# Workspace Visualization for Planning of Air Operations

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Information overload has become a critical challenge within military operations. However, the problem is not so much one of too much information but of abundant information that is poorly organized and poorly represented. Here I describe a prototype information-action workspace, sometimes referred to as a knowledge visualization, to resolve this issue. Development proceeded through a systematic design sequence of cognitive analysis, knowledge representation and workspace design. The cognitive analysis focused on the specific information needed to support military planning and judgment. The workspace was structured in terms of dimensions of functional abstraction and functional decomposition; dimensions that are thought to characterize the fundamental structure of cognitive work. The products of a Cognitive Work Analysis were integrated with insights drawn from operational and scientific literature to develop a prototype workspace. Here I outline some of the features of the prototype workspace.

## Information Management

Information management has emerged as a significant contemporary challenge in modern warfare. The advantage now goes not to those with the more potent weaponry but to those with the more effective information system. Commanders and planners can access a huge amount of information. Where that information is about current status and progress of events, it becomes available with unprecedented speed. It has become available in different forms, at different levels of abstraction and from multiple and diverse sources.

Nevertheless, this information is poorly organized. It is available from diverse sources and in fragments, which leaves a commander or planner with the challenge of searching the information space to find, distinguish, summarize, integrate and understand the meaningful elements that can make a difference throughout the execution of a battle plan. That is both an onerous and a difficult task. In a high-tempo, high-stress environment it will often be an impossible one.

Information has always been central to military success but in the modern military, the importance of its role is increasing. Nevertheless, successful action is rarely based on a mass of information; it typically results from decisions in response to key pieces of information that become available at the right time. A timely decision based on a few key observations can turn a potential disaster into a victory. However, to achieve victory, decision-makers must be able to recognize and to act on the opportunities available to them. That requires a well-designed interface; termed in this paper a *virtual information-action workspace*.

## Ecological Interface Design

… *the conclusion is unmistakable: if displays of data are to be truthful and revealing, then the design logic of the display must reflect the intellectual logic of the analysis.*
Edward R. Tufte (1997), Visual Explanations, p 53

A central assumption of Ecological Psychology is that the functional needs of an organism necessarily reciprocate the functional structure of that organism's natural world (Reed and Jones, 1982). In accordance with that assumption, Ecological Interface Design results in a virtual world that reciprocates the structural constraints on cognitive work. The term *ecological* is drawn from the field of Ecological Psychology in which the driving interest is the relationship between an organism and its environment (Gibson, 1979).

The key tenets of Ecological Psychology as relevant to interface design are:

- Human action is constrained by the work domain
- Interfaces are mediated environments that can reveal the work constraints
- Information can be depicted in a manner that supports direct perception of those constraints

The approach of Ecological Interface Design is to analyze the work domain, to identify its constraints and to then develop perceptual forms that reveal the constraints directly at the interface.

The general claim driving the work reported here is that the information gathered from the world by technical sensors and human observers enters the planning information system as a fragmented and disorganized set. Some form of human-centered analysis and design must be applied to organize that information and extract its significant meaning. Most

forms of human-centered analysis start by addressing cognitive limitations or user preferences. There is typically little explicit concern with the structure of the work domain. Ecological Interface Design starts from the other direction; a consideration first of the structure of the work domain followed by a consideration of how the user might interact with it.

## Design Strategy

The design process for building a virtual information-action space to support cognitive work progresses through four distinct stages; knowledge acquisition, knowledge representation, design specification and fabrication. The role of Ecological Interface Design is oriented around the first three of these, leaving fabrication to the applied engineering disciplines.

The principles and procedures of Cognitive Work Analysis and representational forms drawn from the human factors display literature and from work domain publications are used to develop virtual workspace specifications for:

- Information requirements (what information should be displayed)
- Information layout (how information should be organized relative to other information)
- Workspace navigation (the capabilities needed to search for and integrate or associate different information elements)
- Action on the work domain (the form, content and magnitude of transactions between entities)
- Information representation (how information should be represented so workers can rapidly perceive its meaning)

Work Domain Analysis (one stage of Cognitive Work Analysis) was used to specify information requirements and layout for a workspace.

*Work Domain Analysis*

A Work Domain Analysis results in a knowledge representation termed an Abstraction-Decomposition map. This map catalogues the functional properties of the work domain (objects, resources, constraints, purposes) in a two-dimensional matrix in which the vertical dimension represents levels of abstraction and the horizontal dimension represents varying levels of decomposition.

The upper three levels of abstraction (System Purpose, Values & Priorities, Purpose-Related Functions) identify the intentional (socio-organizational) constraints of the system while the lower two levels (Physical Functions, Physical Properties) identify its physical (causal) constraints. This form of representation can be used to specify the information requirements of a work domain. Each node in the Abstraction-Decomposition map points to information (either directly or indirectly) that must be provided within the workspace. How this can be accomplished has been described in Linegang and Lintern (2003), Lintern, Miller and Baker (2002), Lintern (2002) and Lintern (submitted).

The guiding vision for an information-action workspace is one in which essential information is readily accessible and presented in succinct and meaningful forms. This suggests that there should be summaries of contextually relevant information and readily apparent signs to guide access to it. Evocative visual forms should be used to the extent possible but text information required for support of cognitive work should be summarized and highlighted so that the analyst can converge readily on its essential meaning. In this section, I outline how the results of the analysis as reported by Lintern (submitted) were integrated with selected design concepts to develop a prototype of a virtual information-action workspace.

## Workspace Organization

A planning workspace must present a global structure while it provides access to detail; support for the interplay between top-down and bottom-up exploration that characterizes the cognitive activity associated with planning and deciding. The workspace architecture described here follows the single-window, multi-panel format used by Linegang and Lintern (2003) and Lintern, Miller and Baker (2002) for ecological interfaces developed to deal with the cognitive challenges of military command and planning.

## A Prototype Workspace

The layout for the workspace is shown in figure 1. Typically, information related to intentional constraints is distributed throughout the panels in a default view of the workspace while information related to physical constraints is brought into view by interrogation within default view panels. Previous work (Lintern, 2002; Lintern, et al, 2002) suggests that the top left panel be allocated to System Purpose and the top right panel to Values and Priorities. The central panel was allocated to a geospatial representation. By this means it was possible to distribute the essential resources for activity within the geospatial area around its periphery as is

consistent with the Focus-Periphery Organization Principle (Eggleston, 2002).

The default view of the prototype workspace is shown in figure 2. The top right panel of figure has a Polar Star that depicts normalized parameters associated with Priorities and Values. The top center panel provides access to documents related to System Purposes and Priorities and Values. The cognitive analysis needed to determine the content and style of such documents has not yet been done but these resources are envisioned as succinct summaries of no more than a page or two organized to be relevant to a general context selected via the three-by-three matrix of buttons to the left. The dimensions of this matrix are currently conceptualized as Type of Effect (Physical, Systemic, Psychological) by Level of War (Tactical, Operational, Strategic) as consistent with the results of the analysis (Lintern, submitted).

The Situation Display in the center panel is the primary workspace in which planners or commanders might *drag-and-drop* items from the Allied and Adversary resources panels to the left and right (respectively) and might relocate those resources (as in the old style *sand table*) or interrogate their functional and physical properties. That interrogation could activate more detailed views in the bottom left or right panels.

Information relevant to action within the Situation Display might be assembled in the Problem Work Space (bottom center panel) to explore possibilities for Course of Action (both Allied and Adversary). One of the recurring themes coming out of the analysis was the concern of planners with relationships between allied and adversary capabilities and with the effects of environment on operations. The Problem Work Space of figure 2 is based on a capsule scenario in which a planner is concerned with effects of dust storms on operations. Further exploration would link both allied and adversary capabilities to the information assembled in this panel to examine possible impact of those dust storms on current or potential operations.

Figure 3 depicts how more detailed resources might be brought in to view. The Polar Star for System Purposes shows a problem with one parameter. A depiction of a time history for that variable may be brought into view by clicking on the shortened spoke. This particular format, developed by Tufte (1997), shows status some months in the past, a few days ago, and daily over the last week, with bars showing the limits of normal range. The goal is to remove the problem of understanding what is happening with this variable so that the planner can move quickly into the cognitive problem-solving mode of ascertaining why it is happening (Tufte, 2003).

By interrogating a resource that has been activated in the bottom left panel as a more detailed view, it is possible to bring up more information on that weapons system, in this case a graphic depiction of weather effects on the targeting performance of that system.

Selection of a document icon in the top center panel can open a summary related to Values and Priorities, in this case a summary of Rules of Engagement. The subject matter experts had noted that planners would be familiar with the Rules of Engagement but would occasionally need to check or confirm subtle specifics and may have to do so under time pressure. That forces a scan of a large document; a particularly onerous requirement in a time stressed situation. The pop-up summary, taken from United States Marine Corps (1998), is intended to resolve that problem by having a succinct and pertinent summary at hand.

The top center panel (figure 2) has a video display area and a video library. In addition, a number of photographs are used in the workspace. The inclusion of these items was based on the materiality arguments of Hayles (1999). Nevertheless, these depictions do not yet convey much more than the basic idea. Further cognitive analysis is required to ascertain the character and content of the visual narratives that could satisfy this requirement. It is likely that at least some of these visual narratives will have to be updated frequently (e.g., daily). The source of such resources and the way in which they might be designed to evoke the desired sensitivity to situational events has yet to be determined.

## Conclusions and Future Directions

The final product of this research is envisioned as a worktable with an electronic surface on which it will be possible to manipulate computer representations of information structures. It will have a graphical interface that will rely heavily on iconic representation of critical properties. It will have many of the standard tools of graphics programs (e.g. icon libraries, electronic pens, default shapes, connectors) and many of the standard means of computer interaction that permit intuitive and direct selection (touch activation, drag and drop, selection, pointing and linking).

There is considerable cognitive analysis and design work required as yet to achieve the vision of a fully integrated collaborative workspace. As noted in the

discussion of the pop-up summary for Rules of Engagement (Figure 3), the requirement for this type of resource was identified in the analysis. Although the summary shown in figure 3 was taken from a military document (United States Marine Corps, 1998), the content and form for a resource such as this should be developed through an analysis and design process similar to the one used to develop the workspace prototype but focused on this particular element. Many other elements of the workspace also demand this sort of effort.

**Acknowledgement**

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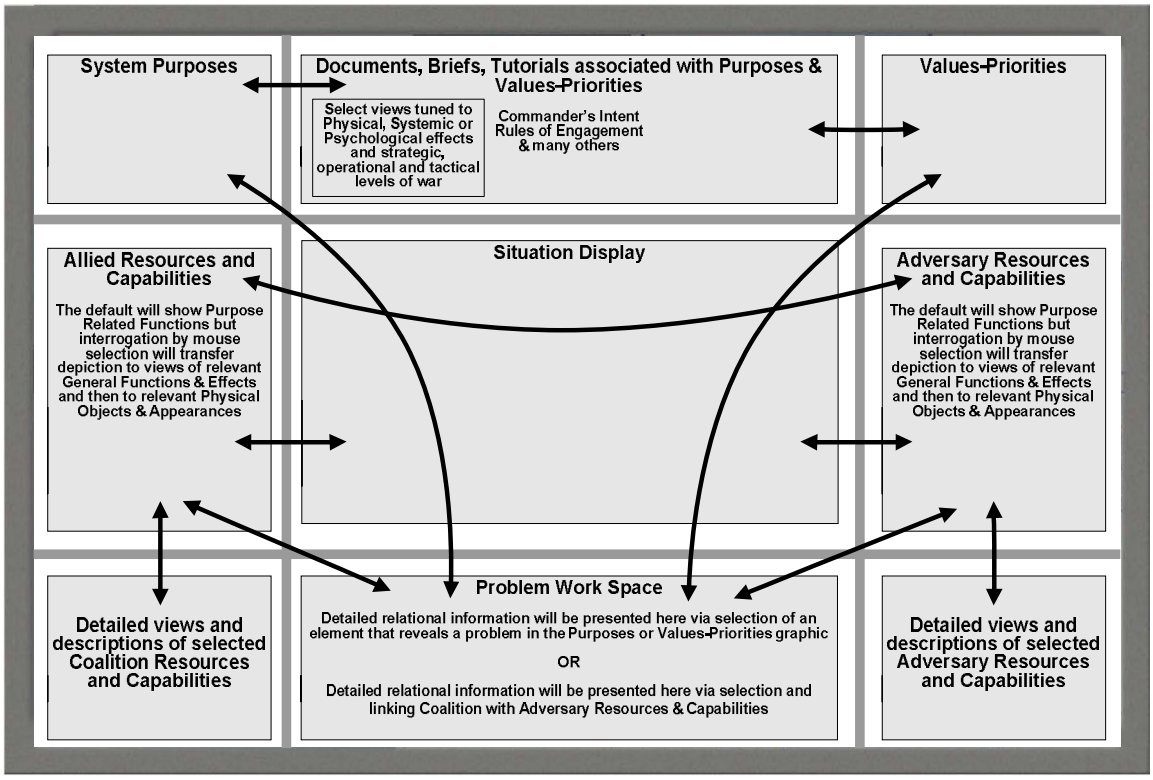


**Figure 1.** *A distribution of functions within the multi-panel format as derived from Abstraction-Decomposition matrices.*

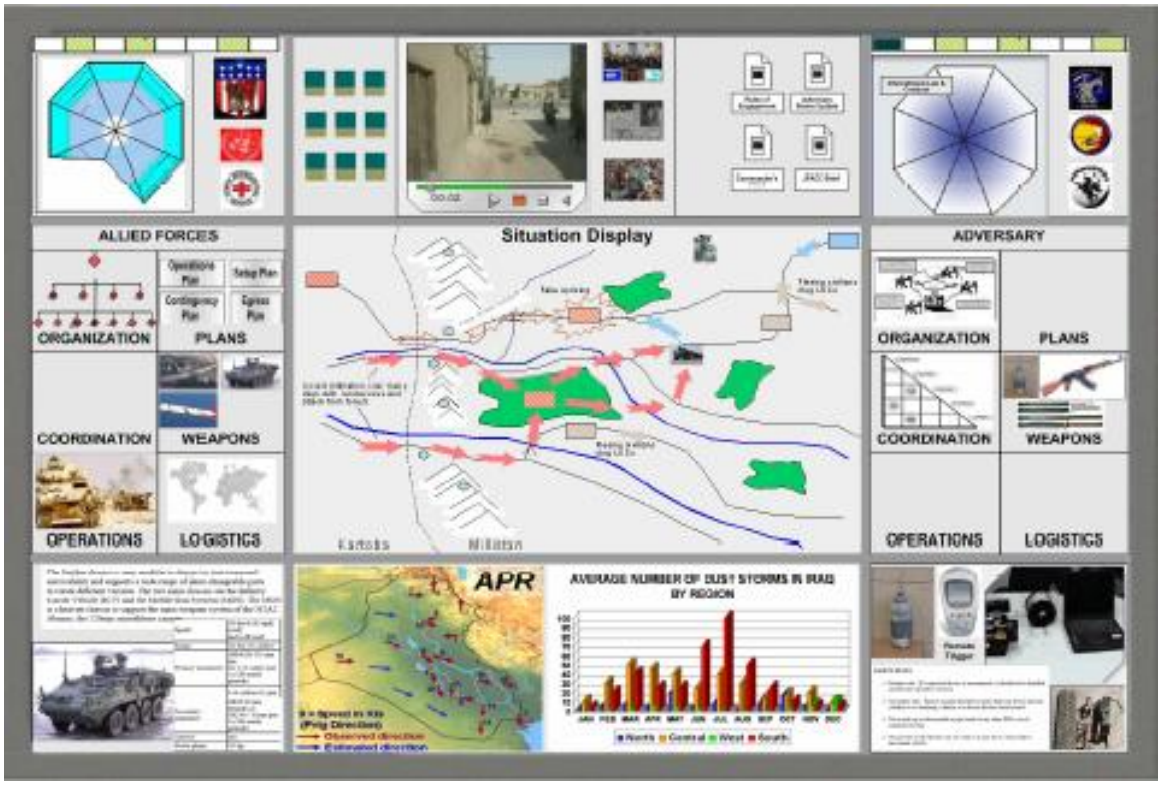


**Figure 2:** *A depiction of an information-action workspace for Intelligence Preparation of the Battlespace.*

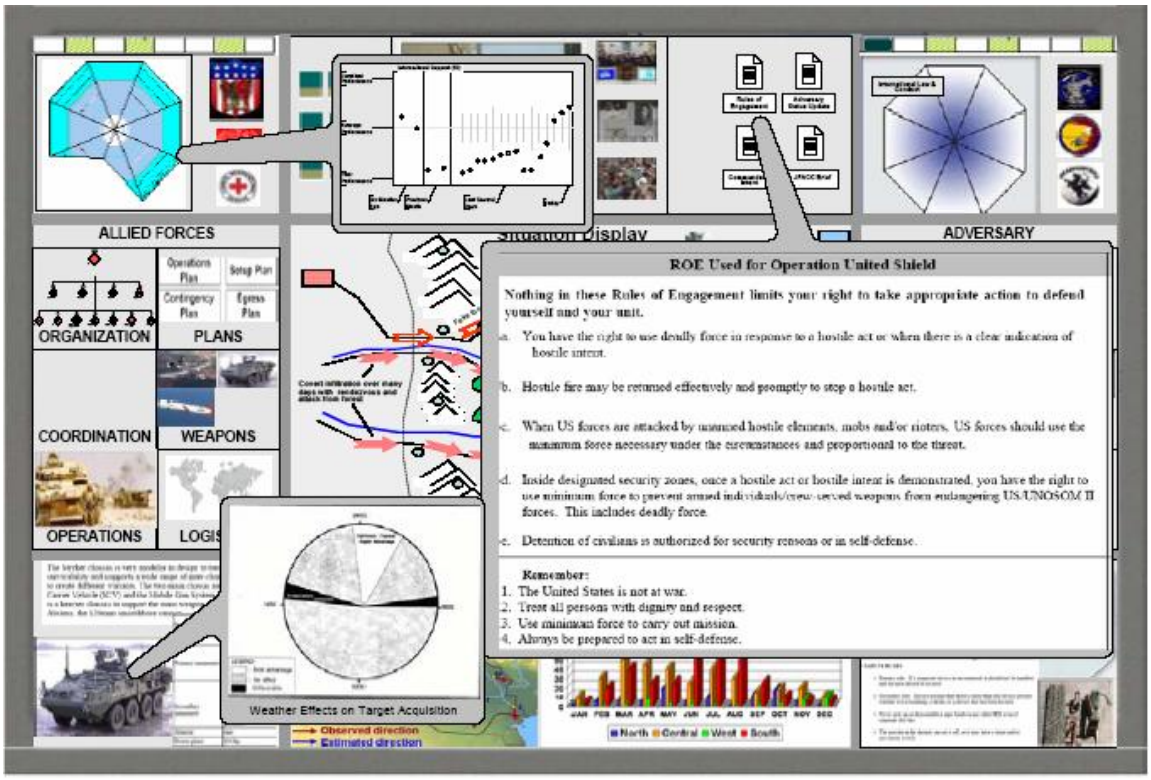


**Figure 3.** *An illustration of how information resources can be accessed within the information-action workspace depicted in Figure 2.*