Designing the Information Space and Physical Layout for a Command Center Based on an Optimized Organizational Structure

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Abstract

This paper presents a method for designing the physical layout of a command center to best support team performance, based on the communication and information structure of the team. The command center design method is based on an optimized team design model that produces the best team structure for a specific mission. Using information about the team's communication patterns and information needs, we apply model-based principles to evaluate candidate designs for the physical layout of the command center and to develop designs best suited to the team structure.

Introduction

The information infrastructure and physical layout of command centers often evolve in a somewhat ad hoc fashion as new technologies are added, new positions created, and new connections and communication links are established within and between command nodes. The problem is especially acute for shipboard command centers like the Combat Information Center (CIC) aboard the Navy's AEGIS ships. Equipment acquisition for the CIC often has been "stovepiped," with each new system or capability developed in isolation from all others, and with little consideration given to the existing CIC team organization or how the new capability will best fit into the existing structure. With each new technology, a new, dedicated team member must be added to operate the new system, and the new equipment and new watchstanders must be fitted into the limited space wherever possible.

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Within the CIC, the physical layout of the spaces is often not optimized for the organizational structure that exists. For example, in an AEGIS Cruiser CIC, the space is organized into basic command, anti-air warfare (AAW), and anti-surface/anti-submarine warfare (ASUW/ASW) groupings. However, each of these sub-teams sits facing away from each other and the leaders of these teams are not convenient to the command personnel. This layout is forced by the design of the display equipment.

Systematic, reliable methods are needed for the design of command centers—both the information space and the physical space—to best support the command team's organizational structure. Under Navy sponsorship, we have applied a comprehensive, systematic, quantitative methodology (Levchuk, Pattipati, & Kleinman, 1998) to design a command center organization optimized for a typical mission for the Navy's next generation of surface combatants (Paley, Levchuk, Serfaty & MacMillan, 1999). Because this Team Integrated Design Environment (TIDE) methodology produces a mission-driven specification of team roles and specifies in detail the interactions of the optimally structured team, the results can be used, in combination with practical design principles, to guide the design of shared information displays, communication networks, and physical lay-outs for command centers that best support future command teams.

Approach

Team modeling can provide powerful insights into the interactions and communication requirements between team members, and this has strong implications for the physical layout of the command space. For example, information that is displayed and acted on by a team of watchstanders is differentiated from information relevant only to individuals. This partitioning can be used to determine requirements for common displays and watchstander groupings. Alternatively, team modeling can help identify the impact of new technology on team layout. For example, a new volumetric display technology might provide a display area that is useful to several watchstanders simultaneously. As a result, these watchstanders could be physically moved in the command space to permit them to share and take full advantage of the new display.

Under the Navy's Manning Affordability Initiative (Cannon-Bowers, Bost, Hamburger, Crisp, Osga, and Perry, 1997), a number of innovative physical designs for command center layouts were developed. These Integrated Command Environment (ICE) designs specified possible future physical layouts and capabilities for shipboard command centers. We analyzed the suitability of several of these ICE designs for an optimally structured command team, and developed a matrix that identified team organizational design issues and possible physical implementations from the ICE designs to address them. This matrix is presented in Figure 1 and served as the basis for developing the physical design principles shown in Figure 2.

Results

Based on the defined principles, candidate physical layouts for alternative command center configurations can be designed based on shared information structures between the members of the command team. Figure 3 demonstrates a graphic version of the shared information structures across five decisions makers (DM1–DM5) in an optimized team structure. This figure is based on who needs access to the various information sources to complete their specified mission tasks. The model contains shared structures as well as private displays. For example, DM1, DM2 and

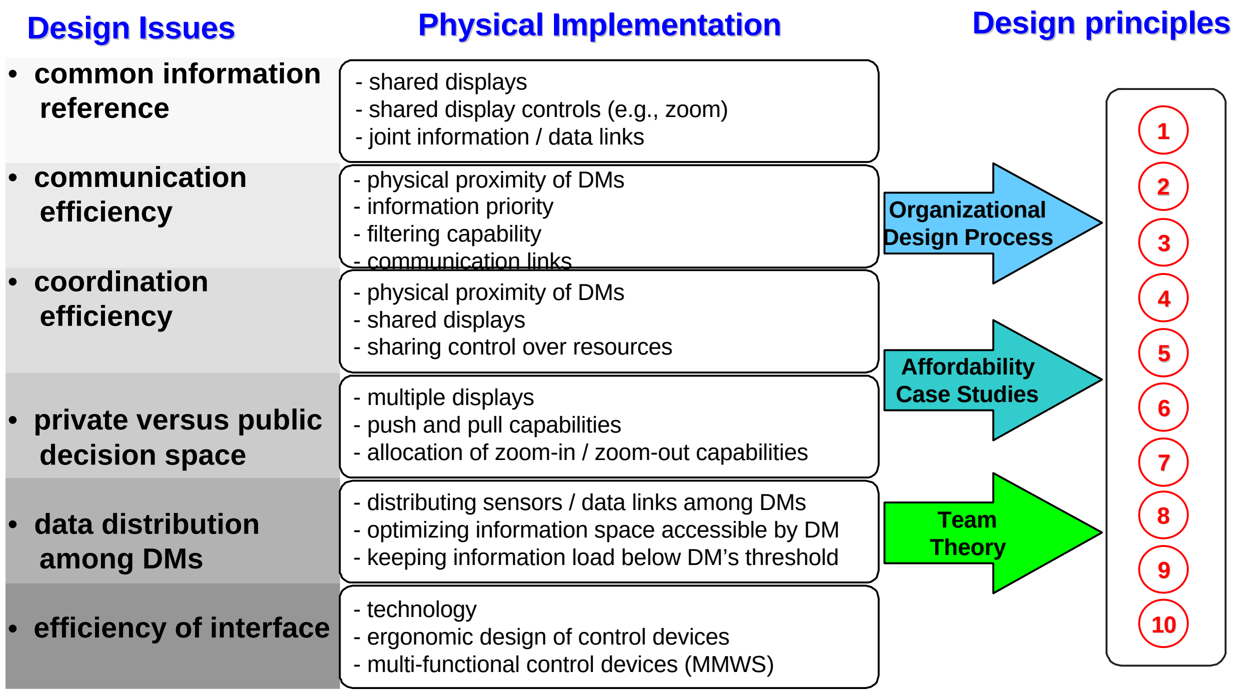


Figure 1. Team Design Issues and Physical Implications

1	• physical proximity among DMs that is concomitant on (i) the information flow and (ii) decision coordination in the organization
2	• physical proximity of DM's decision support / control equipment (sensors, visual communication nets, control devices) that is concomitant on DM's functionality and his internal information flow
3	• allocation of private and public decision domains to DMs according to their responsibility distribution
4	• separating private from public workspaces to filter out the irrelevant information at critical time intervals
5	• segregating information acquisition control and information display features of radar / sensor equipment
6	• multi-functionality of decision support / control equipment (e.g., automated message generation)
7	• ergonomic design of decision support / control devices (MMWS)
8	• providing decision / control systems status monitoring capabilities to the superior DMs in the decision hierarchy
9	• monitoring the levels of DM thresholds (corresponding to different workload dimensions) to prevent failures due to overload
10	• control and display environment transfer from DM to DM

Figure 2. Model-Based Principles for Command Center Design

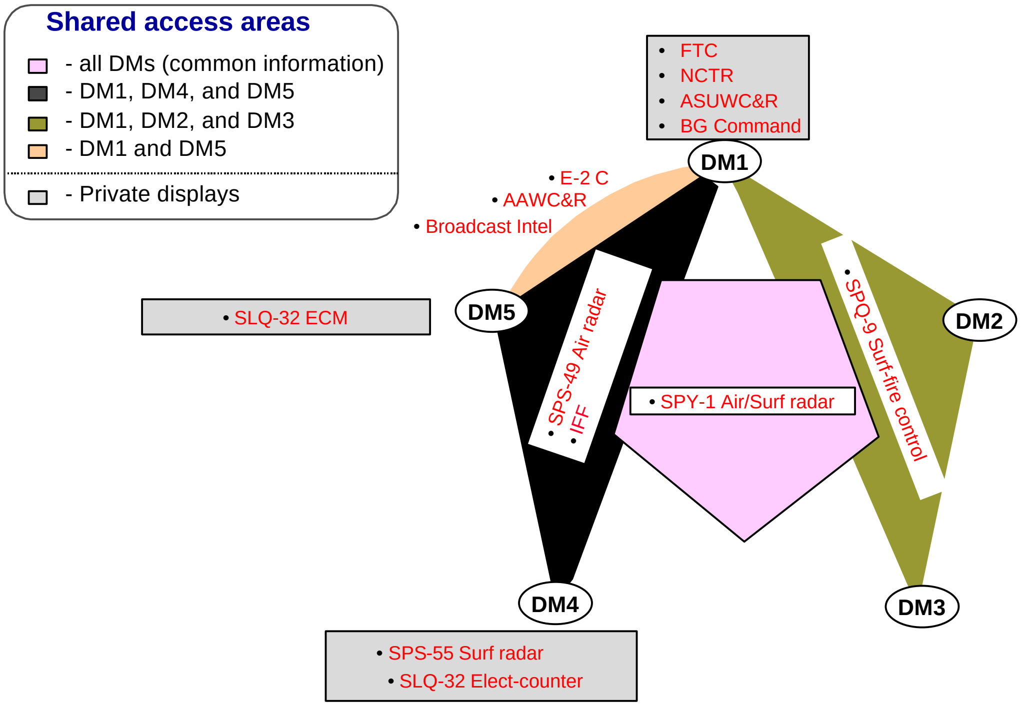


Figure 3. Information Access Structure for a Notional Command Team.

DM3 all must share data from the SPQ-9 radar and DM5 is the only team member with access to the SLQ-32 ECM. These access allocations are a direct output of the TIDE modeling process.

Based on these shared information structures, we are able to analyze the implications of team design parameters for the physical implementation of the command center, as instantiated in candidate physical layouts for alternative command center configurations. Information from the team modeling allowed us to comparatively assess the adequacy of various alternative physical command center configurations for supporting the five-person team design and information structure shown in Figure 3.

Figure 4 shows several "revolutionary" physical layouts developed for the Navy's SC-21 Science and Technology Manning Affordability Initiative program—a "boardroom design with table-based displays and an "arena" design with an central display patterned after a sports arena.

Figure 5 presents an example of a physical layout based on the information access structure needed by the command team described in Figure 3, as implemented in the arena design of Figure 4. Based on the various information sources team members need to complete their specified mission tasks, and the within-team coordination, we can prescribe a physical layout, specifying shared information structures as well as private displays. This process can also be used to specify the contents of shared displays on the operators' workstations.

Based on the command-center design principles shown in Figure 2, we were able to evaluate the adequacy of each of the ICE designs for supporting the team and information structure shown in Figure 3. We were also able to develop an "optimal" design that combined some of the best features of the different ICE designs.

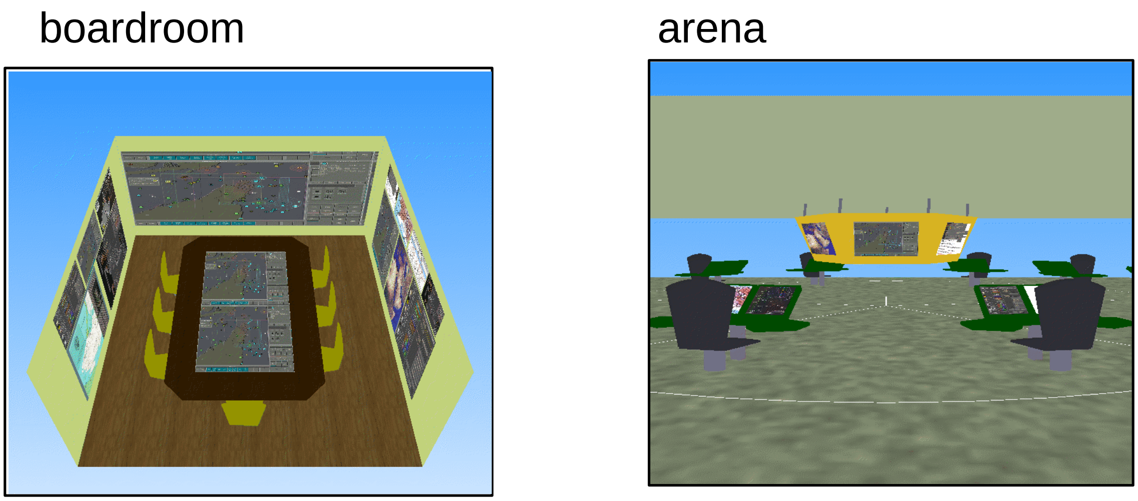


Figure 4. Examples of Integrated Command Environment (ICE) Designs

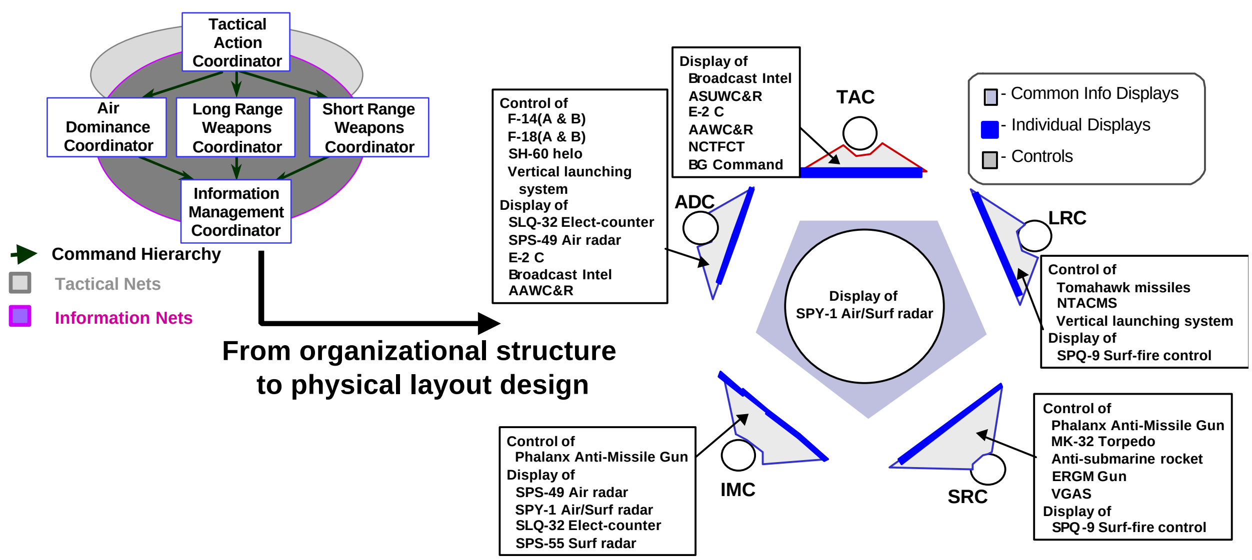


Figure 5. Physical Layouts for Arena Design Derived from Information Access, Command, and Communication Structures

This optimal design is shown in Figure 6. Figure 7 shows the results of a comparison between the boardroom design, the arena design, and the "optimal" design in meeting the principles listed in Figure 2. Although the team, as designed, could function in either the boardroom or the arena designs, we concluded that the somewhat different design of Figure 6 would be more congruent with the team's organizational and informational structure. At this point in our analysis, these comparisons are based on examination and judgment, but they are model-based and guided by design principles.

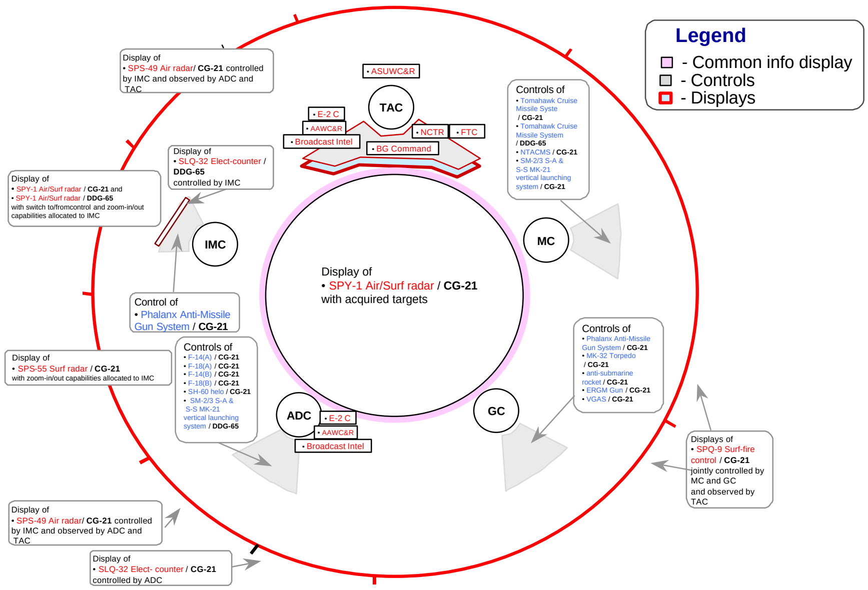


Figure 6. Optimized Physical Design for Command Team

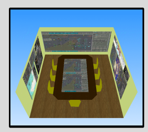
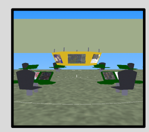
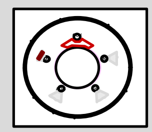
Design Principles	Implementation	 boardroom	 arena	 Optimal
1 • physical proximity among DMs	- for information flow	+	-	+
	- for decision coordination	+	-	+
2 • physical proximity of equipment	- of sensor displays	-	+	+
	- of controls	+	+	+
3 • allocation of private and public domains	- in information distribution	+	+	+
	- in control	+	+	+
4 • separating private from public workspaces	- isolation	-	+	+
	- transformation from-into	-	-	+
5 • segregating control and display features of equipment	- eliminating zooming interference	+	+	+
6 • multi-functionality of equipment	- automatic message generation	-	feasible	feasible
7 • ergonomic design of control devices	- visual control interface	feasible	feasible	feasible
8 • systems status monitoring	- weapon-to-target map	feasible	feasible	feasible
	- system status	+	+	+
9 • monitoring DM thresholds	- dynamic workload estimation	-	feasible	feasible
10 • control and display transfer	- controls	+	via reprogramming	+
	- display environment transfer	+	only with increased information density	+

Figure 7. Comparison of Three Command Center Designs for Optimized Team

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