A Methodology For Determining Optimum Command And Control Structure For Small Ship Combat Systems

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Abstract

Lockheed Martin is investigating small ship combat systems of the destroyer, frigate, and corvette ship types for various international navies. The integrated weapon system command structure is a blend of command & control equipment, sensors, weapons, and communications infrastructure to ensure state of the art command and control facilities. A command and control display architecture that is matched to requirements and operational needs is needed. This architecture should also provide a flexible structure to meet not only the initial-ship-class command structure but also commanding officer's individual operational needs along with future upgrades and improvements. During the concept phase of any large project such as this, the problem is translating requirements/operational needs to the optimum architecture of console and control equipment types. This paper provides a "best practices" process that begins with requirements analyses, addresses options of console/equipment types, manning loads, lifetime costs, and leads to the optimum Combat Information Center (CIC) organization and command and control/display architecture.

1.0 INTRODUCTION

During the concept phase of a ship combat system, the supplier is expected to provide an optimum command and control/display architecture that is tailored to the customers' operational needs and requirements. This paper defines a process that leads to a "best fit" command and control/display architecture based on naval concept of operations and requirements.

2.0 PROCESS DEFINTION

Besides being based on requirements and the CONOPS the process also accounts for numerous factors such as operation of sensors and weapons, job functions, lifetime costs, expected manning, and assessment of console quantity and types. By following the process proposed herein, a complete CIC layout is achieved along with command structure, and job functionality. The proposed process is illustrated in Figure 1 and is described below.

As illustrated in Figure 1, the process starts with the customer's concept of operations along with a definition of requirements. Analyses of these documents leads to the following needs statement example:

- Interoperability requirements (For example, NATO operations, operations with U.S Navy, worldwide operations, independent operations).
- Expected threats
- Threat scenarios
- AAW, ASW, ASU, EW, STW battlespace requirements
- Expected Sensor types
- Expected Weapon types
- Embarked Command needs
- Steaming operations (For example, 30 day steaming without a port stop)
- Operational Roles (For example, protection of shore lines, point defense, convoy protection, etc.)

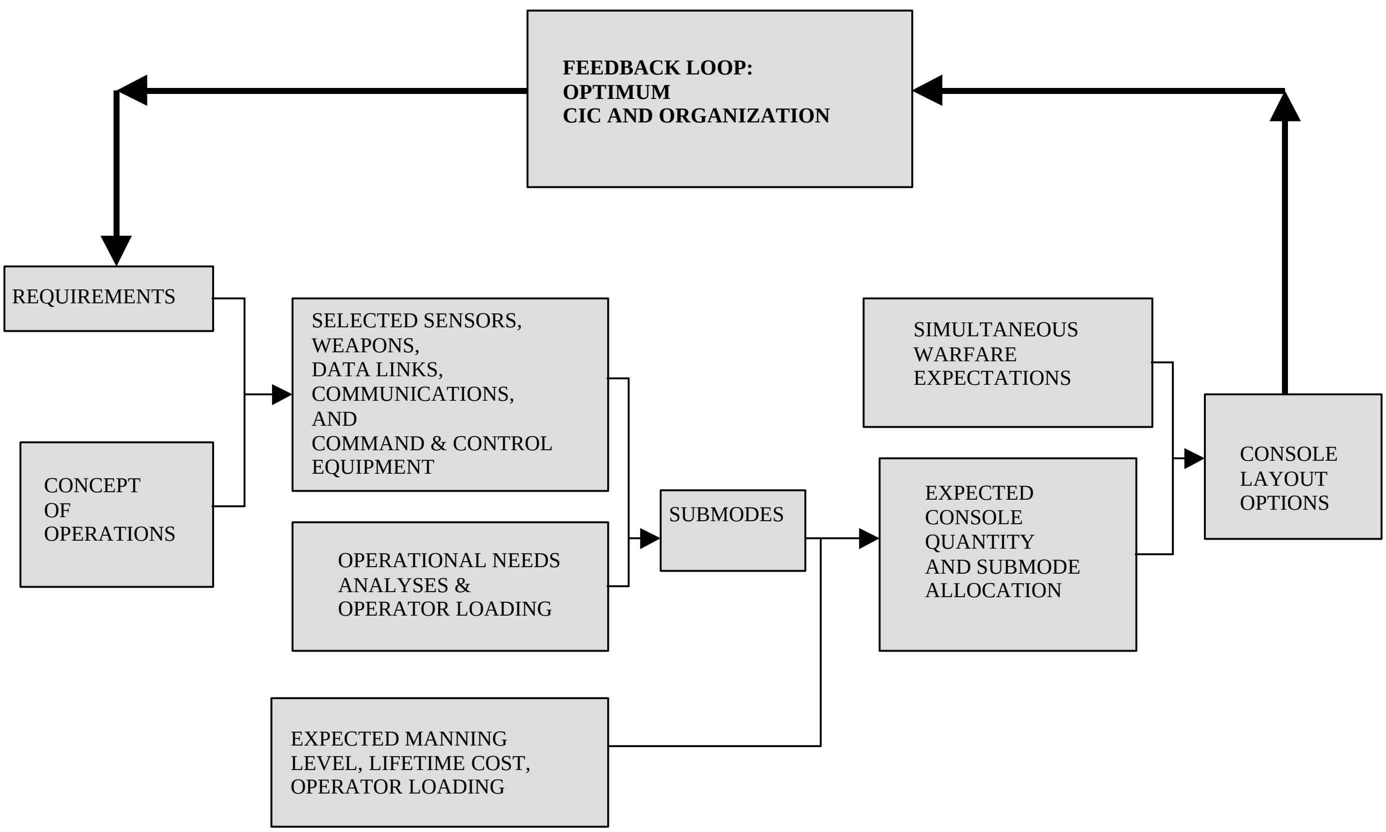

FIGURE 1   COMMAND & CONTROL/DISPLAY ARCHITECTURE PROCESS FLOW

Analyses of the Needs Statement, along with budget constraints and customer expectations of equipment, provides for a selected equipment baseline of sensors, weapons, data links, communication needs, training, and command and control systems.

Once an equipment baseline is defined, an analysis of operator job functions and expected loading can be performed. The output of this analysis provides a definition of expected submodes, where the definition of a submode is a specific job function required to operate specific equipment or perform some battlespace task. For example, if it is expected that multiple radars are part of the configuration and each radar has its own operational tasks, then possibly a submode is required for each radar. A single submode may also define an area of responsibility (e.g., AAW coordination, ASW coordination, or missile system supervisor). Each submode is comprised of:

- A set of allowable button actions,
- Access to specified information,
- Alert destination.

Submodes can reside at any console individually or many submodes can reside at a single console. In fact during low tension steaming operations it could be acceptable to operate every submode from a single console. A Corvette Class, Frigate Class, or a Destroyer Class could expect to have approximately 25 to 30 submodes. Examples of some submode types along with associated job functionality are provided in Table 1.

TABLE 1 EXAMPLE OF SUBMODE TYPES AND FUNCTIONALITY

SUBMODE TITLE	**SUBMODE FUNCTIONALITY**
Radar System Controller (RSC)	• Modify radar system track load • Coordinate radar silence • Monitor radar system performance • Control radar search sectors and subsectors
Missile System Supervisor (MSS)	• Assess Missile System readiness • Monitor Missile Illuminator readiness • Monitor VLS assignment and usage • Monitor AAW engagements and weapon resources
Commanding Officer (CO)	• Monitor and direct use of sensors • Monitor and direct use of sensors • Direct warfare area operations • Respond to force orders, etc
Principal Action Officer (PAO)	• Monitor and direct use of sensors • Monitor and direct use of sensors • Direct warfare area operations • Respond to force orders, etc
Embarked Commander (EC)	• Direct Battle Group operations
Ownship Display Assistance (OSDA)	• Monitor assigned communication circuits • Monitor Large Screen Display activities
Embarked Commander Display Assistance (ECDA)	• Monitor assigned communication circuits • Monitor Large Screen Display activities
Combat System Coordination (CSC)	• Monitor ID activity • Evaluate weapon system performance • Evaluate combat system readiness • Evaluate combat system operations • Determine need for EMCON and battleshort
Anti-Air Warfare Coordination (AAWC)	• Monitor air radar sensor doctrine and loading • Monitor AAW tactical situation • Perform Threat Evaluation of air contacts • Perform target ID of air contacts • Order/delete AAW engagements • Authorize the use of electronic countermeasures • Schedule air intercepts
Anti-Surface Warfare Coordination (ASUWC)	• Assess surface tactical situation • Control surface weapons • Evaluate threat value of surface contacts • Establish system modes, and response patterns in conformance with operational doctrine

TABLE 1 EXAMPLE OF SUBMODE TYPES AND FUNCTIONALITY	
SUBMODE TITLE	**SUBMODE FUNCTIONALITY**
Anti-Submarine Warfare Coordination (ASWC)	• Establish and issue doctrine • Organize and setup ASW sensor parameters • Set up weapon control doctrine • Monitor ASW resources • Coordinate muli-platform tracking
Acoustic Supervisor (AS)	• Assign mode of operations for all sonars • Supervise underwater search and detection • Evaluate sonar tactical situation • Assist in classification of sonar contacts
Identification Supervision (IDS)	• Setup IFF sectors • Identify contacts based on IFF, data links, and track characteristics • Resolve ID conflicts
Training Supervision (TNGS)	• Control team and subteam training • Control training scenarios
Anti-Submarine Air Control (ASAC)	• Direct sensor deployment • Vector helicopter • Display search patterns • Evaluate pilot kill evaluation reports • Report ASW aircraft performance
Air Intercept Control (AIC)	• Enter special points, reference points, operating areas • Enter vectoring orders • Enter emergency downed aircraft • Transmit tracks of interest
Computer Program Interface Supervision (CPIS)	• Monitor data recording • Monitor time synchronization • Monitor system effectiveness and readiness
Electronic Warfare Supervision (EWS)	• Report ESM effectiveness • Schedule electronics countermeasures activity • Direct deceptive electronic countermeasures • Monitor track/bearing associations • Monitor bearing lines and fixes
Tactical Information Controller (TIC)	• Control emissions • Correlate local and remote tracks • Set and Control Link Parameters and Operations • Activate and set up Link-11/Link-14 • Control gridlock • Control transmission of track data to force via Link-11/Link-14/Link 16, etc.

If there is an unlimited budget and no restrictions on manning levels, each submode could be assigned to an individual console. However, lifetime costs are very much impacted by manning levels (especially in today's environment of reduced manning).

The next step in the process is to determine how many consoles are required to support the expected 25 to 30 submodes. To derive the number of consoles required to support the submodes, the following must be determined:

- Understand the manning constraints,
- Estimate submode loading, and
- Determine which submodes perform similar tasks.

Loading analyses of each submode can be subjective unless one has recorded operator workload information from similar previous operations. Expected operator loading can also be estimated based on the specific tasks each submode must perform, how often each task may be repeated, and the duration of tasks. At this point a mapping of which submodes may be operated at what console is obtained (see Table 2). The ideal solution provides for 100 percent integration of all systems, which would provide for all functionality being accomplished at a single console type. This situation usually only occurs when the project has budgeted for a large amount of development. Most projects have limited budgets and many of the selected sensors, weapons, and command equipment are delivered with developed and tested consoles and man-machine interface. What this means to the system provider is that a couple of different types of consoles may be present in CIC. Table 2 also identifies what type of console the functionality may reside at. Depending on the equipment selected, some functionality may be accomplished at more than 1 console type. As stated earlier, this paper assumes a non-ideal configuration where development is minimized. This suggests that multiple console types may exist depending on the degree of integration provided for the selected sensors, weapons, and command and control systems. When this situation occurs, the system provider must evaluate the options of what type of console best suits the needs. Multiple console types may be preferred if the system already has an MMI and console configuration that works and has been tested (it may not be cost effective to integrate all software functionality on a single console type).

TABLE 2 – CONSOLE AND SUBMODE MAPPING

CONSOLE TITLE	CONSOLE TYPE	MAPPED SUBMODES
EMBARKED COMMANDER (EC)	TYPE 1 OR 4	EC, ECDA
COMMANDING OFFICER (CO)	TYPE 1	CO, ODA
PRINCIPAL ACTION OFFICER (PAO)	TYPE 1	PAO, ODA
AIR DEFENCE COORDINATOR (ADC)	TYPE 1	RSC, MSS, AAWC, EWS
ANTI-SURFACE WARFARE COORDINATOR (ASUWC)	TYPE 1	ASUWC, IDS
ANTI-SUBMARE WARFARE COORDINATOR (ASWC)	TYPE 1	ASWC, IDS
ANTI-SUBMARINE TACTICAL AIR CONTROLLER (ASTAC)	TYPE 1	ACS, ASAC, AIC
TACTICAL INFORMATION COORDINATOR (TIC)	TYPE 1	CPIS, TIC, CSC
RADAR ESM OPERATOR	TYPE 3	RADAR ESM OPERATOR
ASU WEAPON SYSTEM OPERATOR	TYPE 2	GUN OPERATOR, SURFACE-SURFACE MISSILE OPERATOR, ELECTRO-OPTIC SIGHTING SYSTEM OPERATIONS
HULL SONAR OPERATOR	TYPE 2	HULL SONAR OPERATOR
TOWED SONAR OPERATOR	TYPE 2	TOWED SONAR OPERATOR
SONAR SUPERVISOR	TYPE 2	SONAR SUPERVISOR

Table 2 is not meant to imply that each submode is hardwired to a specific console. What is suggested is the ideal assignment of submodes to consoles to meet the operational requirements and concept of operations. To accommodate individual commanding officers individual preferences on how to fight the ship along with evolving operational requirements, the designed command and display architecture should allow any of the above submodes to be selected at any console.

Analyzing the requirements of expected simultaneous warfare loading would further refine the list of console types and submode map. For example, if the concept of operations or requirements states that it is expected that all warfare areas are expected to be operated simultaneously 100 percent of the time, then there may be no reduction in the number of consoles. However, some reduction in the number of consoles may be achieved if there is a reduced warfare area simultaneity requirement.

From the list of consoles and console types, multiple CIC layouts can be obtained. One option of a CIC layout is shown in Figure 2. Figure 2 is not meant to show room arrangements. Room arrangement is the topic for another discussion, however at this point in the design, it is appropriate to begin analyses of various room arrangements. Figure 2 illustrates one design of console quantities, console types, and what functionality should exist at a console. Figure 3 illustrates another design option similar to Figure 2 but with a different variation of console types. Multiple options exist, but for the purposes of this paper, we will only illustrate 2 options.

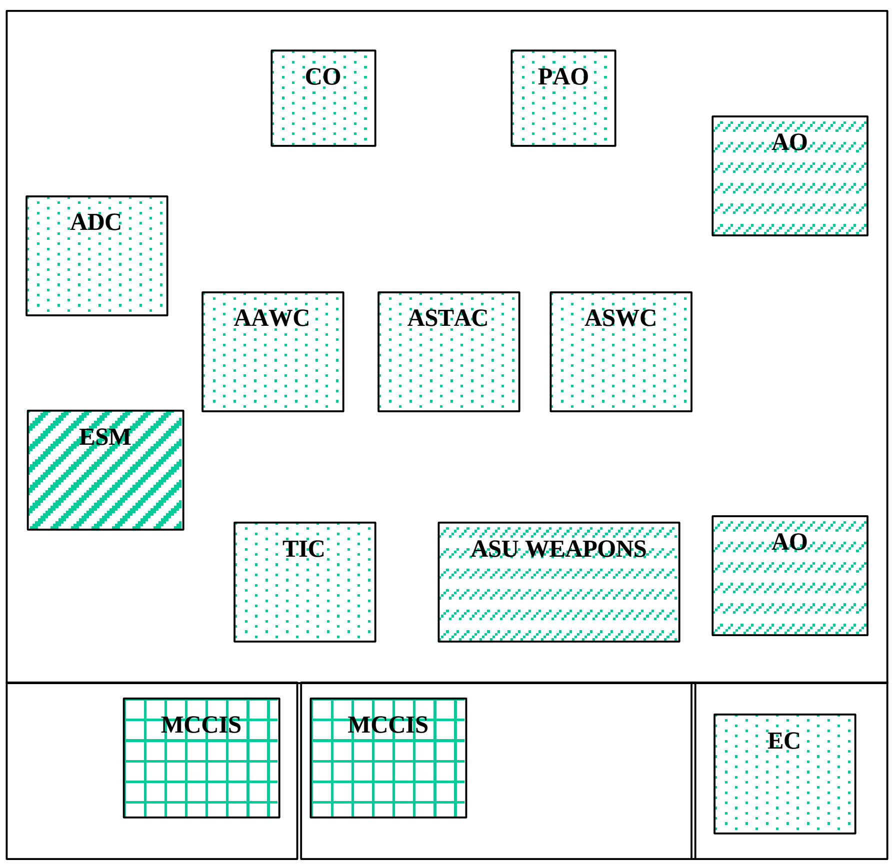

FIGURE 2 –CIC LAYOUT OPTION 1

The process suggested in this paper provides for a feedback loop (see Figure 1) where each option is now analyzed against the concept of operations and requirements along with the other factors. The whole process is repeated for each option (and may be re-

repeated) until the product team determines that all requirements are satisfied and budgetary constraints are achieved.

CIC layout option 1 suggests that 4 suppliers will provide 4 console types as indicated by the various types of shading. There will be 8 consoles from supplier 1, 1 console from supplier 2 (i.e., ESM), 3 consoles from supplier 3, and 2 consoles from supplier 4 (i.e., MCCIS). By utilizing the feedback loop and investigating option 1 against the original requirements and constraints many questions may be generated that must be resolved. Examples of some questions that could occur in a review of option 1 include:

- Do you really need a separate Embarked Command console (EC) and MCCIS consoles?
- Acoustic Operators may be highly loaded operating two sonars. Is there a need for a sonar supervisor to coordinate ownship sonar efforts?
- ASW picture compilation seems adequately covered if you have a sonar supervisor. Is the Air and Surface picture compilation function adequately covered?
- Will both the Commanding Officer and the Principal Action Officer always both be seated in CIC? Will only 1 of the 2 be in CIC and the other located on the Bridge?

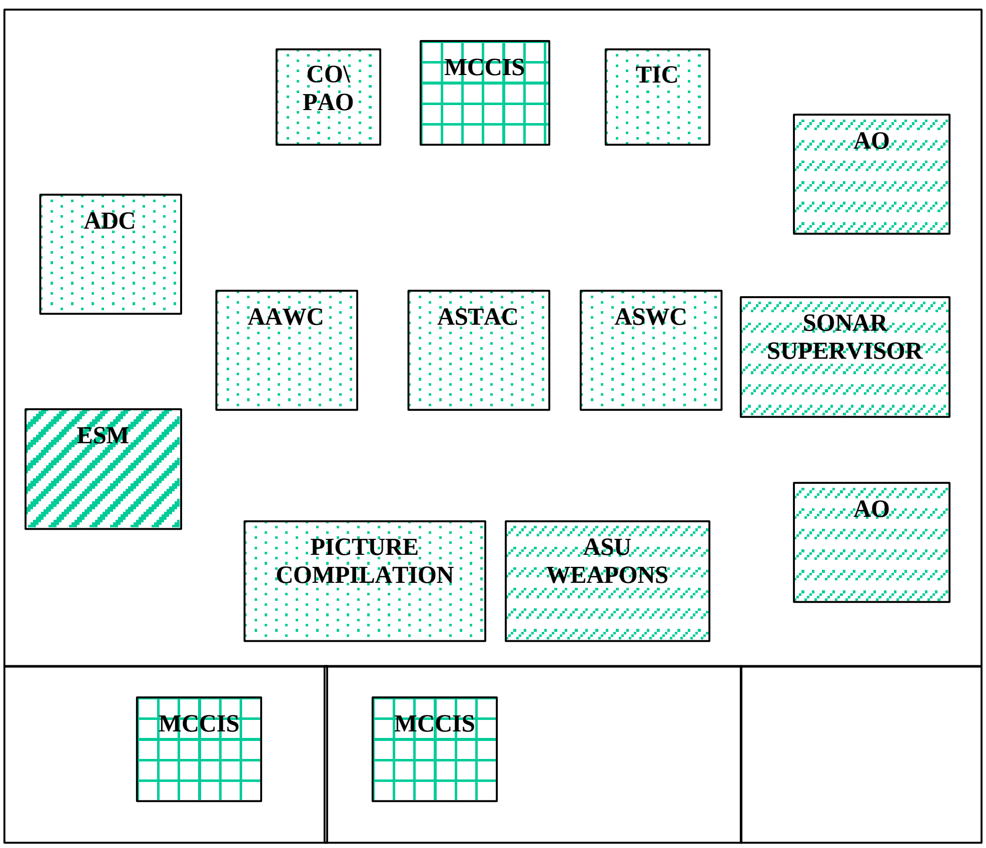

FIGURE 3 –CIC LAYOUT OPTION 2

Many other questions are sure to arise, and a list of questions is compiled. To resolve these questions, the team should now address the issues via review of the requirements and constraints identified in the first pass through the process. This ensures that each of the reviews will stay centered around the initial set of requirements and assumptions. This will also ensure that the original requirements and concept of operations are complied with. Reviews centered on the process will also identify any weakness in the original requirements and concept of operation.

CIC layout option 2 (Figure 3) is a result of addressing the questions generated from the original layout option and following the process through iterative evaluations using the original requirements and concept of operations. Layout option 2 now must also be re-evaluated using the feedback loop. More questions will be generated, which again must be evaluated against the initial criteria. Finally, a layout will be achieved that satisfies the product team and ensures that none of the reviews deviate from the initial design goals and requirements.

SUMMARY

Each step in the suggested process will have different options and outcomes depending on the background of the team involved. This paper is not meant to identify all possible outcomes and options. However, it does provide a “best practices” repeatable process that should be followed by a developing team to rigorously determine an optimum command and control/display architecture based on many (sometimes contradicting) variables.