

Shadows on a Cave Wall: Designing Large Scale Visual Displays to Enable Effective Team Decision Making

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ABSTRACT (150 WORDS)

The complexity of a variety of C2 work domains is driven by the existence of multiple goals, decisions and inherent functional constraints that require to be managed by a team of decision makers. The current state of practice to support this multi-human, multi-agent team is for developers to co-locate the C2 operators in a shared physical work space, incorrectly assuming that the installation of large group displays to display available data streams that “everyone can see,” effective team decision making will naturally occur.

For true individual and team decision making effectiveness, the utilization of large scale displays requires an explicit, purposeful design process, a design process leveraging an explicit functional representation of the cognitive work requirements and functional relationships within the context of the domain.

A CSE derived functional representation of a domain, will yield design requirements that provide insight into the design of large scale displays to organize command teams, group teams for collaboration by their functionally related goals, direct the focus of operators on their responsibilities and allow an operator to manipulate on an individual display to have impact what is visualized for the whole team.

(188 words)

INTRODUCTION

The need for the development of Large Scale Decision-Centered Environments (LSDCE) is directly associated with the relative complexity and amount of the decisions contained in a domain. If the goals and required cognitive work of a domain could be managed by one human, the designer would only need to design a single workstation for that single user. Complex Command and Control (C2) domains such as the Air Force's AOC, a tactical onboard naval operations center and emergency crisis management, dictate the need for a multi-human, multi-agent decision making team to handle the numerous goals within a domain.

The intent of building a LSDCE is to contain this multi-human team in a co-located physical space, providing personal access to corresponding decision makers and information resources, attempting to limit communication and technological lags across internal teams. This current design choice carries the incorrect assumption that because of the proximity of the associated decision makers, coordination and collaboration will occur naturally.

To support the need for effective team decision making (i.e. coordination and collaboration), a technologist's solution for the "design" of the physical space is to place several large panel displays across available wall (ceiling, floor, etc.) surfaces within the room – ready to display any and all data feeds that are available to multiple teams of decision makers. By continuously installing the latest and greatest technology, a technologist's claim is that "they put a large scale display on the wall so that everyone can see" and since everyone can see, they must be getting the support they need.

When designing a LSDCE, it is not merely enough to install technology for technologies sake and assume that because it is newer and better, greater decision making will occur. Rather, explicit, Macro-Cog-like design considerations must be implemented to purposefully design large scale displays within a LSDCE, for effective team decision making support.

Cognitive Systems Engineering (CSE) asks "In what way do we (as designers) provide decision support WITH the displays that everyone (the decision makers) can all see?" for effective team decision making support within a LSDCE for a C2 domain. How do we (as designers) purposefully design large group displays for the functional collaboration of teams, attention direction of team members and coordination between group and individual displays? The desire to explicitly identify such decisions and purposefully design for such individual and team decision support is critical for effective future development of LSDCEs.

BACKGROUND

The critical task for designing a C2 Center or Operations Room is applying the Mapping Principle (Woods, 1991) such that the underlying cognitive work requirements and functional relationships are represented in a LSDCE in which the operators interact.

This has several critical, team decision effectiveness, implications:

- **Command team organization** – the command team was re-organized and physically repositioned so that there was increased observability and directability of the team's resources in response to changes in the situation.

- **Functional collaboration role of group displays** – group displays were displayed to facilitate intra command teamwork awareness and shared situational understanding across the command team
- **Functional attention direction role of specialized group displays** – group displays provide directed attention to events that required the attention of the team.
- **Coordination between individual workstations and group displays** – the entire LSDCE was designed to increase observability of the military situation for all of the team members through a complementary set of individual and group displays, together comprising a single LSDCE system.

The conclusion drawn from this CSE experience is that in order to be effective, the LSDCE must be designed to satisfy decision support requirements. Current state of the practice still focuses on technology upgrades without explicit support for decision-making. This paper walks through the design effort for a command and control center and describes the unique design features that resulted from the mission of satisfying these requirements and the resulting impacts.

UNDERLYING FUNCTIONAL BASIS FOR A LSDCE DESIGN

Meaning arises depending on how marks in the medium (e.g., LSDCE) represent some process in the work domain for someone in some goal/task context (the practitioner's cognitive work). Correspondence refers to inter-connection of referent, representation, and observer that influences how the observer finds what is significant or meaningful given the task and goal context. Poor representations create indirect correspondence that makes the cognitive work needed to find meaning more deliberative, more memory intensive, and more vulnerable to various forms of breakdown. This is especially true in a LSDCE-like setting where collaboration and other Macro-CSE issues result from the fact that no one decision-making agent can accomplish all of the domain related work. Direct correspondence occurs when the LSDCE provides the decision-making agents insight into the overall process. Thus, building direct correspondence to achieve observability presupposes a particular definition of what is informative.

It is this paper's position that the definition of what is informative should be derived from the application of a cognitive analysis of the work domain. For this effort, an Applied Cognitive Work Analysis (ACWA) methodology was used.

ACWA begins with the construction of a Functional Abstraction Network (FAN), a multi-level, recursive, means-ends representation of the essential concepts and relationships of the work domain (Elm Potter, Gualtieri, Easter & Roth, 2003). The purposes of this component of the analysis are to gain a framework for understanding the underlying work domain and to identify intrinsic properties of the domain that shape the required decision-making.

The FAN was constructed by conducting a work domain analysis to understand and document the goals to be achieved, the relationships between goals (e.g., goal-sub-goal relations, mutually constraining or conflicting goals), and the means available for achieving them (e.g., alternative methods available, pre-conditions, side-effects, preferred order) at ever more increasing levels of abstraction (Woods and Hollnagel, 1987). The resulting FAN is independent of the particular

agents (human or machine) accomplishing the specific domain objectives and the functions that must be available and satisfied in order to achieve their goals.

The FAN is an ACWA-derived artifact that serves as the initial scaffolding that will provide the structure for the design of the LSDCE. From this model of the work domain, it is possible to derive, organize, and preserve the goals, processes, decisions, and information requirements. All of which lead to the design of large scale displays for team decision making support.

LARGE SCALE GROUP DISPLAY UTILIZATION

Because C2 teams require communication and coordination among its members, the LSDCE cannot simply be a series of Visual Display Units (VDU) on individual warfighter desktops. Rather, the support environment needs a set of display devices that present results of the various decision-making processes in the context of the C2 team's goals and their current level of achievement. In addition, the LSDCE must address the generic CSE support functions. Members of LSDCE should have a 'workspace' that is made up of:

- Data presented on **Large Group Functional Displays (LGFD)** that are mounted on or near walls of the Operations Room,
- Data presented on multiple **Alarm / Alert Group View Displays (AAGD)** that are mounted near the ceiling of the Operations Room,
- Data presented on the VDUs that are part of their **Individual Functional Displays (IFD)**, the functionality of which is described below.

LSDCE provides the ability to anticipate and adapt to surprise and errors. It enables individual team members to explore outside current boundaries, set, focus, or priority, to make cognitive work observable, and to balance the pressure to narrow/over simplify the decision space with comprehensiveness and broadening checks.

Since the roles and responsibilities of the operators of a LSDCE is derived from the analysis of the work domain (i.e., the FAN), it is logical that the seating arrangement of these individuals within the Operations Room follow the triangular structure of the FAN.

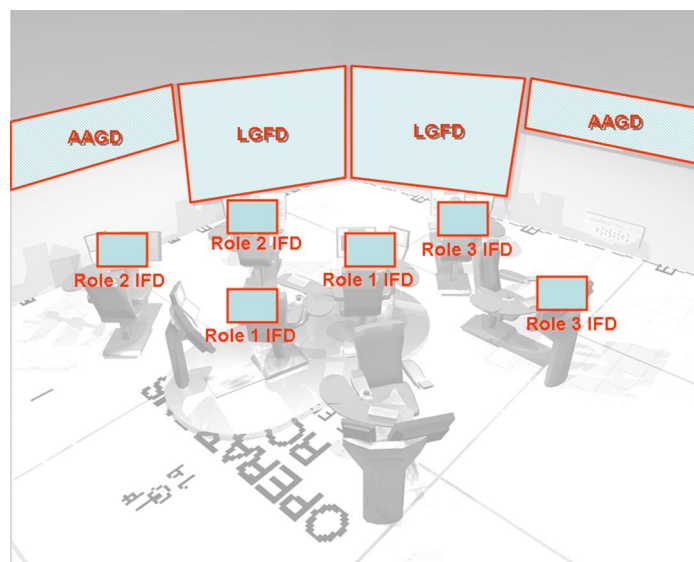


Figure 1. Decision-Centered Operations Room for a Command & Control Team

The LGFDs are the principle means for providing group coordination through observability, directed attention, and teamwork with agents. For example, the LGFDs help increase observability by providing common ground (i.e., a shared frame of reference) and making agents' intent and activities observable to all C2 team members. The LGFDs provide feedback so that the operators can see the emerging effects of decisions, actions, and policies. These representations are mapped in such a way as to capture the functional relationships inherent in the LSDCE domain and to make patterns salient to all the operators on the floor. Because the LGFDs are organized around the FAN, they have the ability to provide feedback into the underlying work domain process.

The AAGDs support Directed Attention by re-directing agent resources as situations change. They also support Coordination functions by seeding other team member activities (i.e., structure & kick start initial activity) and reminding each role member of alternative possibilities as activity progresses. But the AAGD do not treat alarms like other systems which view alarms as messages from one agent, a first stage monitor, to another, a second stage supervisory agent who monitors multiple channels and whose cognitive resources can be under workload constraints. The alarm is an interrupt signal intended to redirect the attention of the operator from their process monitoring tasks to examine some particular area or topic or condition in the LSDCE process. Thus, the alarm system participates in processes of joint reference as the signal refers to events in the monitored process in order to direct another's attention to this event.

Because of their role in supporting teamwork and coordinating and synchronizing activities across agents, the LGFDs and AAGDs are 'system paced' displays. The LGFDs present functional depictions of the current state of the components of each of the functional processes at a pace that is consistent with the world events from which those data are derived. While the AAGD directs the attention of the decision-makers to non-normative domain events, the LSDCE team members cannot directly influence what is displayed on the LGFDs and AAGDs.

However, the individual team members can 'tag' or highlight items on these displays as a means of communicating items of special attention. In addition, the AAGDs are devoted to the display of abnormality indications that are related to the functional processes represented in the FAN. The AAGDs present text messages related to problems within these processes. These could include, but are not limited to:

- Messages about the underlying functional process, or
- Messages about functional goal success.

In addition to the group collaboration design concepts, the operators within the LSDCE require a set of function-based visualizations that provide the operators with a revolutionary work environment that enables them to be agile in response to events in the world that would disrupt their goal seeking performance. As one example, the functional displays should provide the results of inference algorithms in a manner that permits the operator to monitor the overall state of the work domain process with the specifics for any particular element of interest. Despite the previous role allocation, each IFD is available at every VDU.

The individual workstations and their IFDs within the LSDCE should be arranged so that they provide adequate viewing of the LGFDs and AAGDs by workstation occupants. The IFDs also should be arranged to provide effective face-to-face communications between the various members of the C2 team. ACWA provides a set of requirements that are sufficiently aggregated /

abstracted so as to cover the full decision-making scope for a node within the FAN. This follows the CSE support function of directability, which states that the means for taking control actions in the work domain should be presented at the same level of abstraction as that used for the presentation of data that are used in the decision-making related to those actions. This prevents added (and unnecessary) work and time delays related to locating appropriate control action devices once a decision to take action has been made. *Thus, the total of any agent's decision support environment is the sum of the LGFDs, AAGDs and IFDs as an integrated and synchronized whole.*

SUMMARY

The complexity of any C2 work domain is driven by the existence of multiple goals, decisions and inherent functional constraints that require to be managed by a team of decision makers. The current state of practice to support this multi-human, multi-agent team is for developers to co-locate the C2 operators in a shared physical work space and installing large group displays to display available data streams that "everyone can see" from their respective position on the floor. This technologist's view of design incorrectly assumes that coordination across, collaboration within decision making teams will naturally occur because of the installation of high-resolution, wall mounted large scale displays.

For true individual and team decision making effectiveness, the utilization of large scale displays requires an explicit, purposeful design process, a design process leveraging an explicit functional representation of the cognitive work requirements and functional relationships within the context of the domain.

A CSE functional analysis of a domain, will yield critical design representation requirements for the content for specific displays as well the design of everything from the positions of individual chairs on the floor (Command team organization), how to keep the groups on the same page (Functional collaboration role of group displays), how to direct the focus of operators on their responsibilities (Functional attention direction role of specialized group displays) and how to the manipulate on an individual display to be visualized for the whole (coordination between individual workstations and group displays).

For a Large Scale Decision-Centered Environment to be effective in a C2 work domain, the LSDCE must be designed to satisfy explicit decision support requirements. Working to meet these support requirements can be seen as a means to manage the complexities of C2 Center designs, so that its overall decision effectiveness is improved. So that the information "everyone can all see" across the C2 Center is providing the specific decision support that everyone needs.