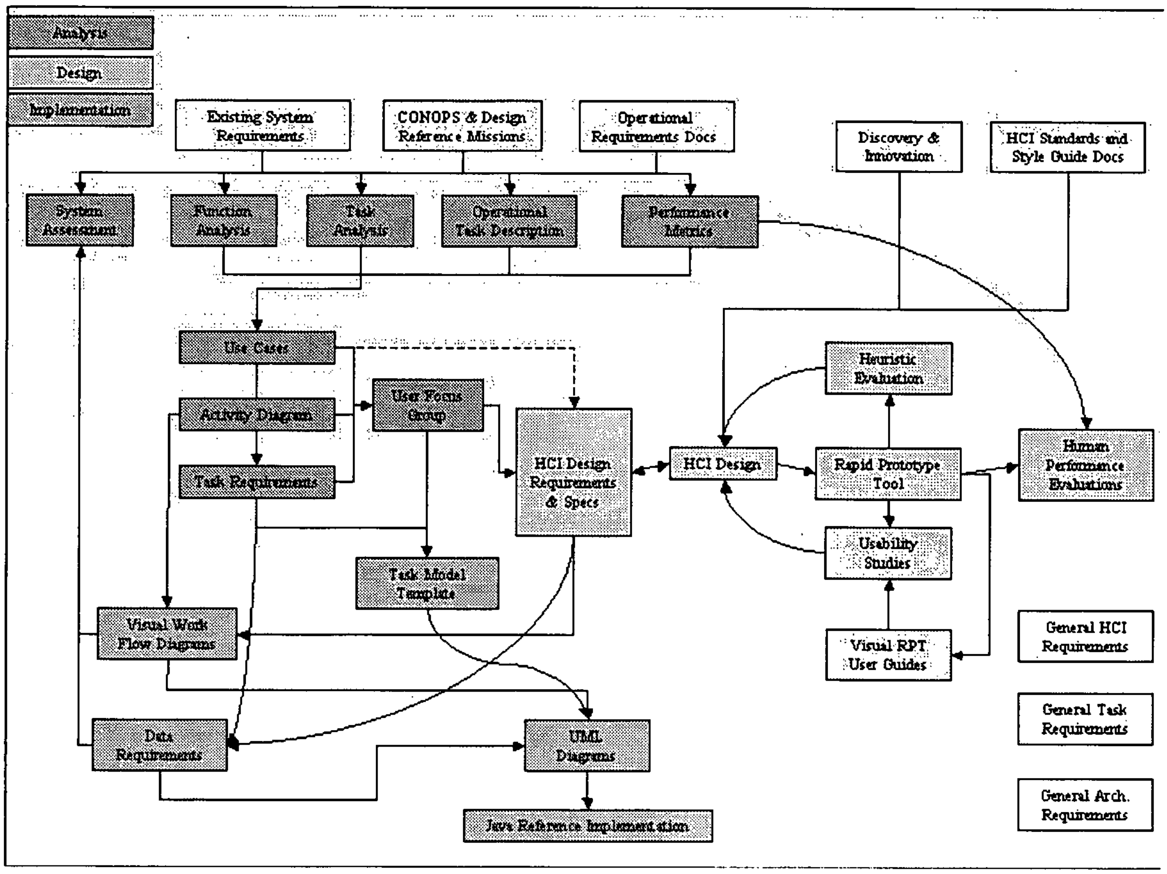

Figure 1. Representation of HCI design and test process.

3.2.1 Analysis

The Analysis Phase focuses on understanding the warfighters, their mission, the environment they work within, and the tasks they must perform to achieve their mission. The goal of the Analysis Phase is to develop Use Cases that define the warfighter mission goals. An Activity Diagram details the task steps, task allocation (who does the task), decision points, information requirements, and major task products. Existing Performance Metrics are examined, and may be modified. These metrics will be used in the evaluation of the design. The primary mechanisms used to obtain these

Analysis Phase Products include cognitive work analysis, task analysis, field studies, and user focus groups.

3.2.2 Design

The Design Phase focuses on developing a design that allows the warfighter to perform each of the Use Cases identified during the Analysis Phase. This phase begins by identifying the HCI requirements for decision making, information presentation, process monitoring, collaboration, etc. An investment in research and development (R&D) can refine design concepts specific to mission domains to reduce risk during formal implementation. Re-useable and generalized HCI design patterns (decision support templates) are refined into task-specific display components based on the specific task requirements. For example, a general mission response plan template may be refined into a time, range, or step-based format depending on the type of mission task (see Osga, 2003b). Specific task products are formulated for each important step or phase of the mission process. Then cognitive walkthrough and design sessions are required to customize these displays to support the defined Use Cases. Low-fidelity prototypes are used to evaluate initial designs via user (warfighter) focus groups, heuristic evaluations, and usability testing (with warfighters). The input from these evaluations is then compiled into a draft User Interface (UI) specification used to produce a high-fidelity prototype. These higher fidelity, dynamic prototypes can be used to evaluate the aspect of time and how the design fits within the general UI framework. The defined Performance Metrics are used to evaluate the high-fidelity prototype in another round of usability testing. The results are factored to produce a final design that is documented as a User Interface specification for implementation. The warfighter is incorporated early into the design and testing process using this approach of iterative design and usability testing. This improves the HCI product quality, reduces risk for product acceptance, and requires fewer modifications to future software builds.

3.2.3 Design Reference Implementation

The goal of the Implementation Phase is to model the defined UI specifications and the decision, information, UI, and task requirements into software design. Frequent discussions are needed between the software designers and the HCI designers to ensure thorough understanding and intentions from the Design Phase. The software designers also evaluate adapter requirements for legacy systems and propose architectures for new systems in this phase. The Implementation Phase results in a reference implementation that needs to be subjected to usability testing as soon as possible to ensure that requirements and specifications had been interpreted correctly. An initial means for confirming successful interpretation is a heuristic evaluation.

3.2.4 Development

The Development Phase is the actual coding of the UI design, and may be done by a different team (e.g., a primary contractor) than the team that executed the analysis, design, and implementation phases. Users (warfighters) should be involved as frequently as possible to evaluate the final product. Once fielded, a mechanism to collect user feedback should be introduced and field studies conducted to observe how users are actually employing the fielded system. These observations should be documented and provided as inputs to the next Analysis Phase.

3.3 MCD HCI INFORMATION MANAGEMENT AND ARCHITECTURE

Mission requirements and processes change over time. MCD requires software architectures that are amenable toward changing task conditions. Hence, we should build using architectures that allow for new task support and reduce cost and development time. Fortunately, best practices in modern

Web-based computing afford designs with a separate HCI presentation layer, which can use adapters to access task-relevant information from legacy systems. This allows us to transition from today and add new capabilities for tomorrow in a common approach.

To truly revolutionize toward an MCD, we need to develop a standardized terminology and modeling language for representing missions and their interrelated tasks. This would involve the development of a standardized markup language for tagging task-relevant information so that systems can publish data according to the standard, and mission-centered HCIs can then subscribe to it. Currently, there may be several Navy mission domains each needing the same type of task products and decision support, yet each is paying for engineering development and production. They could be making minor changes to common aids at much reduced corporate Navy cost. As naval capabilities evolve and grow with new sensors, weapons, and joint collaboration, redundant software changes in HCI across system domains are minimized and new decision support capabilities can transition from R&D to field use in a minimized time. Within this open architecture, information must flow freely from source to use. Barriers and stovepipes within Navy and across joint mission domains must be reduced. The goals of FORCEnet can support these MCD requirements.

Figure 2 shows a candidate MCD architecture deployed as a distributed, task management enterprise application. The presentation and application tiers connect to corporate information management systems via Web Services and custom adapters. Presentation clients are both thin and thick, as dictated by HCI autolinking requirements. Thin clients can also run on laptops and other systems outside the watchstation cluster. This means, for example, that currently unsupported (by a watchstation) warfighters have access to mission planning and weapon control system information. The automated assistance of task and workload management is implemented within an application server that supports a team of warfighters. Mission tasks are triggered by external events such as a call-for-fire or hostile track detection by the legacy system. Tasks execute on the clients (presentation tiers), mediating the presentation of data, status, and draft products in the HCI to the warfighter. The connection tier "talks" native protocol on the legacy side, and standard Web Services on the task management side. The legacy system's public functions have been exposed through a variety of means, including native application programming interfaces (APIs) and Common Object Request Broker Architecture (CORBA).

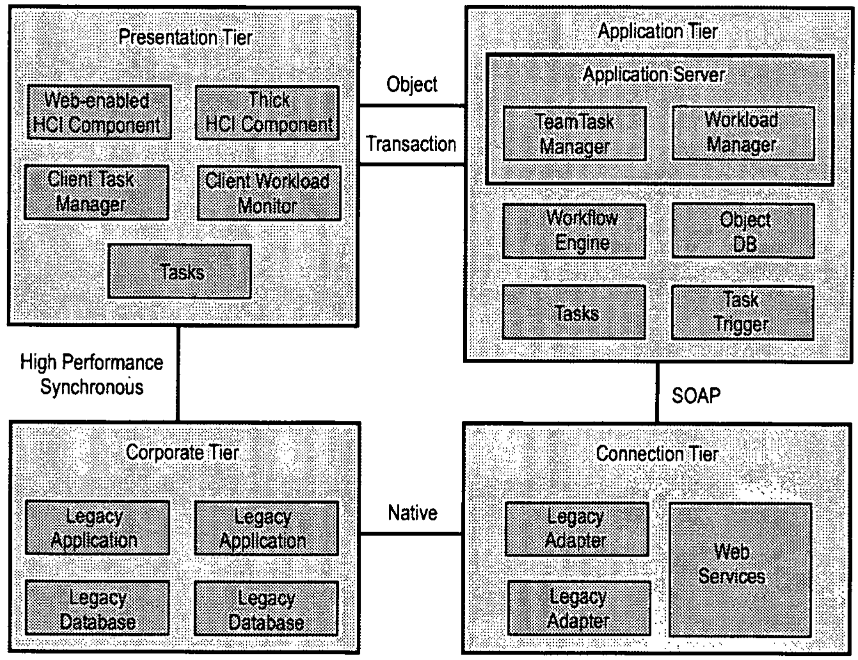

Figure 2. Conceptual model of a task management system deployed in an enterprise architecture.

4. HOW TO TRANSFORM HCI

A Mission-Centered Design Consortium (MCDC) should be created to advance each of the HCI-related transformations (design, process, software, and information infrastructure) through the creation of open standards and the development/description of best practices. The goal is to nurture active participation in a DoD-wide consortium modeled on civilian standards definition organizations.

Currently, individual Program Offices make decisions on HCI related to procurement, administration, quality control, configuration management, etc. Commonality occurs only to the degree that standards such as DII/COE (Defense Information Infrastructure/Common Operating Environment) are used or enforced. To achieve significant performance improvement and impact on mission success, the notion of HCI must be expanded beyond the bounds of individual systems and their associated Program Offices. "We must change from an approach that is optimized by program and platform to one that can solve the challenges of integrated systems that cross many platforms and functions" (Navy message from Assistant Secretary of the Navy, Research, Development and Acquisition (ASN RDA) dated 11 Oct 2002 on ASN RDA Realignment).

The design notion of MCD embodies a connected set of HCI models or design views. There is no one single "ownership" issue but, instead, multiple issues of sharing design knowledge and design practice at each level of the design view. There may be Central Ownership of agreed-upon standards and the HCI infrastructures, but quality control and content for specific warfare and task-specific components and their content should remain the responsibility of individual Program Offices. The net result is that centrally owned tools, standards, and infrastructure allow for an easier "plug and play" method for assembling innovative decision aids and HCI tools. The ultimate goal for any HCI design business strategy must be to bring the best result to the warfighter with the most efficient design process.

The following qualities should exist in future HCI design practice:

1. Standards for information sharing and availability. Standards are useful to allow connectivity and information interchange among systems and components. This is required for successful inter-Navy and joint collaboration through electronic (vice voice) means. Within warfare domains (air strike, land attack, mine warfare, undersea warfare, etc.), information should be posted and shared in a seamless manner. Information should be made available to other domains as security levels allow. Collectors and producers of data (e.g., sensors, intel) should be required to post data in a format that is accessible by information databases and decision support tools. The format for HCI-related information should be established by the MCDC.
2. Common warfare decision support tools. There are common cognitive decision-making requirements across mission domains, e.g., warfighters need to see the mission plan as well as any delays or roadblocks relative to the plan. The need exists to visualize current and future events. There could be a central ownership of various decision support tools, with variations available to Program Offices for tailoring to their specific domain. For example, there could be time-, range-, and step-based formats for representing ship doctrine/processes for each mission in a decision support tool called the Response Planning Manager (RPM) (Osga et al 2002). (The notion and requirements for the RPM were derived from Office of Naval Research (ONR)-sponsored 6.2 and 6.3 research.) In this manner, a Program Office preparing a new RPM or updating a previous RPM would save cost and time while focusing on the specific RPM requirements for their mission domain.
3. Best-practice information architectures. The information architecture supporting the HCI—thus supplying information to decision aids—should be standardized such that decision aid developers can integrate updated tools and techniques into an open architecture. Management of the architecture should be within an enterprise or domain such as a major systems command (e.g., Space and Naval Warfare Systems Command, Naval Sea Systems Command) but certainly could be broader (all combat and C^4I systems [command, control, communications, computers and intelligence systems]). Any information support architecture should support the premise of HCI Design Practice item #1 above, that information can be shared and accessible by decision support tools across domains. The architecture should be open and shared and a consensus of the government and industry consortium (MCDC). This would result in the incorporation of best ideas and improvements, with shared benefit for all developers and users. The MCDC should define the architectural system structures, their components, relationships, and the principles and guidelines governing their design most appropriate to MCD.
4. Proprietary and non-proprietary components. Proprietary components should be minimized, though they may be necessary at some level to foster competition. Competition is healthy for innovation and new ideas, while proprietary components can impede innovation and progress when an established company has little motivation for change or risk. For HCI, competition among decision support tools could be healthy and foster design innovation. In the example above, an improved RPM would benefit fleet operators. Thus, developers of decision tools such as the RPM may be allowed to hold their design qualities as proprietary to protect intellectual property. However, the infrastructure and integration standards into which the decision tool interacts and connects to the broader tool-base should be open and shared. Thus, it should be easy for a developer who desires to create a new RPM to inspect the MCDC requirements and use the integration specifications to develop a new version of the RPM tool.

A spiral development program should be fostered where anyone at any time can present an improved design for a decision aid to support iterative design improvements with faster introduction to the fleet.

5. Standards for decision tools plug and play. The MCDC should establish and control the standards for how decision support tools plug and play in the common HCI architecture. The standards should be based on Navy stakeholders in each mission area producing a method that supports the performance requirements for each warfare domain. If a single standard or approach cannot be identified, tiered approaches based on cost and performance may be selected.
6. Task Library and Definition. Ultimately, an MCD is based on a mission process and concept of operations (CONOPS), and identification of tasks and products within the defined operational concepts. Naval Warfare Doctrine Command (NWDC) has recently been in the lead in the development of Navy Task Lists, which are related to Mission Essential Task Lists and Joint lists. These lists must be improved and extended down to an operational and tactical level to support MCD at the individual weapon and sensor system level. The tasks must mature beyond title or task name and be subjected to a rigorous work-domain analysis and/or cognitive task analysis. This would be a large undertaking likely beyond the capacity of NWDC and should be shared by the warfare specific domain Program Offices. The resulting task identification and cognitive requirements provide guidance to developers and designers of decision support systems for those tasks. Information should be managed and stored by NWDC or possible ASD (RDA) CHENG (Assistant Secretary of the Navy for Research, Development and Acquisition, Chief Engineer) personnel and available as needed by developers. Common task characteristics can be extracted to develop a standard, template definition of a warfighter task. The MCDC would determine the best methodologies for software modeling of the generic task that could then be reused in all task implementations. The MCDC would also resolve ambiguities in terminology such as the relationships between tasks, subtasks, workflow, work items, task steps, etc.
7. HCI Testing Standards. The government should set standards for HCI usability testing such that developers know precisely what level of test is required to ensure that usability test goals are met and represented in the test results. These standards should be held by a central Navy-wide policy command such as Office of the Chief of Naval Operations (OPNAV) N-125 H.S.I. Division. The important points of usability testing are that different levels of fidelity are allowed (ranging from paper to full mockup) and that it should occur early in the design process and iterate throughout. The MCDC can also establish a set of target performance metrics and specifications that a system based on MCD must achieve.

Difficulties that typically impede inter-program cooperation and advancement on HCI-related standards often stem from the fact that no two programs are ever in the exact same stage of development. Some programs are more "open" and others have many proprietary or closed components. Also, budgets may scale up or down during any given fiscal year within or across warfare domains. Thus, a dual approach to ownership of HCI components could address legacy system upgrades and a fully "open" approach. The legacy approach may include standards and available methods for connection of legacy components with advanced HCI software layers. This approach might also contain funds to allow legacy systems to publish information as electronically available to decision aids. The MCDC would assist in defining standard technical approaches, data definitions, and guidelines for migrating application-centric legacy systems to accommodate mission-centric HCI. The open approach should develop the best-practice approaches based on the MCDC. The result will be a targeted architecture and development framework that new components could adhere to, and older components could migrate toward. The design must be continuously updated and revisited such that it does not become obsolete or outdated as other standards and methods evolve over time.

Table 2 summarizes the components of HCI and how "ownership" may be employed for each component. In each case, advancement and innovation must not be impeded by the owner or stakeholders, but must be fostered to keep the Fleet at the cutting edge of technology and performance.

Decision aids and their products are directly affected by the quality and timeliness of information available to algorithms and methods. Successful HCI will occur when information is collected at a source unrelated to the decision aid, but made available to the aid through the use of standards that allow the information to be posted and then used by the aid. Thus, each aid will be empowered by a far greater number of sources of information than previously available. Issues of quality and reliability exist, but they are solved or allow for user inspection, vs. the greater evil of having no information available or having it arrive too late to support key mission decisions or events.

HCI is a cooperative and shared design problem that transcends information sources and storage and creates opportunities for reducing cost of design, test, and delivery within and across warfare domains. Greater capability and support can be brought to the warfighter much sooner than HCI development efforts within a single Program Office might allow.

Table 2. HCI architecture components by organization, status, and use.

HCI Component/Standard	Ownership	Organizations Using	Advancement	Current Status
Presentation HCI patterns look and feel	MCDC	Government, industry, labs	Performance based for speed, accuracy, and training	DII/COE, DISA, industry best practice
Presentation decision aid and support tools	Specific programs	Warfare domains, labs, and industry	Innovation fostered through R&D	No common design themes
Information support structure	Specific programs	Government, industry, labs	Open and available where and when needed by DAs	Stove-pipes, gaps within mission domains.
Business logic of individual systems	Specific programs	Government, industry, labs	Tested and reliable and (possible) re-usable across domains	Individualized by each system

5. SUMMARY

We have identified three key strategy areas for a revolution in Navy HCI to enable the vision of SeaPower 21 of improved effectiveness, faster speed to capability, reduced manning, and reduced cost. These transformations are in MCD HCI Design, HCI Design Process, and HCI Software and Information Management Architecture. Fortunately, our Navy, through ONR sponsorship, has the benefit of years of HCI research in support of these transformations. The results are now transitioning within focused mission domains through Future Naval Capability programs, and provide a wealth of requirements and guidance on which to launch a revolution in naval HCI process and design. The ingredients needed now are the will, resources, and a teamwork commitment to excellence across a transformed Navy HCI.

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Nancy Campbell, Glenn Osga, David Kellmeyer,
Daniel Lulue, Earl Williams

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14. ABSTRACT
A transformation is needed in Human–Computer Interface (HCI) to accommodate transformations in information availability, computing power, and changing warfighter roles. The HCI paradigm should be transformed from system-centric to mission-centric, and the HCI should be decoupled from individual weapon/sensor/command and control (C^2) systems to span across multiple systems to accomplish mission goals. A mission-centered design (MCD) approach can achieve the needed revolution in HCI via transformations in three areas: (1) HCI Design (how the HCI supports the warfighter); (2) HCI Design Process; and (3) HCI Software and Information Management Infrastructure. A Mission-Centered Design Consortium (MCDC) should be created to advance each of these transformations through the creation of open standards and the development/description of best practices.

15. SUBJECT TERMS
Mission Area: Command and Control
human–computer interface (HCI), HCI transformation

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