A Task-Based Design Guide for Command and Control

Topics:
Architectures, Technologies, and Tools
Concepts, Theory, and Policy
Approaches and Organizations

Alan G. Lemon
Space and Naval Warfare Systems Center
Code 53621
53560 Hull Street
San Diego, CA 92152-5001
619-553-9226
alan.g.lemon@navy.mil

Michael B. Cowen
Space and Naval Warfare Systems Center, Pacific
Code 53621
53560 Hull Street
San Diego, CA 92152
619.553.8004
mike.cowen@navy.mil

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Alan G. Lemon
Michael B. Cowen

Abstract

The need for better design of user interfaces (UI) has been required by the ever-increasing complexity of command and control (C2) systems, the life cycle constraints (LCC), and the increasing operational dynamics and needs of the combatant commanders (COCOM). With usability issues becoming widespread in the C2 community, there is now an even greater need for UI standardization, which is advanced by the plan to adopt a UI style guide for C2 systems. Although UI standardization in the form of a style guide seems to be a step in the right direction, a style guide alone may be inappropriate given the inherently diverse nature of C2 systems. Here, we will discuss a more logical solution that explores a fundamental change away from the current function-based design methodology and suggests moving towards a task-based design approach. A key component of task-based design is articulated in the scientific publications within Human Factors Engineering (HFE). 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. Other operational domains that have employed HFE design-engineering approaches have found major impacts in system effectiveness, suitability, and affordability. Development and deployment of task-based human interfaces in C2 configurations can reduce LCC and improve the operational capability available to the COCOM. Operation of C2 systems must be driven by what needs to happen next in the command environment, not by the limitations of a function-based user interface.

Introduction

A key component of command and control systems is to enable the effective transfer of information between and among systems. Operational users will gain situational awareness to make decisions and execute appropriate courses of action. When information is acquired, understood, shared, and used properly, it rapidly affords knowledge to human decision makers. Human Systems Integration (HSI) is a formal acquisition process that provides techniques for identifying human performance issues in defining mission capability for system development. HSI is a human engineering practice designed to ensure that human performance related issues are identified within the systems engineering processes. Ideally, HSI considerations and trade-offs are made early enough to mitigate issues during system development and testing in the acquisition lifecycle. HSI integrates human capabilities and limitations into system definition, design, development and evaluation to optimize total system performance in operational environments using appropriate performance metrics and data collection methods. DoD Instruction 5000.02 [1] requires a comprehensive plan for HSI to be in place early in the acquisition process that will optimize total system performance, minimize total ownership costs, and ensure that the final product is built to accommodate the user population characteristics for operations, maintenance, and logistics.

Effective HSI planning for C2 relies heavily on the Human Factors Engineering (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. HFE designs should minimize or eliminate system characteristics that require excessive cognitive, physical, and sensory skills; entail extensive training or workload intensive tasks; result in mission-critical errors; or produce safety or health hazards. 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. Best HFE practices optimize the mix of these elements based on discovered interdependencies and trade-offs that balance performance and cost. A detailed requirements description of the HFE domain can be found in a previous ICCRTS paper [2].

User Interface Design

The need for better design of user interfaces (UI) has been required by the ever-increasing complexity of Command and Control systems. With usability issues becoming widespread in the C2 community, there is now an even greater need for UI standardization, which is advanced by the plan to adopt a UI style guide for C2 systems. Although UI standardization in the form of a style guide seems to be a step in the right direction, a style guide alone may be inappropriate given the inherently diverse nature of C2 systems. Here, we will discuss a more logical solution that explores a fundamental change away from the current function-based design methodology and suggests moving towards a task-based design approach.

The need for a C2 style guide is a response to a requirement to secure "common human computer interfaces" as noted in CJCSI 6212.01 [3]. An additional driving factor is the requirement to improve usability for end-users as required by SECNAV Instruction 5000.2E [4]. The challenge is not exclusive to military systems. Executive Order 13571 [5] directs that agencies "will use technology to improve the customer experience" for streamlining service delivery and improving customer service. Projects and programs keen on improving the usability and the user experience of products often begin by requesting a style guide. Traditional design-engineering approaches see the style guide as the documentation of a design and the end product of a design process. The style guide is not the starting point to develop a usable interface for a system. The style guide is simply a set of directions and formats that should provide general human engineering design criteria, principles and practices to be applied in the design and development of C2 systems.

Challenge

Style guides do not ensure usability of the UI. Developing a style guide is just one activity in the user-centered design process that begins with the analysis phase of the idealized UI design and test process. A common mistake is the assumption that once a style guide is produced, no additional usability or consistency work is necessary to address macro interaction problems that occur between mapping system functions to tasks, which can often lead to usability issues and overall product failure.

Style guides normally emphasize presentation rules and visual design elements, such as use of color, hue, saturation, fonts, and font size in order to achieve a common look and feel. Style guides can also establish the use of standard controls such as switches, knobs, buttons, drop-down menus, check boxes, radio buttons, and even radio dials. However, style guides cannot address the appropriateness of the design. Style guides also cannot solve specific usability issues for a given system, nor can style guides provide the interface designer with the focused tactics and techniques derived from the human engineering analysis, which presents and organizes user

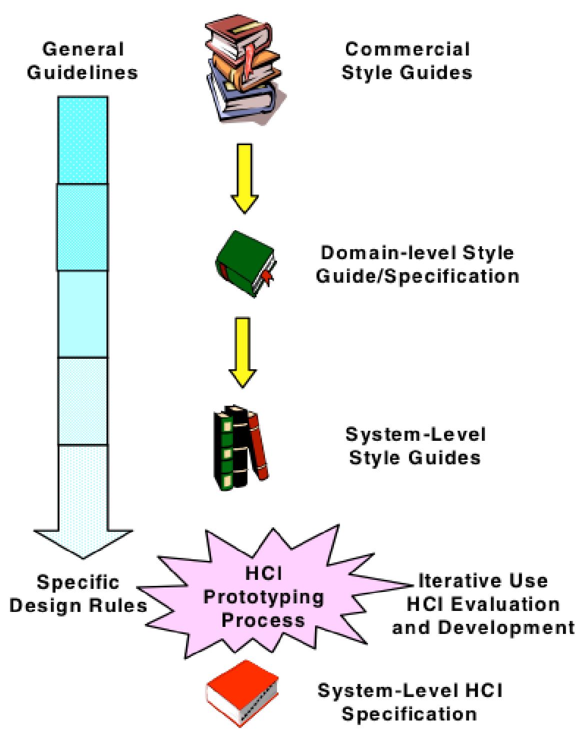

Figure 1. UI Development Guidance

performance data in a structure optimized around the human user to achieve the objectives of the system. A style guide, to be effective, must be accepted and used. While style guides can provide guidelines for a common look and feel, they cannot provide software developers the design-engineering flexibility required by the complexity of today's command and control systems. Style guides are often requested by software development teams, but are rarely used, because they don't provide solutions for usability issues.

Style guides are addressed in the DoD Joint Technical Architecture (Volume 1, Section 5.6, Human-Computer Interface Standards) [6] and provide a generalized view (see Figure 1) of "the hierarchy of style guides that shall be followed to maintain consistency and good UI design within DoD." While a style guide can be an excellent example of best practices and solutions for some common design problems with regard to look and feel (e.g., font, color, etc.), it can hardly determine or establish the appropriateness of the design. Although a style guide can provide a definitive set of templates for an interface, it cannot guarantee that the resultant UI will be appropriate, efficient, effective, and will satisfy the user's goals.

Problem

Human Factors Engineering leverages cognitive science as a firm foundation for system designs based on understanding human capabilities. Often cursory reviews of the user interface replace or are mistaken for the considerable efforts made by HFE professionals who provide detailed heuristic evaluations during the iterative design process. While user reviews can certainly provide some benefit to the design process, such reviews often do not address operational workflow and cognitive workload issues.

System development can be so challenging that HFE guidance can be lost or inadvertently ignored by the software developers when coding and rendering the UI. As a way to simplify development, software reuse is often employed as a cost savings measure. Unfortunately, this practice can result in transferring usability issues from the legacy system to the new one. Is there a way to integrate HFE best practices and guidance into the development of the UI? HFE expertise will not only benefit programmers in developing the UI, but will also provide the end user with an interface that fully supports their tasking and objectives.

HFE Design Guide: Exploring a Better Alternative

The solution may come in the form of an HFE design guide, not a style guide. The HFE design guide focuses on the design engineering required to establish information architectures and flows, a user perspective, task modeling, and other design aspects. The development of an HFE design guide would reduce and eliminate usability problems, and create a common intuitive approach to human-computer interaction. A design guide would deal with the complexity of user interfaces with the goal of reducing cognitive workload by migrating away from the common function-based displays, towards the inherent simplicity of task-based user interfaces. A design guide is the first step in implementing smarter processes for conducting human factors engineering.

A Task-Based Design Guide

The visual absence of every system function is a characteristic of software engineering following task-based design. While some systems certainly require function-based displays, most commercial multi-media devices now protect users from the complexity and details required by software programming. This is consistent with findings [7] supporting user-centered design (UCD). 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.

For example, smart phones are popular because their interfaces are intuitive and they tend to provide a consistent consumer experience. Smart phones do not come with a user's manual. This is a key indication of a properly engineered task-based design–it provides an intuitive UI that does not require the consumer to think about how the phone works. The consumer can make the phone work by following easy-to-find affordances or recognizing simple metaphors.

Consider the following example (Figure 2) of the two different ways a user interface can be designed to reserve a hotel room.

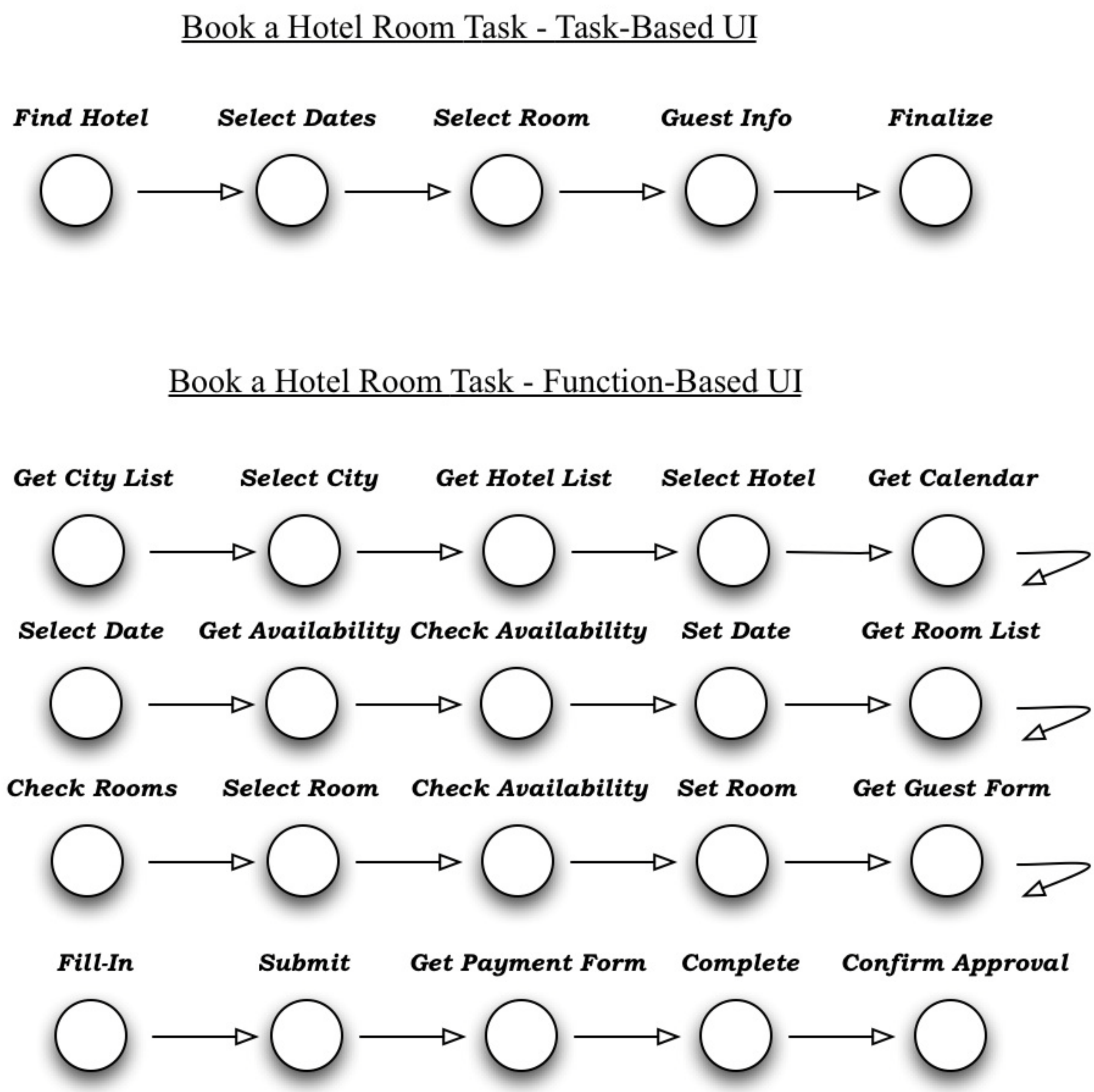

Figure 2. The Difference Between a Task-Based UI and a Function-Based UI

In contrast, a function-based design can be cumbersome to users, because it provides multiple windows and drop-down menus that allow easy access to all of the functions that rely upon the users ability for cognition and recall. The user must hunt for information and remember the procedural steps involved with a task. This often requires user manuals, guides, or some other reference material to supplement and explain the UI. Most Navy systems use function-based designs that require extensive formalized training and sustainment training to make the system work. However, in the small number of cases when UCD was employed to develop task-based interfaces, the UIs were less cognitively demanding and were found to mitigate the training and readiness issues within the Fleet [8].

In this example, there is a level of implied automation for the task-based UI where the system works behind the scenes to assist the consumer. The user begins the task with a single goal in mind, to secure a room that meets his or her requirements and accommodates scheduling and budgetary constraints. The consumer is not interested in what type of technology runs behind the UI. The consumer wants to accomplish the task with a minimum number of mouse clicks and text entries, and no duplication of effort.

A task model is defined within ANSI/CEA-2018 Task Model Description Standard [9] as a "formal description of the activities involved in completing a task, including both activities carried out by humans and those performed by machines." The task-based design guide being discussed here is intended to optimize the usefulness of the UI by providing tasked-based guidance to the system engineering process in order to establish clearly defined user requirements to achieve total system performance. This formal guidance would help both designers and end-users to evaluate and identify UI features that are convoluted, illogical, or even an outright eye sore that would make even a great system seem difficult to use. A task-based design guide would improve integration efficiency to achieve a UI that not only enhances and compliments systems functionality, but also is attractive, intuitive, and compelling, and results in a positive consumer experience.

Discussion

Human Factors Engineering focuses on the human perspective of the system to be designed. HFE helps ensure that the usability of systems is optimized for how people think and work, providing guidance for intuitive UIs, which minimize workload, and which will reduce the overall training burden of C2 systems and the overall LCC.

The direct benefits of human factors engineering in the design, development, and production of systems are briefly stated in the relatively new ISO (the International Organization for Standardization) Standard 9241 Part 210 [10]: Human-centered design for interactive systems, which reads:

> "Using a human-centred approach to design and development has substantial economic and social benefits for users, employers and suppliers. Highly usable systems and products tend to be more successful both technically and commercially. … Taking a human-centred design approach contributes to other aspects of systems design, for example, by improving the identification and definition of functional requirements. Taking a human-centred design approach also increases the likelihood of completing the project successfully, on time, and within budget. Using appropriate human-centred methods can reduce the risk of the product failing to meet stakeholder requirements or being rejected by its users."

DoD 5000.1 [11] also drives toward such advances by calling for a Total Systems Approach, which provides for a human-focused design. Section E1.1.29 reads:

> "The PM shall be the single point of accountability for accomplishing program objectives for total life-cycle systems management, including sustainment. The PM shall apply human systems integration to optimize total system performance (hardware, software, and human), operational effectiveness, and suitability, survivability, safety, and affordability."

While traditional systems engineering focuses on the capabilities of the system (i.e., software and hardware), HFE can provide the requirements, objectives, and logical architectures required to develop systems that address the human element. Proper employment of human engineered systems will optimize the system for the user and achieve total system performance. It will also drastically reduce the inconsistency and complexity found in the UIs for current C2 systems. Human factors engineering provides systems engineers the advantages of design practices that can clearly define user requirements. Such advantages provide engineers a baseline to build towards resulting in interfaces that mitigate usability issues and augment human performance limitations. HFE optimizes the design of user-machine interface to improve human performance, which is a delicate appreciation of achieving system design objectives for operational capability while balancing task load between machine capability and user needs.

Conclusion

A common appeal has been voiced from the Program Offices for a C2 UI style guide. However, it is the need for better implementation of human factors engineering that will help mitigate the inconsistency and complexity of human-computer interfaces plaguing users of our current C2 systems.

DoD Instruction 5000.02 [1] states:

> "The PM shall take steps (e.g., contract deliverables and Government/contractor IPT teams) to ensure ergonomics, human factors engineering, and cognitive engineering is employed during systems engineering over the life of the program to provide for effective human-machine interfaces and to meet HSI requirements. Where practicable and cost effective, system designs shall minimize or eliminate system characteristics that require excessive cognitive, physical, or sensory skills; entail extensive training or workload-intensive tasks; result in mission-critical errors; or produce safety or health hazards."

The recommended solution is an HFE design guide, which will focus on the design engineering required to establish information architectures and flows from a user perspective to provide task modeling over system function. This approach will provide users with expert displays, which have been optimized to the task at hand, and reduce the current burden of user cognition and recall. This approach will enhance the usability of command and control systems, reduce the life cycle constraints, and increase the operational flexibility of the combatant commanders.

While style guides can be developed to assist with the display design process, a more comprehensive human factors engineering effort with tasked-centered analysis can provide for the most uniformity of human-machine interactions for C2. Increasing usability by following task-based guidance will encourage the development of intuitive displays that are predictable and capable. Operation of C2 systems must be driven by what needs to happen next in the command environment, not by the limitations of a function-based user interface.

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A Task-Based Design Guide for Command and Control

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Alan Lemon, Human Systems Integration
Michael Cowen, Research and Applied Sciences
Space and Naval Warfare Systems Center, Pacific
Command & Control Technology - Experimentation Division
User-Centered Design & Engineering Branch, Code 53621

HSI Requirements

DoDD 5000.01
May 12, 2003

E1.1.29. Total Systems Approach. …The PM shall apply human systems integration **to optimize total system performance (hardware, software, and human),** operational effectiveness, and suitability, survivability, safety, and affordability. …

DoDI 5000.02
December 2, 2008

This Instruction **applies to**:
… b. **All** defense technology **projects** and acquisition **programs**, including acquisitions of services. …
ENCLOSURE 8 HUMAN SYSTEMS INTEGRATION (HSI)
…The PM shall have a plan for HSI in place early in the acquisition process to optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system.
… HSI planning shall be summarized in the Acquisition Strategy and SEP and shall address the following: …Human Factors Engineering,…Personnel,… Manpower, … Training, … Safety, and Occupational Health…

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HSI Requirements

SECNAVINST 5000.2D
October 16, 2008

The **provisions of this instruction apply to all** DON organizations, to all Acquisition Category (ACAT) **acquisition programs, …nonacquisition programs, and Rapid Deployment Capability programs**. …CNO (N12) serves as Human Systems Integration (HSI)…advocate, and is the Navy HSI requirements authority. …CNO (N12) serves as the single governance authority for HSI policy, requirements and resources… Chapter 7 Systems Engineering and Human Systems Integration
…The Program Manager (PM) … shall **employ systems engineering** as a mechanism to achieve the program objectives of optimal **total system performance** (hardware, software, **human**, firmware, … **Systems engineering** … **includes** the hardware, software and **human operators, maintainers, support personnel, and the operating environment**. … PMs shall use a **systems engineering process** to translate operational requirements/capability needs into a system solution that **includes …Human Systems Integration (HSI)**… The **PM shall apply HSI as part of a systems engineering approach**. … **PMs** and sponsors **shall address HSI throughout all phases of the acquisition process** to optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system. …When modifying a system (e.g., modernization or block upgrade), HSI issues and domains must be considered to ensure that configuration changes do not create new or unforeseen HSI issues.

OPNAVINST 5310.23
November 10, 2009

...Responsibilities...Deputy CNO (Information Dominance) (CNO (N2/N6)), … shall:… **Ensure HSI requirements are adequately resourced….**

SYSCOMs will: …Support PMs and CNO (N1) in the documentation of HSI technical requirements to ensure adequate resource sponsorship and technical authority assessment.

So how do we get there and optimize total system performance?

ICCRTS Briefing
A.G. Lemon
20 June, 2012

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Our Broad HSI Knowledge

Our Expertise

Seven Pillars of Human Systems Integration +						
Human Factors Engineering	**Manpower**	**Personnel**	**Training**	**Habitability**	**Survivability**	**Environment, Safety and Occupational Health**
Human Performance	Workload	Personnel Classification	~~KSA~~ **KIASAM**	Quality of Life	Anti-Fratricide Identification / Confirmation	Accident Avoidance
Cognitive, Physical, Sensory Abilities	Wartime Requirements (Quality/ Quantity)	Recruiting	Initial Skill Skill Progression **Apprentice-Master**	Quality of Work	Personnel Protection	Safety Hazard Avoidance
Human Interfaces	Officer, Enlisted and Civilian	Retention	Functional Individual and Team	Environmental Limits and Controls	Damage Control	Health Hazard Avoidance
HCI GUI	Force Structure	Career Progression	Training Concepts	Personnel Services	Performance Effects of Ensembles	Risk Mitigation
Human Error Avoidance	Operating Strength	Skill Mix	Initial & Follow-on **Sustainment**		**Hardware/ Software Configuration**	Medical
Top Down Analysis	**PBD**	Special Skills	Delivery Systems Realism/ Applicability		**Battlespace Omniscience**	
Design for Usability/ **Utility**		Occupational Standards	Organic Training Distance Learning **CBT ICW**			
Design for Maintainability		Distribution	Virtual Environment Intelligent Tutoring			
Team Dynamics HSD		Manning Concepts **Personality Classification & Management, Personnel Management**	Knowledge (formal cognitive), **Intelligence (informal cognitive)**, Abilities (informal psychomotor), Skills (formal psychomotor), **Attitudes (formal affective), and Motivation (informal affective)**			

What is the Open Systems Interconnection (OSI) Model?

These OSI layers comprise the Software and Hardware configurations

	Layer	Description	Data unit
Software	Layer 7	**APPLICATION** Network Process to Application	Data
Software	Layer 6	**PRESENTATION** Data Representation and Encryption	Data
Software	Layer 5	**SESSION** Interhost Communication	Data
Hardware	Layer 4	**TRANSPORT** End-To-End Connections and Reliability	Segments
Hardware	Layer 3	**NETWORK** Path Determination and IP (Logical Addressing)	Packets
Hardware	Layer 2	**DATA LINK** MAC and LLC (Physical Addressing)	Frames
Hardware	Layer 1	**PHYSICAL** Media, Signal, and Binary Transmission	Bits

Adapted from: Berkley (2003) SSC-Pacific. Human Systems Integration in Support of the Open Systems Interconnection (OSI) Reference 7-Layer Model. Bauer & Patrick (2004). A Human Factors Extension to the Seven-Layer OSI Reference Model. Retrieved 11/1/10 from http://www.andrewpatrick.ca/OSI/10layer.html.

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How does HFE relate to the OSI Model?

User	Layer 10	**NEEDS** Optimized Solutions for Technical Capability	BooYah!
	Layer 9	**HUMAN PERFORMANCE** Optimized Solutions for Technical Capability	High Pk
	Layer 8	**DESIGN** Human-Machine Interface (HMI) Through I/O Devices	Ao
Software	Layer 7	**APPLICATION** Network Process to Application	Data
	Layer 6	**PRESENTATION** Data Representation and Encryption	Data
	Layer 5	**SESSION** Interhost Communication	Data
Hardware	Layer 4	**TRANSPORT** End-To-End Connections and Reliability	Segments
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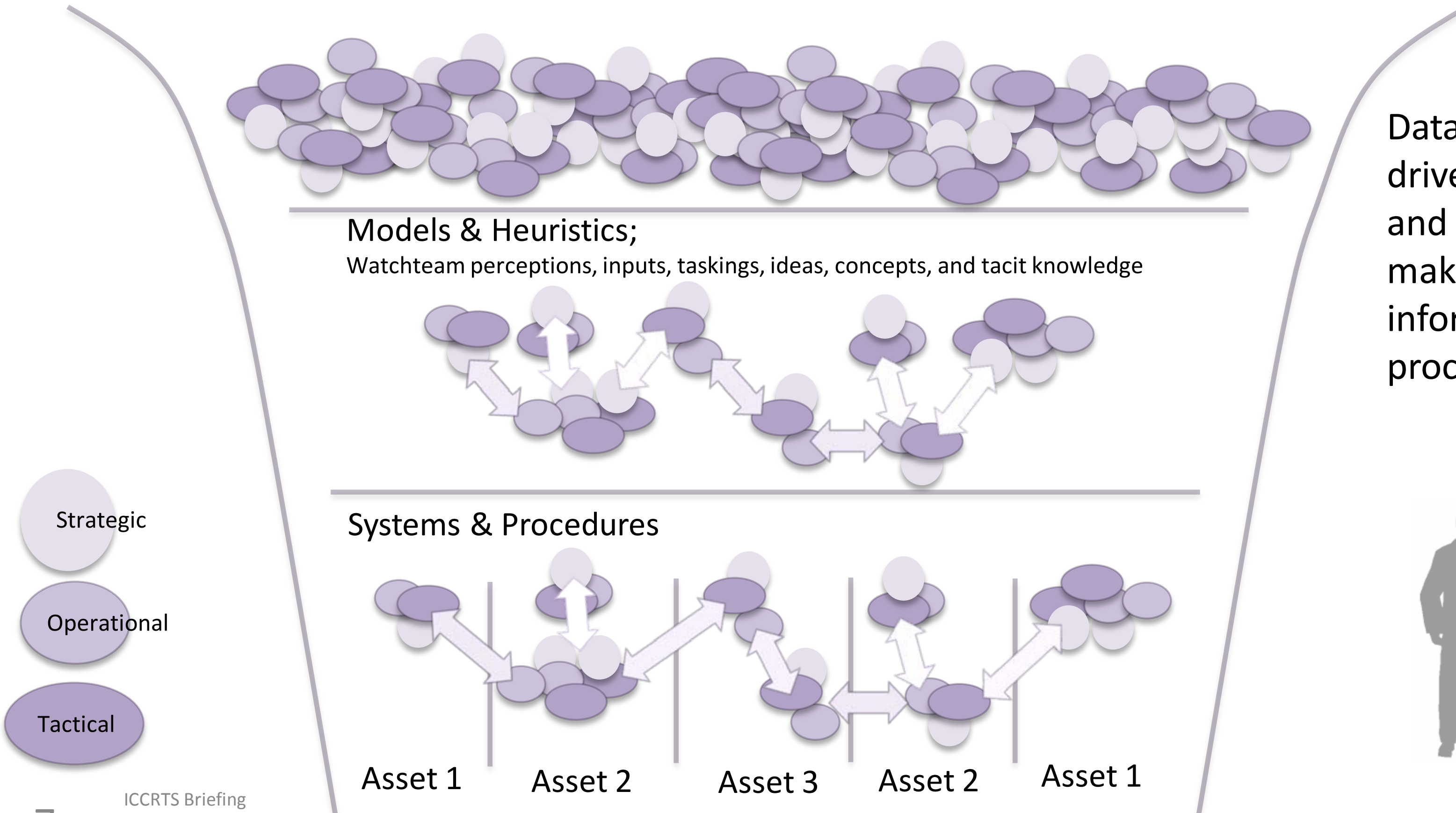
Function-Based Knowledge Funnel

Disparate data sources, computational resources, and products into and out of the AOR



Data Centered Model drives the workflow and forces Users to make sense of the information and process to action.

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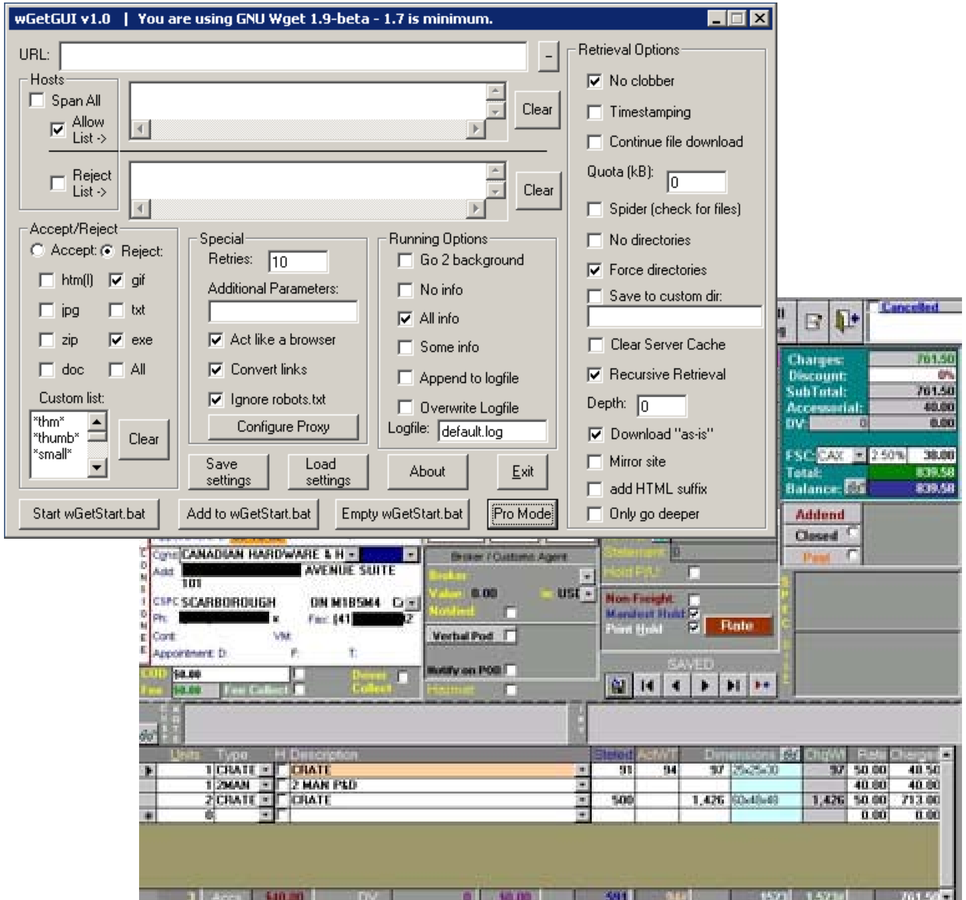
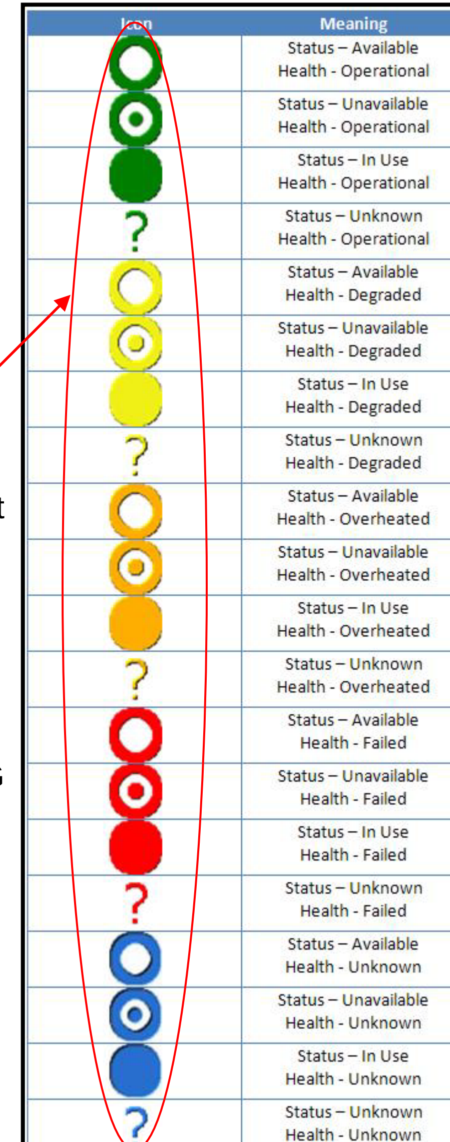
Bad Design



Rejected.
Not Compliant with MIL-STD 1472F, DoD HCI Style Guide Vol 8.
Contractor ignored repeated USG requests for oversight and inclusion in development effort.



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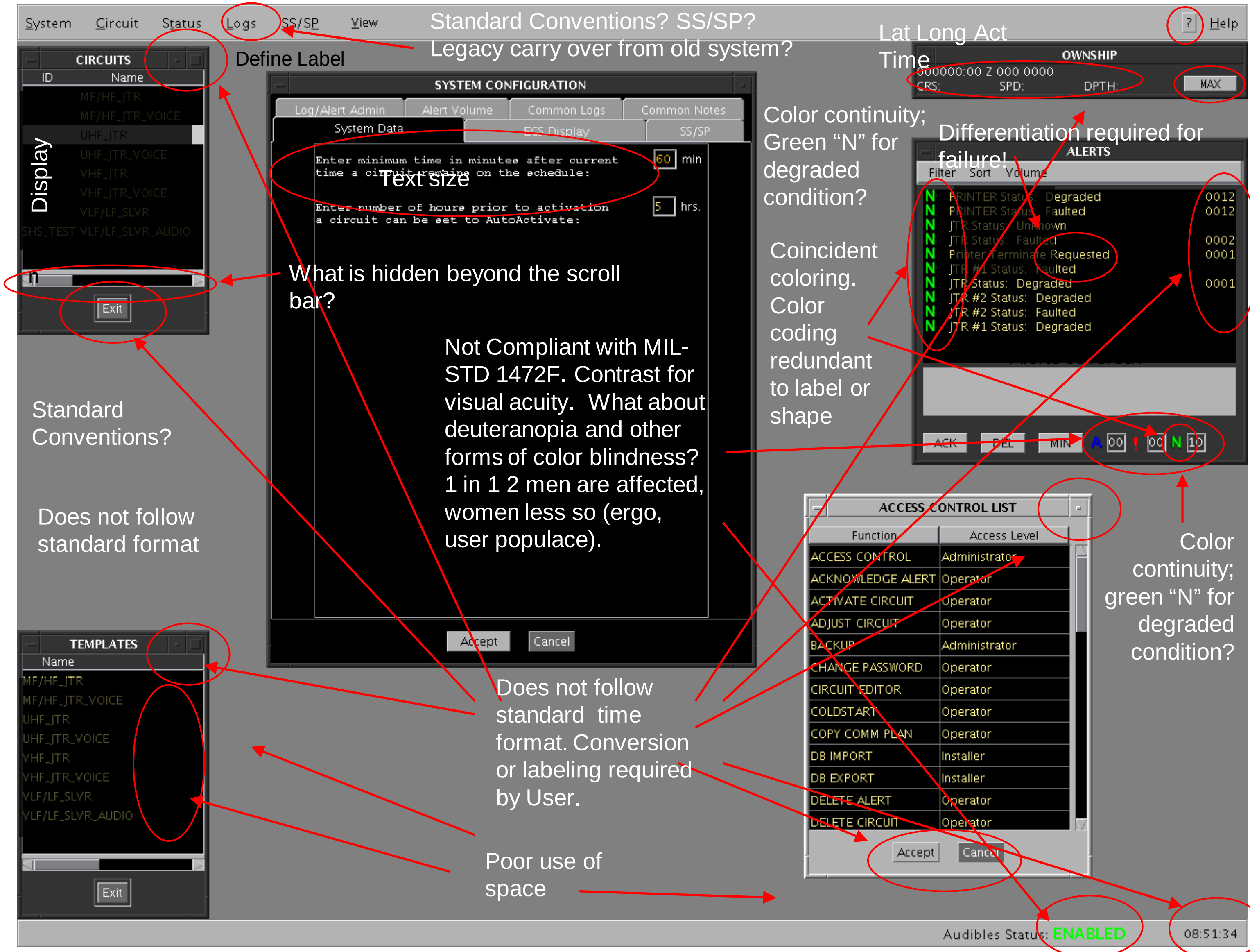

UNCLAS, Distribution A

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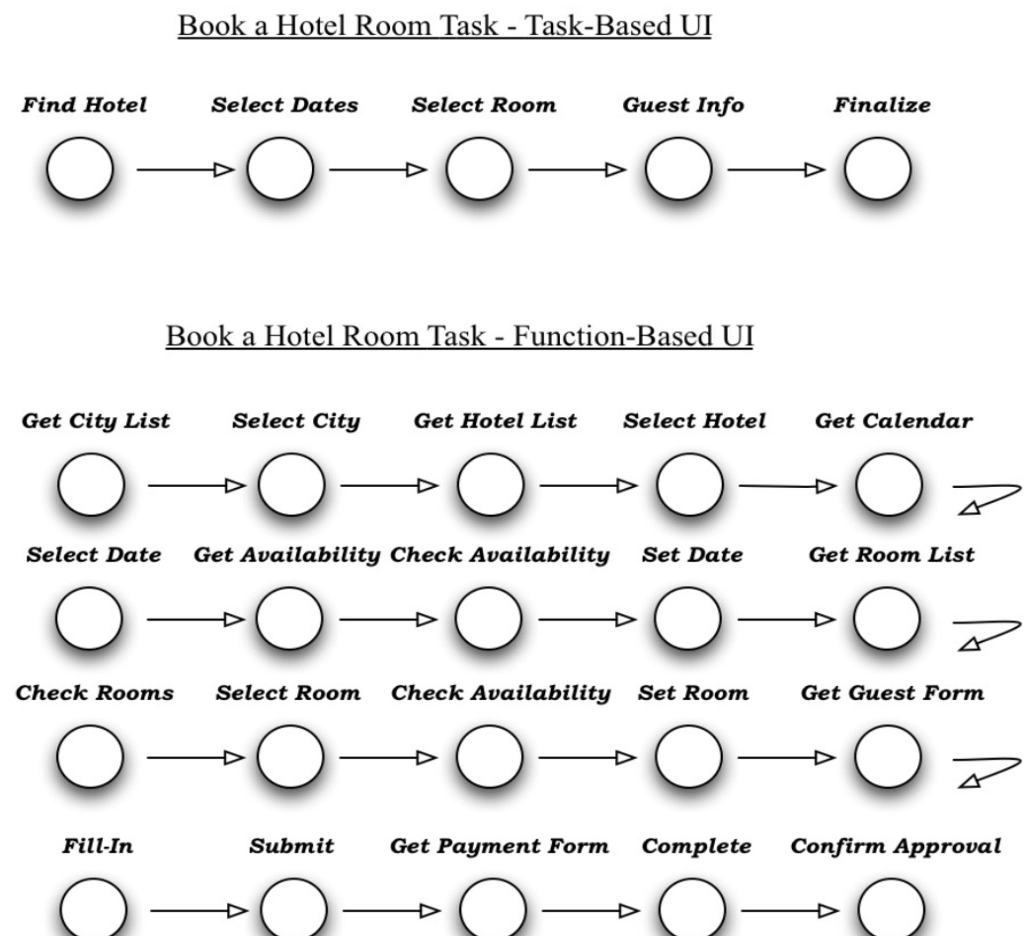
Task-Based Versus Function-Based Design

Worse than Bad Design

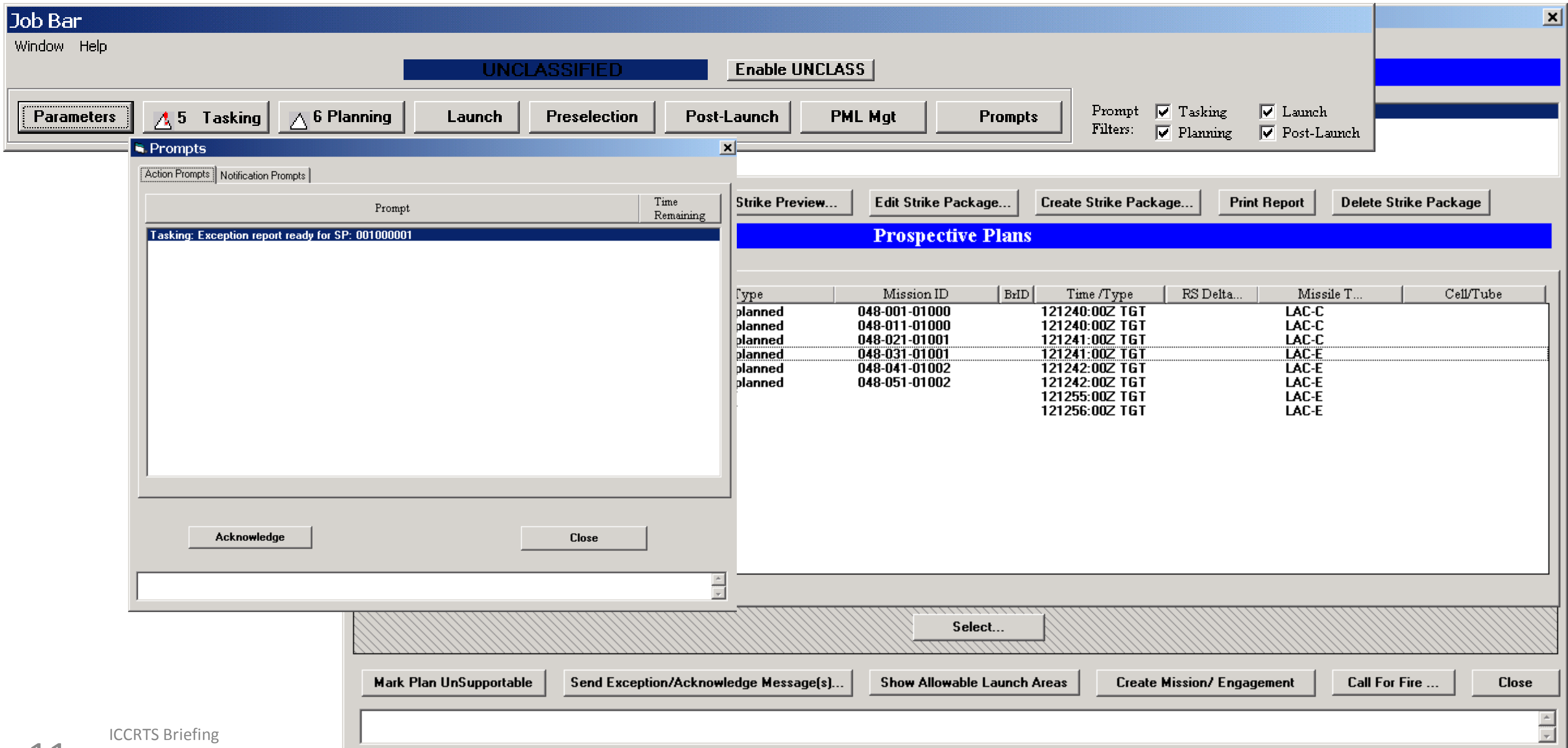
Trade-offs exist between Function-based and Task-based design.

Task-based design will be less effective for complex tasks that are poorly defined or too general.



Function-Based Design

BEFORE: Multiple windows with data not integrated or organized by user tasks.



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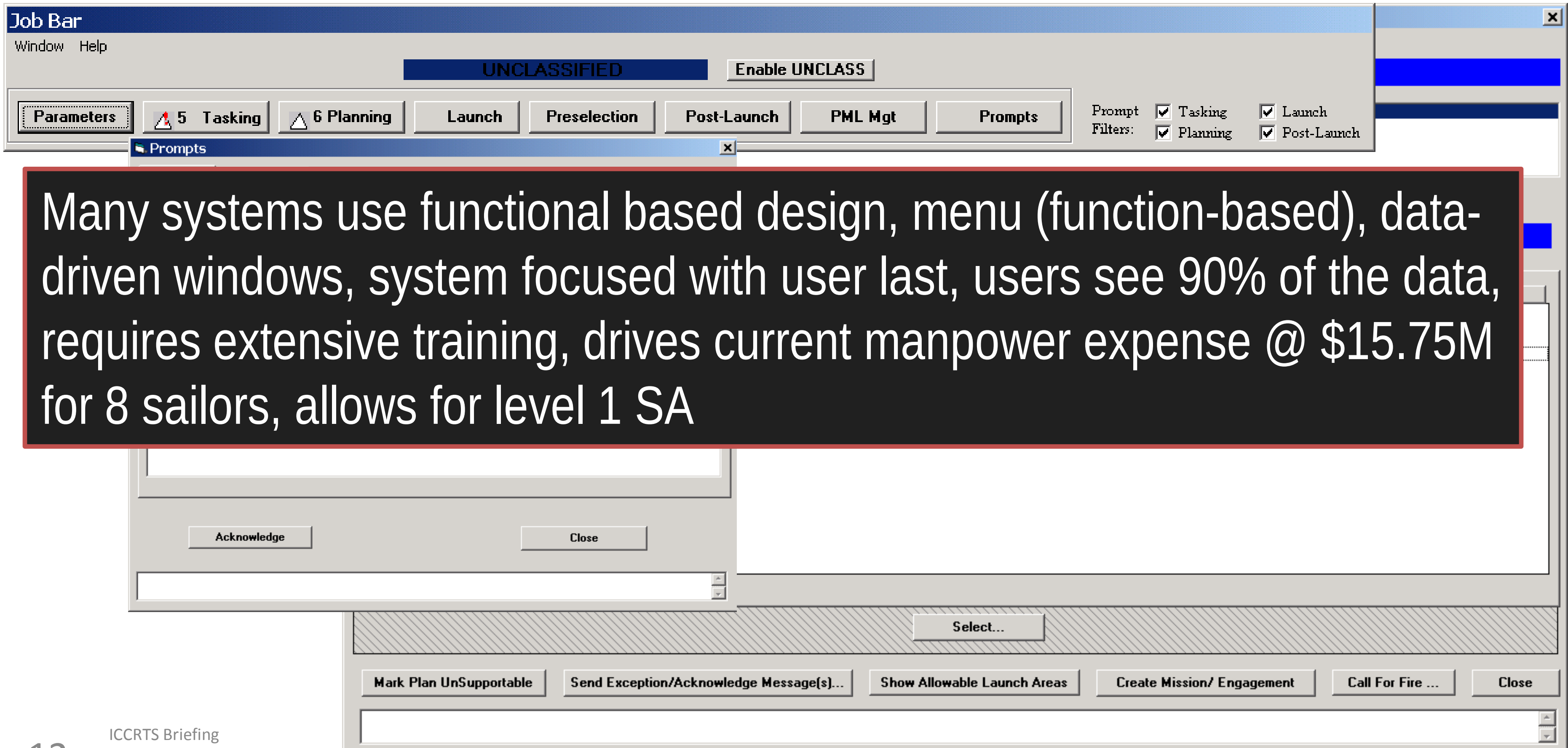
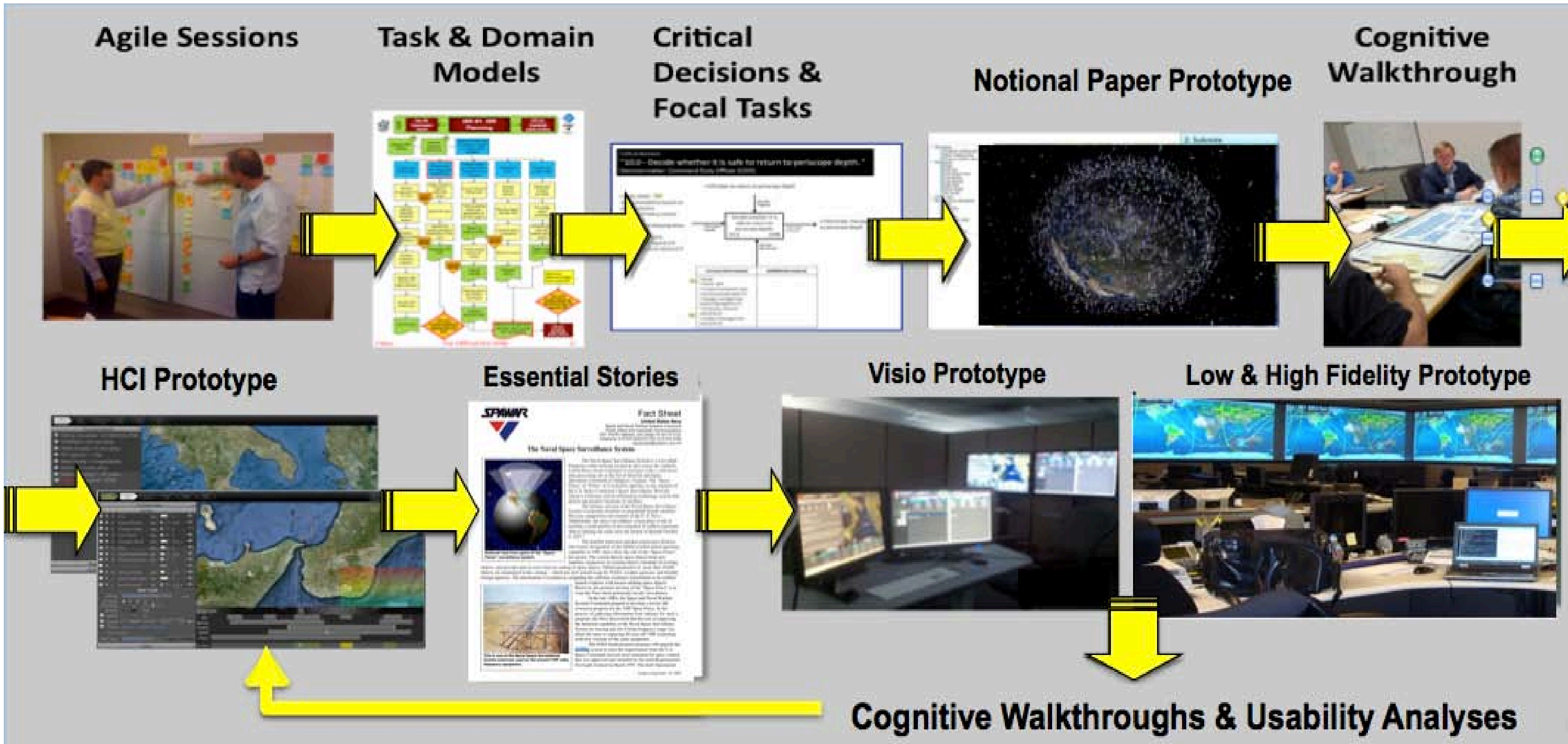
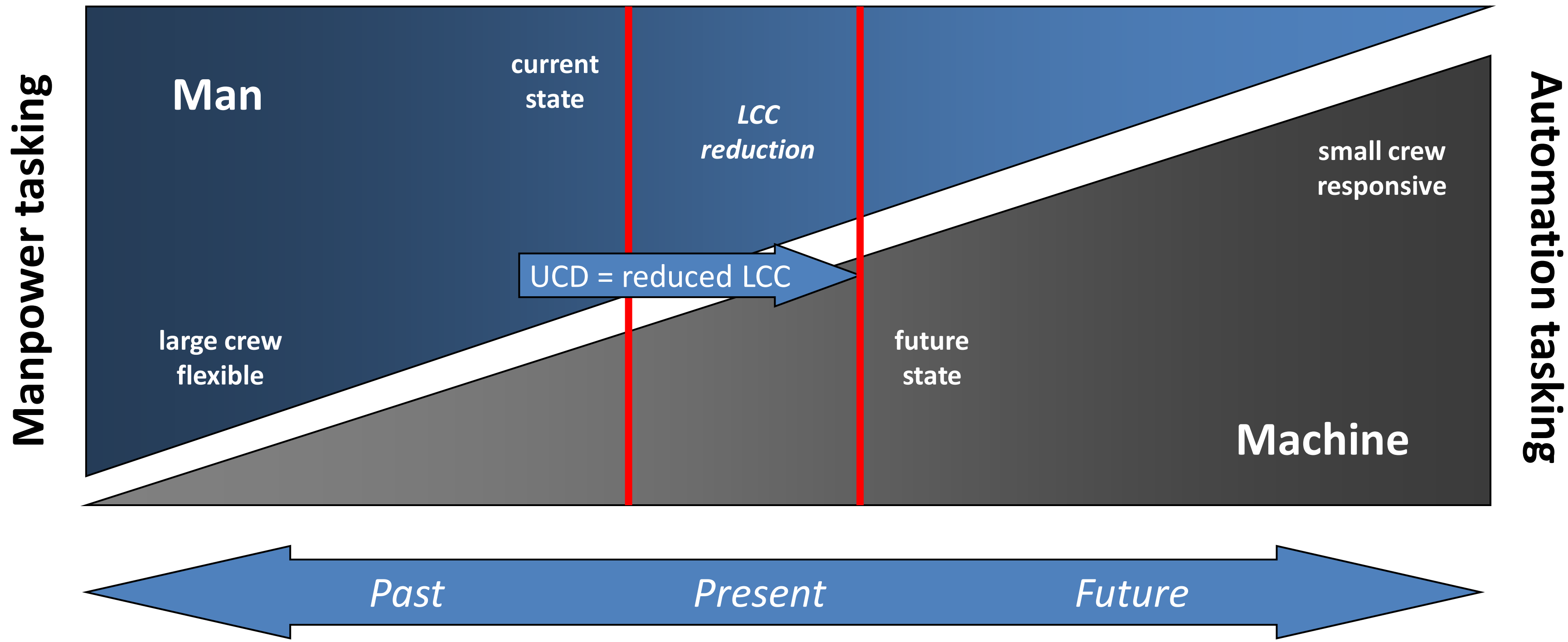


Many systems use functional based design, menu (function-based), data-driven windows, system focused with user last, users see 90% of the data, requires extensive training, drives current manpower expense @ $15.75M for 8 sailors, allows for level 1 SA

UCD Agile Design Process



Results of UCD Agile Design Process

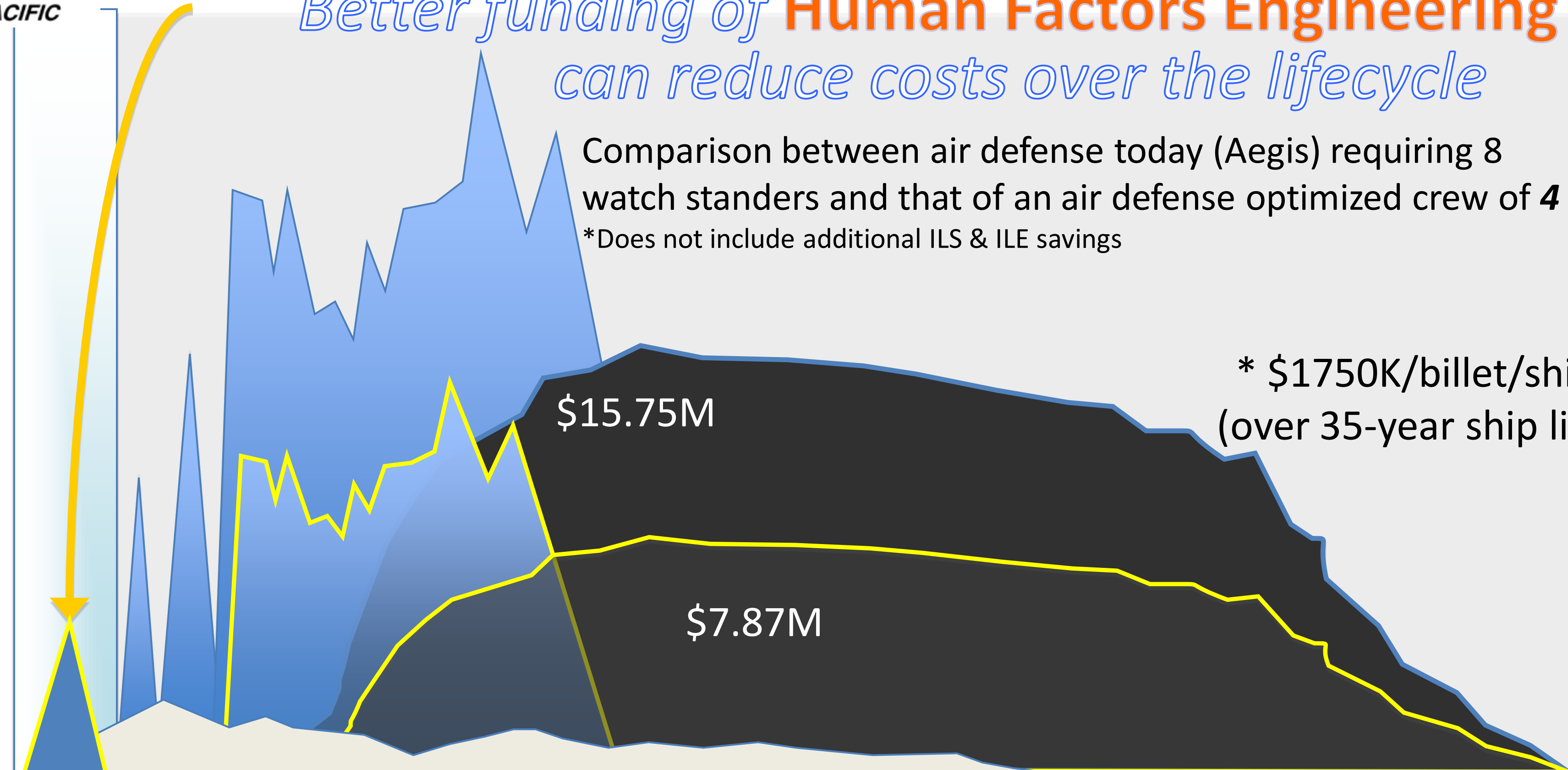


UCD is an HFE best practice focused on obtaining knowledge from the users to increase efficiency, performance, and improve long-term cost savings.

Caution: Not all automation decreases workload. Potential to increase workload and error, decrease situational awareness.

Why HFE provides best ROI

Better funding of **Human Factors Engineering** *can reduce costs over the lifecycle*



Development costs
Procurement costs
Operating and Support costs

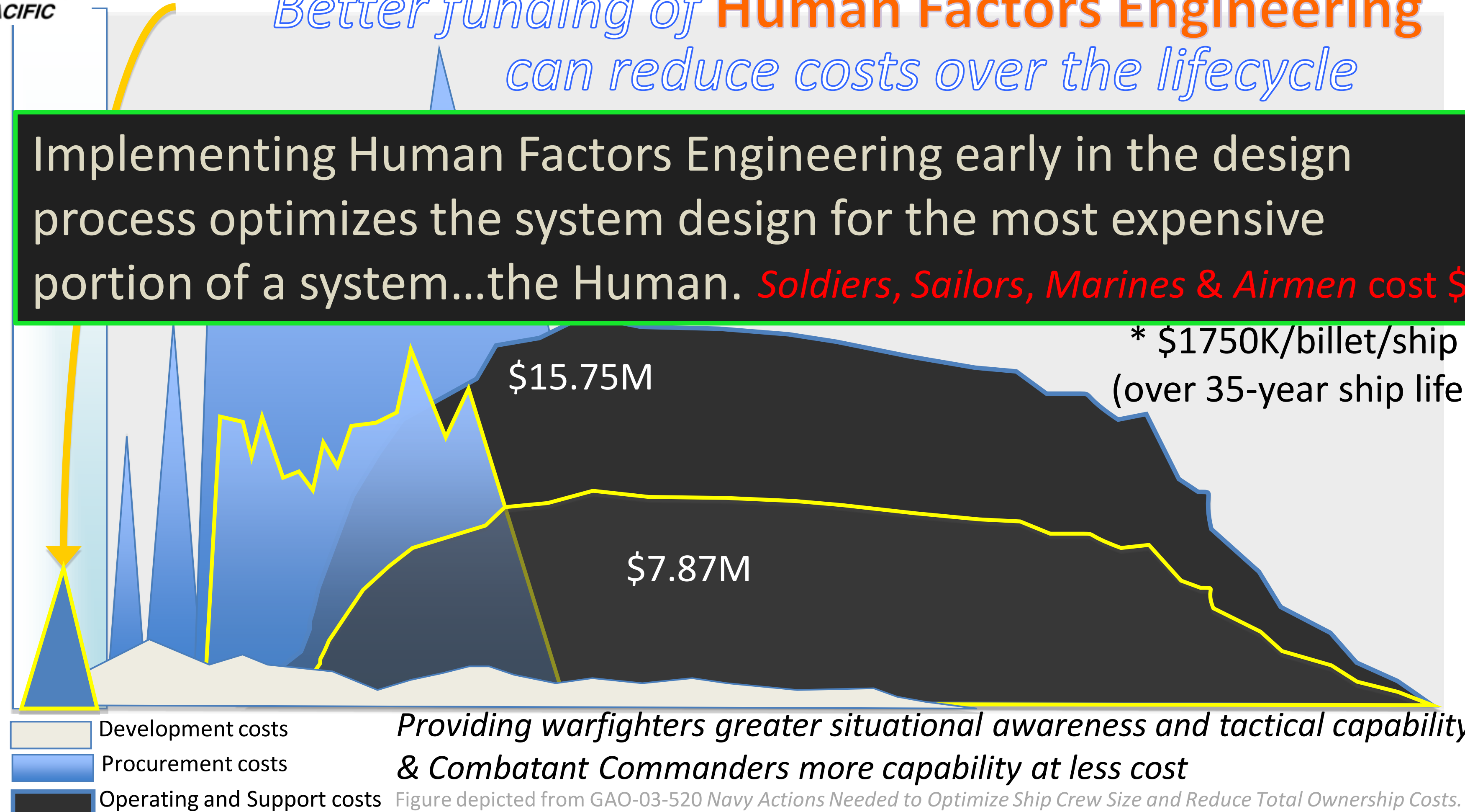
Providing warfighters greater situational awareness and tactical capability & Combatant Commanders more capability at less cost

Figure depicted from GAO-03-520 *Navy Actions Needed to Optimize Ship Crew Size and Reduce Total Ownership Costs.* Source of data: U.S. Navy affordability values from MMWS crew optimization thrust conducted for ONR 34

Why HFE provides best ROI

Better funding of **Human Factors Engineering** *can reduce costs over the lifecycle*

Implementing Human Factors Engineering early in the design process optimizes the system design for the most expensive portion of a system…the Human. *Soldiers, Sailors, Marines & Airmen cost $!*



Providing warfighters greater situational awareness and tactical capability & Combatant Commanders more capability at less cost

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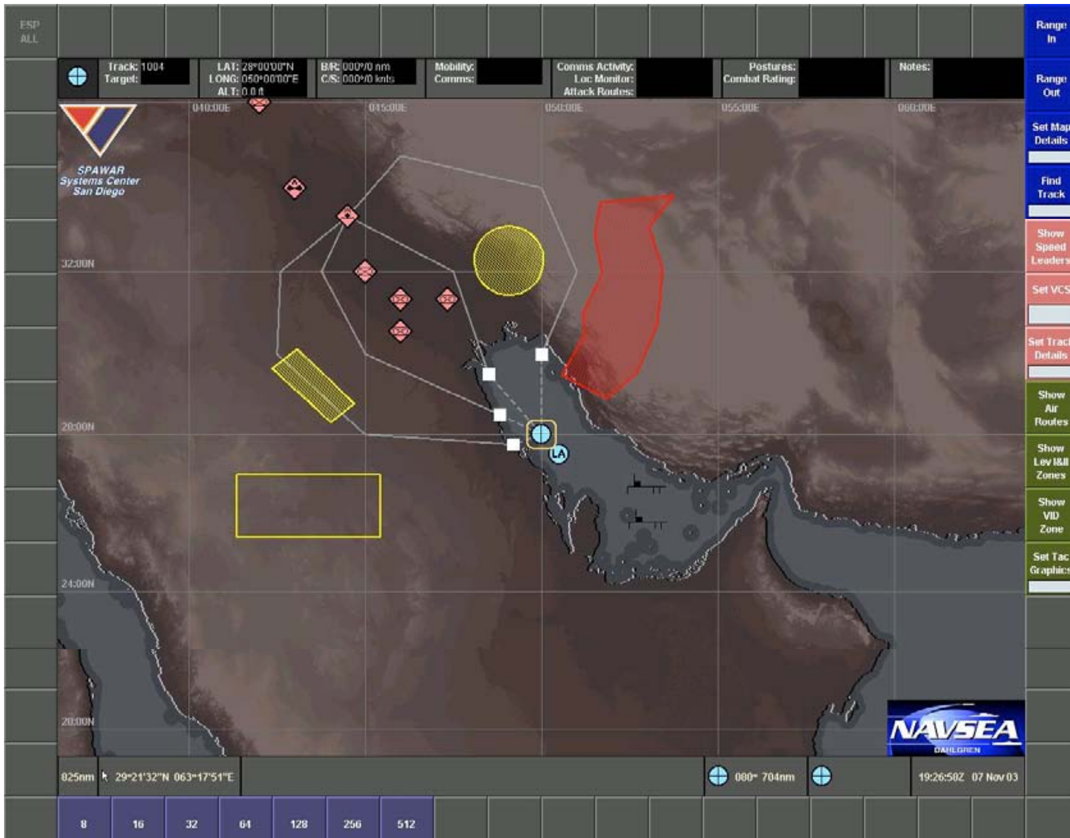
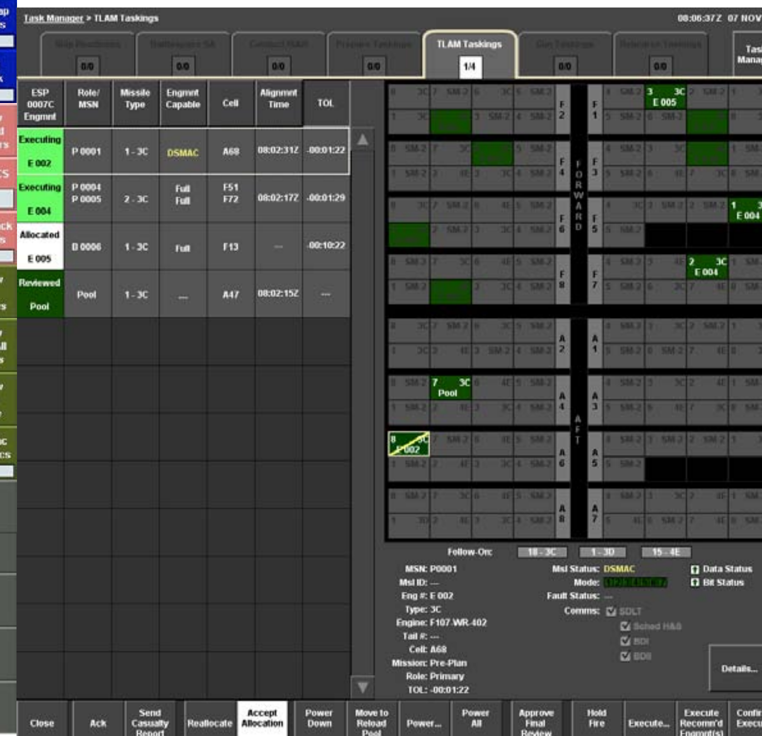
Task-Based Design

AFTER: ***Improved*** user navigation through tasks and attention management and mission process visualization





Task-Based Design

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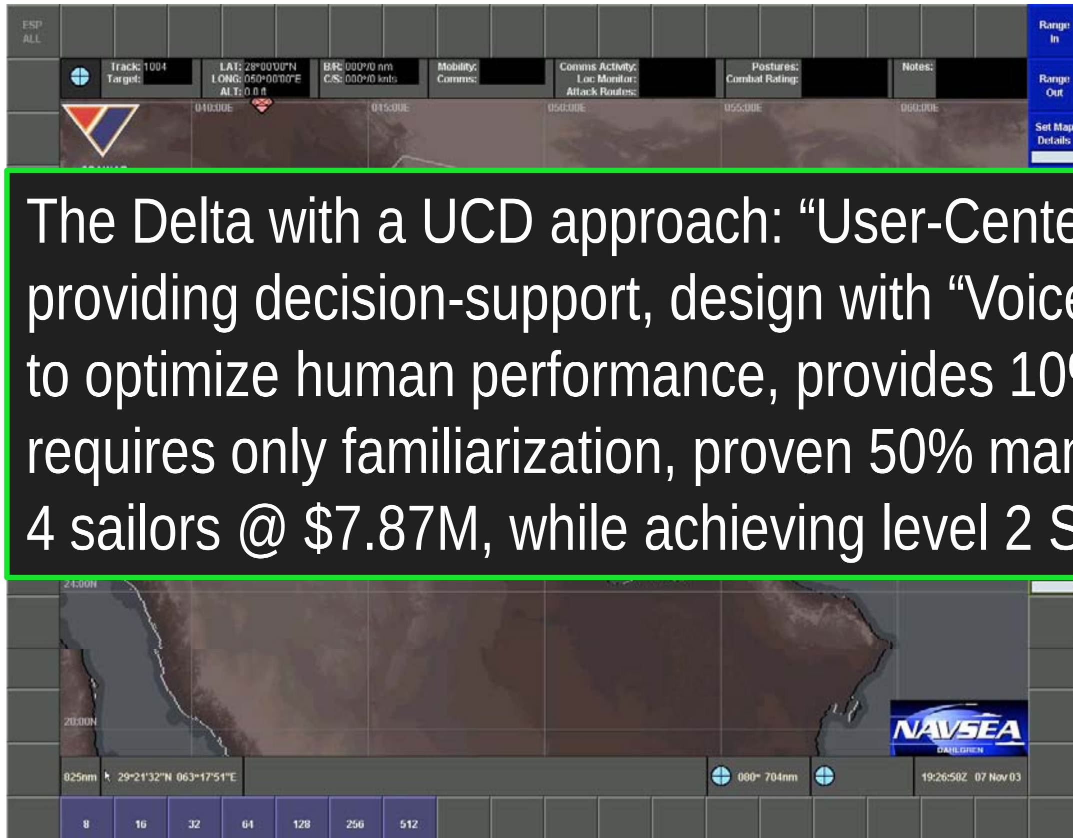
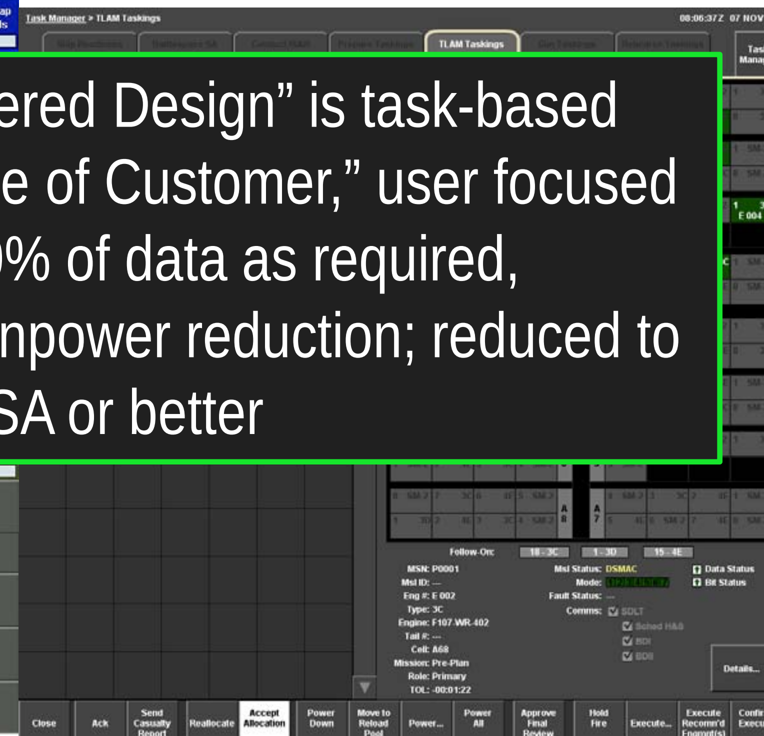


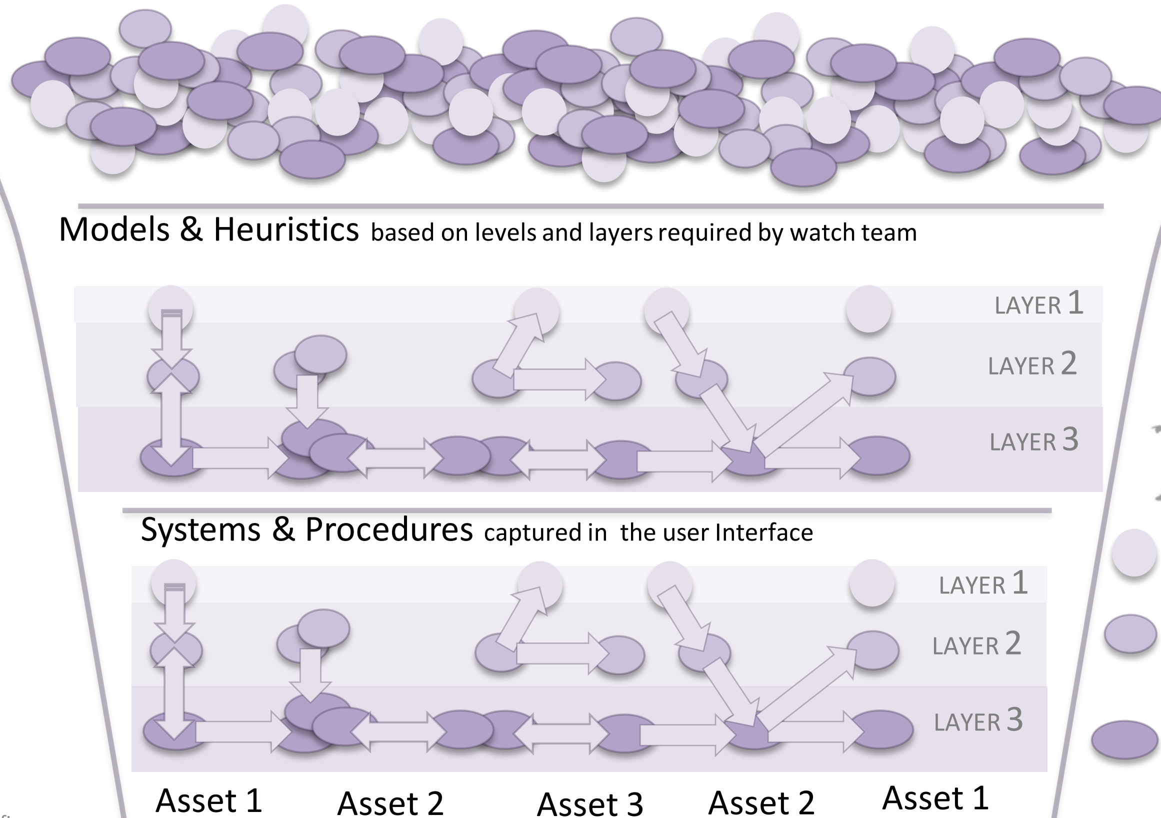


The Delta with a UCD approach: "User-Centered Design" is task-based providing decision-support, design with "Voice of Customer," user focused to optimize human performance, provides 10% of data as required, requires only familiarization, proven 50% manpower reduction; reduced to 4 sailors @ $7.87M, while achieving level 2 SA or better

Task-Based Knowledge Funnel

Users don't have to think. All of the information needed for the task at hand is there when needed.

Disparate data sources, computational resources, and products into and out of AOR



Proposed UCD support to provide Users leveled and layered information designed from tasking

Strategic

Operational

Tactical

User Centered Model drives the workflow to support the users at the appropriate level of action.

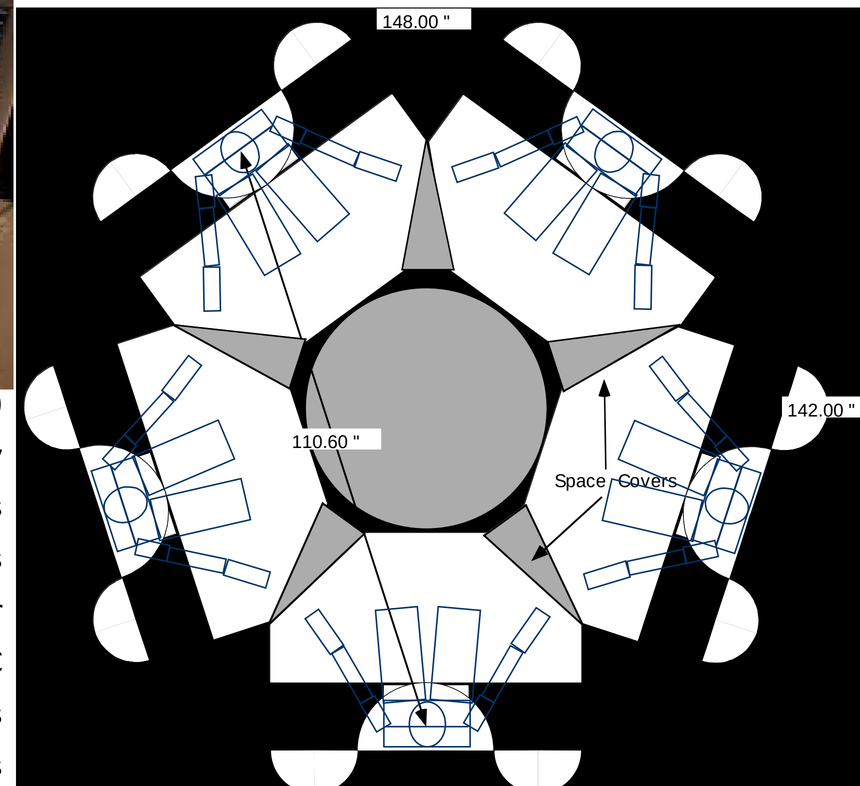
LAYER 1. Quick-Look always available or one-key popup. *Team and individual.*

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

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

Task-Based Design

Multi-Modal Watch Station (MMWS) Five Operator Pod



Multiple windows reduced to four (Task > Function)

Increases SA, design ensures Tactical Primacy

Significant ILS reduction for manned systems

Manning reduced 8 Sailors 4 Civilians

Training reduced 2 weeks to 1 hour

Significant reduction in LCC

Repeatable proven results

Expert displays

Task-Based Design

User 2: "it's because of the flow…everything, it flows…it's got a real nice progression of flow through the whole thing…."

"…You took a 2 week Wallops Island course and put it into 30 minutes! …and it probably in fact, sitting at the console, it could've been 15 minutes."

HSI = HFE = UCD = Task-Based Design

Paired with *Lean Six Sigma* in a product development environment User-Centered Design (UCD) actualizes the full six sigma, *Power of performance* becomes attainable.

User-Centered Design = Human Factors Engineering which optimizes manpower and achieves more capability at less cost to accomplish the "correct" watch floor structure and workload balance.

Significant reduction in initial and sustainment training.

Significant ILS reduction for manned systems.

Design ensures tactical primacy.

Significant reduction in LCC.

Repeatable proven results.

Increased SA.

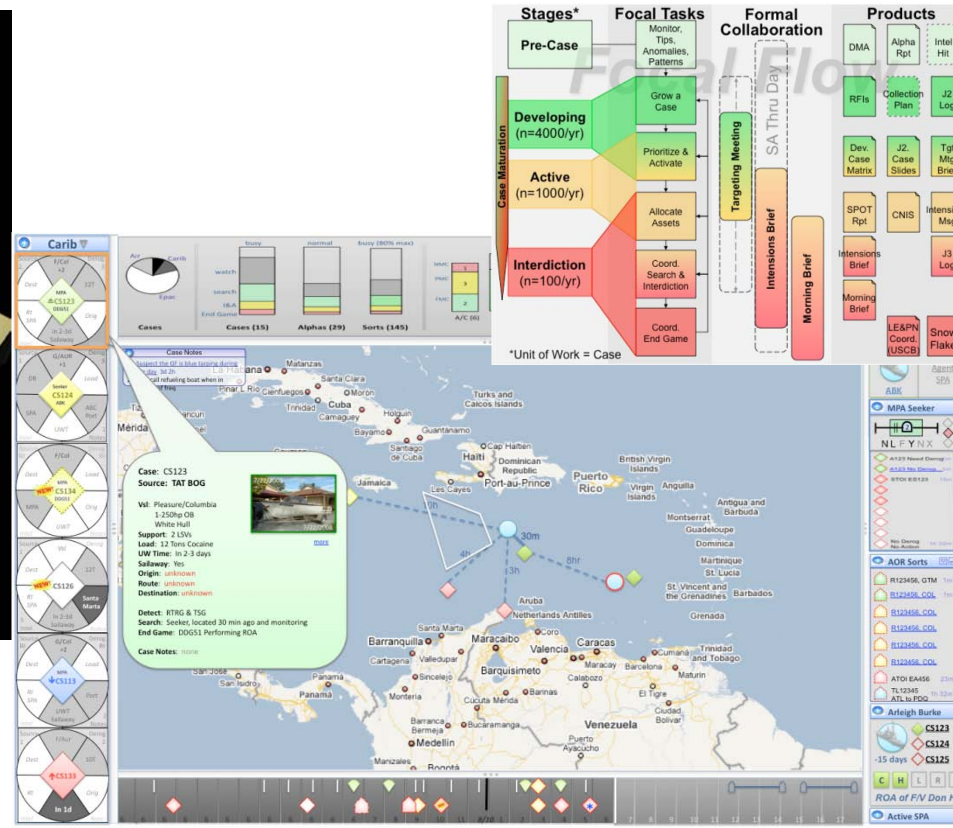
Expert displays.

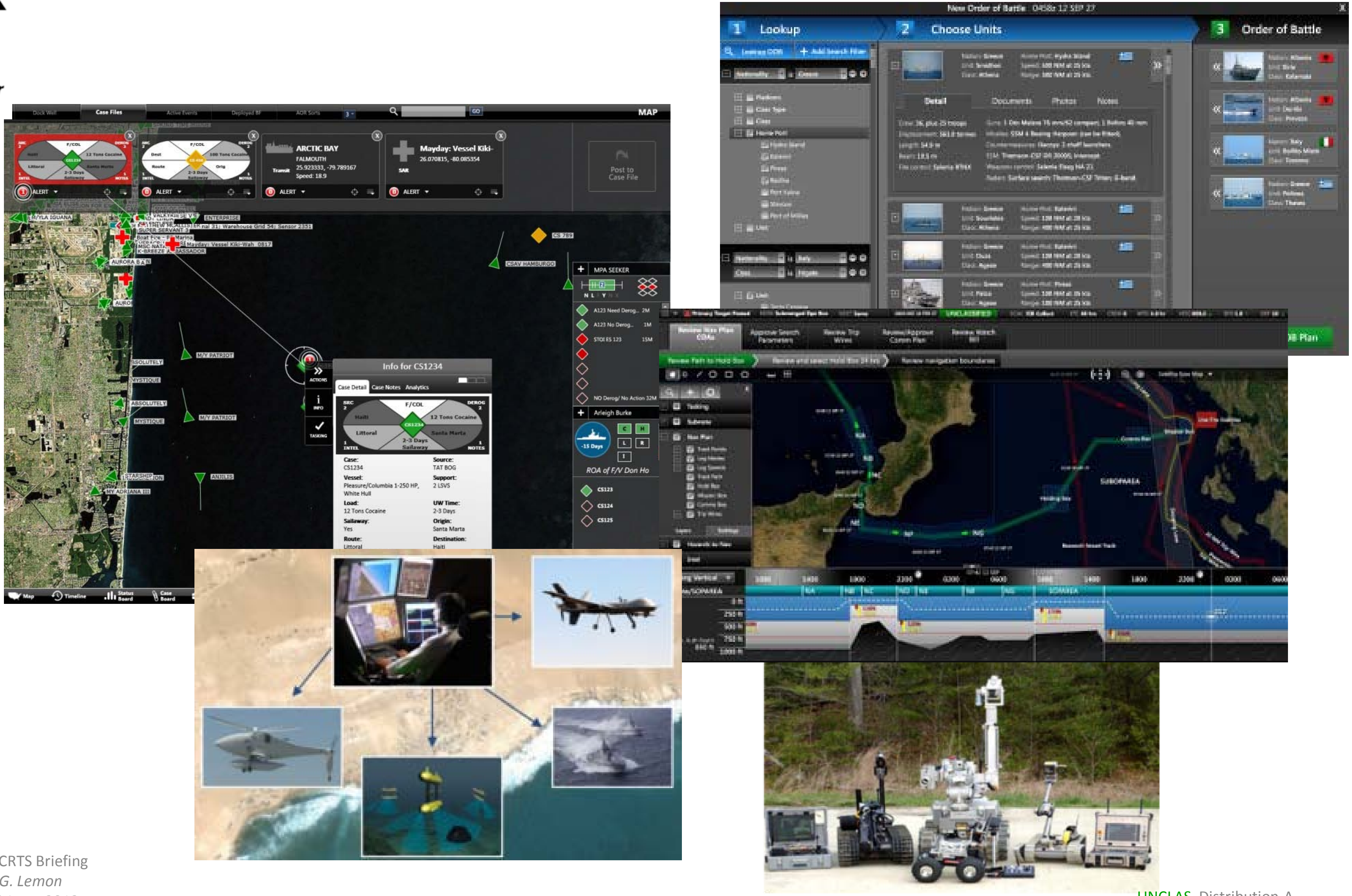
Task-Based Design

Joint Interagency Task Force-South (JIATF-S)

redesigned space increased SA

repeatable, proven results expert displays




Lookup
Choose Units
Order of Battle
Case Files
MAP
ARCTIC BAY
Mayday: Vessel Kiki-
Info for CS1234
MPA SEEKER
Arleigh Burke
ROA of F/V Don Ho

Way Ahead

How do we implement a task-based design approach within DoD?

Implement a task-based design approach within DoD?

Create a task-based design guide within DoD?

Create a separate CDRL DID?

ISO 9241-210, *Ergonomics of Human-System Interaction- Part 210: Human-centred design for interactive systems*, 2010