THESIS

A TASK ANALYSIS OF UNDERWAY REPLENISHMENT FOR VIRTUAL ENVIRONMENT SHIP-HANDLING SIMULATOR SCENARIO DEVELOPMENT

by

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The approach taken was to survey cognitive task analysis models to find a notation that would document the tasks performed by a bridge team during an UNREP. The Goals, Operators, Methods, Selection Rules (GOMS) model was selected. A GOMS-like model was used to represent the sequential aspects of the UNREP task, while a table was developed to capture the parallelism of the tasks. The UNREP task analysis was then reviewed by qualified Surface Warfare Officers to validate its accuracy.

The result of this effort was a validated task analysis model of a Conning Officer during an UNREP. This model was provided to NAWCTSD in support of their future efforts in the development of a VR UNREP Ship-handling simulator scenario.
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ABSTRACT

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I. INTRODUCTION

A. MOTIVATION

Post Gulf War personnel reductions and budgetary cutbacks have forced the United States Navy's Surface Warfare Community to search out new ways to leverage technology against increasing operational commitments and declining assets. As commitments continue to grow and forces shrink, increased demands to produce highly trained officers faster are placed on training programs, and as a result, deficiencies in these programs have become evident. The big question now is how do we meet these training challenges today and beyond [MURP95]?

Historically, Surface Warriors have been slow in demanding the same technology that has been utilized by Naval Aviation for decades. Today, the Navy is placing its money and future in technology. Thus, it appears that advances in training methodologies and technologies offer hope to develop and deliver well trained officers to the fleet in a timely and cost effective manner.

In the last ten years, marine simulators, whether they are for ship-handling, propulsion plant operation, or radar navigation, have caught on in the commercial maritime industry [NIER95]. For the most part, these commercially available simulators have been of the special purpose, room-sized, bridge mockup variety, and are generally manpower intensive to operate. Recently, significant increases in computer hardware performance along with declining prices have made relatively portable, commercial-off-
the-shelf, but highly capable 3D graphics rendering computers, such as Silicon Graphics Incorporated’s (SGI) Octane, available for about $20,000. As a result, ship-handling training stands to benefit tremendously by enabling computer-based training system developers to design relatively portable, low cost, network capable VE simulators.

B. OBJECTIVE

A real time, networked, high fidelity, virtual environment (VE) ship-handling simulator that addresses human performance and training requirements would revolutionize the Surface Warfare Officer School’s (SWOS) capability to teach ship-handling skills at all levels of officer development, from the Division Officer on up to the Commanding Officer. The specification for this ship-handling simulator is not yet set in stone nor are the requirements well understood. However, the final system should include multiple scenarios, which can be modified to increase the scenario complexity by adding contacts and changing environmental factors, while minimizing scenario redundancy. This simulator will fill two needs for SWOS. It will provided a tool that can be used to teach and reinforce abstract concepts such as relative motion, and it will provide a cost effective method for students to practice many ship-handling scenarios in a safe environment where they can afford to make mistakes and learn from them.

With SWOS’s guidance, Naval Air Warfare Center, Training Systems Division (NAWCTSD) researchers are currently in the process of developing a VE underway replenishment (UNREP) scenario to use as a research test bed. This simulation system is currently known as the Conning Officer Virtual Environment (COVE) system. Since
UNREP is a Navy-specific, at sea operation, knowledge elicitation for the UNREP scenario was targeted towards experienced Surface Warfare Officers. After spending several months acquiring the necessary domain knowledge, researchers have developed a high fidelity UNREP scenario that appears to closely model reality. Their goal is to continue to refine the UNREP scenario and to use SWOS students to evaluate its performance. If this evaluation indicates that ship-handling techniques, such an UNREP, can be modeled in a VE with high enough fidelity to make the scenario a beneficial and transferable training experience, the project will be handed off to the next higher level for system development.

At this point in the developmental process, it will be critical that the developers have a superior understanding of the actual scenarios for which they will be writing specifications. Since the developers probably will not be domain area experts, they will need to research each task in depth to develop an understanding of what exactly they are trying to model. The objective of this thesis is to provide a thorough task analysis to support the further development of an UNREP VE ship-handling scenario. A secondary objective is to provide a methodology framework that can be used as a starting point to do task analyses in support of future VE scenario development.

C. APPROACH

This thesis, although related to previous research, is unique because it describes a cognitive task analysis of a shipboard watch team conducting an underway replenishment
task. Previous research has focused primarily on task analysis of an individual performing a task, e.g. a telephone operator interacting with a workstation.

In order to accomplish the task analysis in the most logical and comprehensive framework, while assuring the accuracy as well as validity of the task representation, the analysis and validation were conducted in three phases. First, acknowledging that the teamwork nature of the UNREP task greatly increases the difficulty of capturing the task using a single task analysis method, an analysis method that could be expanded to encompass a complex team executed task had to be found or developed. Second, domain knowledge acquisition was accomplished by using a multimedia UNREP knowledge elicitation tool constructed for this purpose. Additionally, the author has had four years of ship-handling experience as Division Officer in the US Navy. Finally, once the task analysis was constructed, it was presented to several SWOs experienced in UNREP for validation. All data collected during the validation period was scrutinized and corrections and additions were made to the task analysis as necessary.

Subsequent chapters will present each of the above mentioned phases in greater detail.

D. **THEESIS QUESTIONS**

The following questions are addressed in this thesis:

- *What specific tasks are required of a conning officer during an UNREP?*
- *What are the cues used for ship-handling during an UNREP?*
What is a suitable level of analysis and associated methodology required to conduct a task analysis of a ship-handling task?

E. SUMMARY OF CHAPTERS

The remainder of this thesis is broken down into the following chapters:

- Chapter II provides a more detailed discussion of the current training situation at SWOS as well as a proposed solution. Additionally, previous and current VE ship-handling simulation research is discussed. Finally, a brief explanation of ship-handling fundamentals is provided.

- Chapter III discusses a methodology for constructing a cognitive task analysis. This chapter also discusses question set development as well as limitations of the thesis.

- Chapter IV examines the UNREP task and discusses basic ship-handling principles and terminology.

- Chapter V provides the details of the implementation of the task analysis and the data collection process.

- Chapter VI presents a final discussion of the results of this thesis and describes areas requiring further research.
II. BACKGROUND

A. CURRENT SITUATION

The primary force behind the push to build a VE ship-handling trainer for the Navy is the Surface Warfare Officer School (SWOS) in Newport, Rhode Island. SWOS is the center of all Surface Warfare Officer (SWO) training, from the most junior Ensign to the most senior prospective Commanding Officer (CO). However, the current simulator available at SWOS is at best a navigation simulator. It is only used during Division Officer training and is inadequate and unable to meet the training requirements of intermediate to advanced level ship-handlers. As a result, SWOS Department Head students are sent to use a simulator located at the Marine Safety Institute for approximately 16 hours out of the six months spent at Department Head School.

How does a SWO acquire ship-handling skills today? On-the-job training is unfortunately the answer. The following is a brief summary of the training SWOs receive at various stages of their careers. As Ensigns, potential SWOs attend six months of schooling at SWOS Division Officer Course (SWOS DOC) where they receive instruction on a broad range of topics to include: personnel management, damage control, engineering systems, combat systems and ship-handling. Prior to 1993, Yard Patrol (YP) boats were used at SWOS to provide ship-handling training during Division Officer training. However, due to the age of the YPs and lack of funds to replace them, these assets are no longer available at SWOS. YPs are still in service at the Naval Academy
and are utilized to teach Midshipman basic ship-handling skills. After graduating from SWOS DOC, junior officers are assigned to a ship in the fleet where they start an eighteen-month to two-year qualification process. To qualify as an Officer of the Deck (OOD) is one of the first major milestones in an Officer's path to qualifying as a SWO. Generally, an officer will qualify as a SWO soon after completing the OOD qualification. While the actual shipboard qualification process varies from ship to ship and is largely dependent on the ship’s CO, qualification typically includes learning the ship’s combat and engineering systems as well as spending hundreds of hours conning the ship under the instruction of a qualified SWO. During this qualification process, the officer must complete the required Personnel Qualification Standards (PQS) books in a number of areas to include: bridge watch standing, engineering, combat information center watch officer and damage control. Finally, after completing all the PQS requirements, the officer must pass a rigorous oral board exam with the ship’s CO. This qualification system requires having more than the minimum required number of officers onboard so that the qualified officers can train the unqualified officers who will replace them.

Once qualified, SWOs usually are given charge of their own watch section and are permitted/trusted by the CO to drive the ship safely in accordance with the Rules of the Road and the CO’s Standing Orders. Standing Orders are a Captain's personal instructions to the OOD on how the ship will be operated at sea. Now fully qualified, these junior officers will log hundreds of hours standing OOD watch over the next couple of years while on various overseas deployments. After serving about two years as a
qualified OOD, or approximately at the four-year point of the SWO career path, Officers have a couple of options: (1) stay at sea for two more years and go to another ship where their ship-handling skills should continue to develop, after which they will usually go on to Department Head School back at SWOS; or (2) take a shore duty assignment for two years where their ship-handling skills will likely deteriorate over time, after which they will also go on to Department Head School at SWOS. Officers who choose the first choice do so for one of the following reasons: (1) they have not qualified as a SWO on time; (2) they have not received great Fitness Reports on sea duty; or (3) some believe that staying at sea is the way to the fast track in the SWO community.

After returning to SWOS for Department Head School, the Officers may either have very sharp ship-handling skills as a result of extended time at sea or their skills may be somewhat rusty from being away from a ship for a couple of years. In either case, both groups must meet the same requirements at Department Head School as well as at sea. There is currently neither a requirement nor a method in place for officers on shore duty to maintain their ship-handling skills. After two years of shore duty, SWOs returning to SWOS for Department Head (DH) School receive a very limited ship-handling refresher. As a result, newly assigned DHs report to their new ships where they are expected to train and qualify junior officers with tarnished, if not rusty, ship-handling skills. Clearly, this is a problem.

Even commercial and international agencies have started to experiment with using ship-handling simulators to train and qualify ship handlers. Recently, some nations, the
United States included, have started to offer commercial mariners who seek a Masters license the choice of either taking the traditional written exam or taking a partial written exam along with a simulator-based bridge performance assessment [NIER95].

B. POSSIBLE SOLUTION

How do we meet these training challenges today as well as in the future? The real answer for the Navy is very complicated and somewhat political in nature. However the development of a relatively low cost, portable VE simulator would be a step in the right direction.

A close look into ship-handling simulators available worldwide reveal that there are generally two types of ship simulators in use or under development; the bridge mockup and the Virtual Environment experienced through a head mounted display (HMD) or desktop monitor.

The bridge mockup is the more expensive option, requiring more people to operate while providing services to only a small group of officers attending a particular school. However, there are a few benefits associated with the bridge mockup interface. For example, if used as a team trainer, it can build teamwork among watch team members. Also, the bridge mockup provides the user with a more realistic user interface since instruments can be almost identical to the actual instrumentation onboard a ship. Users of this type of simulator can touch and manipulate the modeled equipment in the mockup in the same way as they would the actual equipment in reality. For example, the Conning Officer can see an actual RPM indicator or rudder indicator map.
Mockup type simulators are the most widely used in the civilian sector today. More than a dozen marine safety schools around the world offer courses, which include simulator-based training. However, VEIs experienced through HMDs appear to be the future of training simulators. This is a less expensive, more portable alternative. Large staffs of instructors/operators are not required to maintain and operate these systems. As for the interface, the immersive qualities of the HMD may allow VE simulators to provide a greater sense of presence within the environment. The drawback is that outside of visual presentation, there are few ways available today to interact with the environment using any of our other natural senses. Haptic feedback devices and speech recognition systems are still largely open research areas which have not produced many commercially viable products as yet [DURL95]. In other words, the technology to make a real world VE simulator that is up to standards depicted in recent movies is not currently available. However, today’s VE technology can provide significant improvements over current training simulator alternatives. The question is how much improvement to expect and how to get it.

What should the Navy look for in a VE ship handling simulator? A simulator that will fill the void must be available to Surface Warriors of all levels, stationed throughout the world. This implies that the computer hardware the simulation runs on must be a sea-going system or, at a minimum, be available pier side. It must correctly model ship-handling tasks by providing high fidelity environmental and vehicle models. This ship-handling simulator should be designed to be network capable from the beginning. This
would ensure that it could be integrated with other military simulators currently under development. Another benefit of having a networked system is that the actual participants within the VE could rehearse at-sea operations before getting underway to do the real thing. Currently, ships from Mayport, FL and Norfolk, VA get underway, meet someplace in between, rehearse for a day, and then do the exercise. This is not to say that VEs can totally eliminate the need for practice at sea, but they could potentially enable more effective use of time spent underway.

A simulator meeting these requirements would provide the most flexible training aid to naval leaders. COs could schedule their officers for simulator time during extended in-port periods. This would allow junior officers to log simulator time while in port as well as provide COs with a better mechanism to evaluate and/or monitor junior officers progress through a simulator debrief report/evaluation. In the best case, providing officers with the opportunity to do simulated maneuvers while in port could significantly reduce the time required to qualify, thus supplying the fleet with qualified ship-handlers faster. At a minimum, the VE simulator would allow Conning Officers to practice dangerous maneuvers (e.g. Underway Replenishment and Plane Guard) and emergency procedures (e.g. Man Overboard and Engineering Casualties during restricted maneuvering) in a safe environment where they can learn from their mistakes.

C. CURRENT RESEARCH

With a better understanding of the Navy’s need for a VE ship-handling simulator, a further discussion of current research is appropriate. This section as well as the
remainder of the thesis will focus on research being conducted in support of developing a VE based system. Three ongoing projects have made significant progress in this area. The first system of interest is the Canadian Navy’s MARS project. The second and third projects, the Virtual Environment for Submarine Handling Training (VESUB) and Conning Officer’s Virtual Environment (COVE), do not share identical goals, but are co-located at the Naval Air Warfare Center Training Systems Division (NAWCTSD) in Orlando, Florida.

1. MARS Virtual Reality Simulator

Canadian fleet reductions, growing reliance on reservists, and the high costs and difficulties of training officers at sea prompted the development of the MARS VE simulator. In 1991, the Chief of Maritime Doctrine and Operations requested the investigation of VE technologies that would enable the development of a low-cost simulator for training ship-handling skills. Formation maneuvers were identified as a prime requirement of the system [POIN95]. As a result, an exploratory development model was constructed to determine the technical challenges and risks associated with using VE technology to train Officers of the Watch (OOW). The target users of the system were to be junior officers at the Canadian equivalent to SWOS.

The system consists of a network of simulators, each of which can be configured to simulate any ship class in the Canadian inventory. Each simulator is broken into three functional components: the OOW interface, the simulated bridge team, and the instructor control facilities.
The OOW interface uses a commercial HMD and electromagnetic tracking system as depicted in Figure 1. The hydrodynamics and physical appearance of any Canadian ship can be modeled. Bridge instruments are computer generated and displayed in the VE. A speech recognition system and sound generation system are used to recognize verbal commands and play recorded sounds such as engine noise.

Figure 1: MARS Virtual Reality Simulator HMD.

The simulated bridge team uses the sound generation system to play back a unique voice for each bridge team member when interacting with the OOW. The voice recognition system recognizes orders given by the OOW and initiates the required changes to the throttle and rudder. Instructors are also able to interact with the OOW through the sound generation system. This eliminates human to human interaction during the simulation. Additionally, the time stamping and recording of all commands provides a valuable tool for evaluation and debriefing. The instructor control facilities enable lesson
planning, simulation monitoring and control as well as providing for review and
debriefing.

Training effectiveness testing has included allowing half of two separate classes
to use the VE simulator for a week, while their classmates received the regular program
of instruction. Both groups were then required to do formation maneuvers on the
equivalent to the previously mentioned YPs. The results showed that the groups who
were exposed to the VE simulator performed better at sea. A separate experiment showed
that, through the use of several networked simulators, it was feasible for multiple ships to
do exercise rehearsals within the VE [POIN95].

2. Virtual Environment for Submarine Handling Training (VESUB)

VESUB came about as the result of a recognized training deficiency. Specifically,
submariners did not have a simulator that allowed them to practice entering and/or
leaving port. This is a significant problem due to the nature of submarine operations.
Typically subs go to sea, submerge for a few months, and then return to port. This
operating schedule allows few officers a chance to practice harbor entries and pier work.
NAWCTSD researchers built an exploratory simulator system to evaluate the potential of
training submarine OODs to drive in a VE. Figures 2 and 3 show the HMD and the
VESUB model as seen through an HMD. The VESUB system has been well liked by
evaluators and trainees and is currently being upgraded to provide a more robust
simulation for further evaluation at Submarine School in Groton, Connecticut [NAVL98].
3. **Conning Officer’s Virtual Environment (COVE)**

   Extensive research regarding the possible benefits of training ship-handling tasks in a VE is being conducted under the Virtual Environment Training Technology (VETT) project sponsored by the Office of Naval Research (ONR). While VETT research covers a wide spectrum of VE topics, this thesis is in support of NAWCTSD’s current effort to
develop a VE UNREP training scenario. As previously mentioned, this thesis constructs a cognitive task analysis of an UNREP for future use in the development of the system specification for the actual UNREP scenario delivered to SWOS with the VE ship-handling trainer. A VETT research goal is to determine how well ship-handling skills trained in a VE transfer to real world ship-handling maneuvers. NAWCTSD researchers and contractors are currently in the process of developing a VE UNREP scenario to use as a test-bed. The goal is to use this test-bed to break down primary ship-handling tasks into abstract sub-tasks that can be used to teach ship drivers the underlying fundamentals of ship-handling.

The model is functional but not yet fully developed. It has multiple ship class models and modifiable environmental effects. Figure 4 is a screen capture of the most resent version of the COVE model.

![Figure 4: The COVE ship handling model.](image-url)
The model is experienced through an HMD and electromagnetic tracking system or desktop monitor. Currently, user commands are received verbally by a research assistant and then entered into the system. The user-independent speech recognition software has not performed up to expectations, and is currently a hurdle that must be overcome. The model's visual and hydrodynamic handling fidelity have thus far been well received by SWOS students of all levels. The simulator was unveiled and exposed to SWOS students for the first time in March of 1998. The objective of the trip was to see how SWOS would respond to the simulation and to collect feedback from domain experts.

By all accounts the students at SWOS thought the COVE simulation was very accurate and would be a useful training aid.
III. METHODOLOGY

A. TASK ANALYSIS

The simplest definition of task analysis is the observation of a human performing an activity, usually involving a machine interface, followed by recording detailed information describing the tasks that the person must accomplish to achieve a given goal. However, there is not a universally accepted definition of what constitutes a task, nor is there agreement of what components the task analysis process consists. Additionally, there have been few exact notations or recording systems developed to capture complex tasks in a standard format [CARD83]. Although much progress has been made related to the methods and theories used in cognitive task analysis, it has been strongly associated with the development of cognitive task analysis techniques for individual human performance rather than team performance. However, the complexity of tasks such as ship handling dictates that decision making and task accomplishment be achieved as a team effort. Comparatively little research has thus far been dedicated to the analysis of team decision-making and problem solving. Recent research at CHI systems has attempted to modify the currently accepted COGNET model of individual human task analysis so that it encompasses the team executed task domain [ZACH97]. Although not as advanced as research done at CHI systems, this thesis research lead to a similar solution to the current void of a team task model. The solution developed herein will be
explained later in this chapter, but first the sequential CMN GOMS model will be discussed.

1. **Models Used**

The GOMS (Goals, Operators, Methods and Selection Rules) family of cognitive task analysis models is a well-established set of models that are frequently used to model human-computer interface tasks. There are several spin-off models, such as CPM (Cognitive, Perceptual and Motor or Critical Path Method) GOMS, from the original notation, known as CMN GOMS, introduced by Card, Moran and Newell in their book, *The Psychology of Human-Computer Interaction* [CARD83]. This thesis limits the discussion of task analysis models to those models that were used or strongly considered for use, namely CMN GOMS and CPM GOMS.

2. **Selecting a Model**

The primary reason there have been so many models developed, and that there is not a universally accepted model, is because each problem domain often requires a customized model to capture the tasks executed within that domain. For this research, the CMN GOMS model was selected to model the sequential tasks, since it only required slight modifications. CMN GOMS, also known as KLM (Keystroke-Level Model) GOMS, was based on the sequence of keystroke-level actions the user must perform to accomplish a task [KIER94]. It is the easiest and most fundamental level model of cognitive task analysis. CPM GOMS was initially strongly considered to model the
parallel tasks associated with UNREP; however, it was designed to model parallel tasks within a single human not a team. It turned out that CPM GOMS was not used. Rather, a parallel task table was developed to capture the parallelism between the tasks accomplished by each of the bridge team members. A full explanation of the parallel task table follows later in this chapter.

B. CMN GOMS NOTATIONS

CMN GOMS is made up of Goals, Operators, Methods and Selection Rules. Goals define what is to be achieved and present a set of possible methods by which it can be accomplished. There are several levels of goals, the highest being the Unit-Task-Level, next the Functional-Level, and finally the Argument-Level. Within each of these levels there are usually sub-goals and sub-sub-goals that are required to accomplish complex tasks. These sub-goals are in some instances also called Methods. Methods are essentially the procedures used to accomplish a goal. Operators are elementary perceptual, motor, or cognitive acts that are required to change the user's mental state or change the task environment [CARD83]. Selection Rules allow the user to choose the optimal method to use for a particular task when presented with more than one method.

How does one do a CMN GOMS analysis? The first step is to determine the task to be modeled. Next, generate a task description by picking high level goals. Determine the methods that are required to accomplish the high level goals. These methods may invoke sub-goals as they are executed. Determine the methods required to accomplish the
sub-goals that were identified. This process breaks down larger goals into smaller sub-goals that require a very specific method or operator to be accomplished. It also groups goals into Unit-Level, Functional-Level and Detailed-Level. The above process stops when the operators required to achieve the methods are reached.

CMN GOMS notation is very similar to an outline. The higher level goals are left justified and the other goals, operators and methods are indented to the right according to their position in the hierarchy. In order for a Functional-Level goal to be accomplished, all the subordinate sub-goals and methods below it would have to be completed first. For example, in Figure 5, Turn_Ship is the Functional-Level goal, and the goals Visually_Verify_Direction_Of_Turn_Clear, Issue_Rudder_Order, Starboard_Turn, Determine_How_Far_To_Turn and Determine_Degree_Of_Rudder_To_Use must be completed before Turn_Ship is accomplished.

```
. . . goal: Turn_Ship
. . . goal: Visually_Verify_Direction_Of_Turn_Clear
. . . . [select: Walk_To_Bridge_Wing_Of_The_Direction_Of_Turn_To_Look
. . . . Request_Another_Watch_Team_Member_Visually_Check]
. . . goal: Issue_Rudder_Order
. . . . [select goal: Starboard_Turn
. . . . . goal: Determine_How_Far_To_Turn
. . . . . . [select: Use_Prior_Experience_To_Estimate_Distance
. . . . . . Use_Radian_Rule_To_Monitor_Turn
. . . . . . Follow_CO's_Orders]
. . . . . goal: Determine_Degree_Of_Rudder_To_Use
. . . . . . [select: Use_The_Rule_Of_Thirty_To_Determine_Amount
. . . . . . Use_Prior_Experience_To_Estimate_Amount
. . . . . . Follow_CO's_Orders]
. . . . . . goal: Give_Verbal_Order_To_Helm
```

Figure 5: Example CMN GOMS Notation
The granularity of the CMN GOMS model can be adjusted to capture various levels of detail and different parts of the model can be done at different levels of detail [CARD83]. The standard CMN GOMS model required a couple of slight modifications in order to customize the model to efficiently and effectively capture the Execute_UNREP task. UNREPs typically take hours to complete and involve many of the same tasks being repeated over and over in sequence. It was determined that it would be best to document the task or task sequence once and then call the task by name as a sub-routine whenever it reoccurs or loops. These situations are noted in the CMN GOMS-like analysis in chapter five as loops or repeated tasks. An example of a looping task sequence occurs when own ship is maintaining station alongside the replenishment ship. The Conning Officer must repeat the same tasks over and over, for hours, in order to maintain station. Second, some tasks are repeated periodically or whenever the overall task load allows. These are denoted as periodic tasks in chapter five. Goals such as Maintain_Awareness_Of_Third_Party_Ships is a good example of a periodic task. The Conning Officer should scan the horizon for contacts as often as possible.

C. PARALLEL TASKS WITHIN A TEAM

This portion of the thesis sailed into uncharted waters, so to speak. As previously mentioned, little research has focused on formulating a methodology or notation for capturing team accomplished tasks. A goal of this thesis was to capture the parallelism in a task accomplished by the combined actions of each member of the bridge watch team.
After an exhaustive search for an established methodology that would accomplish this goal, which even included considering modifying a parallel programming notation. It was decided that a table constructed of the CMN GOMS-like notation discussed in section B of this chapter would best capture the team, as well as parallel, aspects of the task.

1. **CPM GOMS**

CPM GOMS was designed to be suitable for analysis of parallel activities [JOHN94]. CPM GOMS is also known as Critical Path Method GOMS because it can be used to construct a cortical path of tasks on a PERT chart type graph. CPM GOMS is intended to analyze at the operator level of individual cognitive, perceptual, and motor operations. For example, when humans see an object move, they first attend to the visual stimuli, a cognitive operator, then they perceive the motion, a perceptual operator, followed by moving their eyes to follow the motion, a motor operator. CPM GOMS results in an extremely detailed level of analysis. CPM GOMS was strongly considered for the parallel portion of the analysis presented in chapter five, however, it was not easily modified to capture a team executed UNREP task.

2. **Parallel Task Table**

The parallel task table basically takes the CMN GOMS notation for each of the watch team members, Conning Officer, Officer of the Deck, Helmsman and Lee Helmsman, and puts it into a tabular format. The sequential tasks associated with each watch team member are listed vertically in a column next. A very rough time line runs

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along the vertical axis of the table. This time line is intended only as an approximation of when tasks may occur. The parallel task table presents a hypothetical UNREP scenario and the tasks that each team member must accomplish at an approximate time in the scenario. A sample of the parallel task table is depicted below in Table 1. When the table is read down a column a sequential list of tasks associated with the chosen watch team member is presented. When the table is read across a row the tasks that each watch team would be in the process of doing at that approximate time is presented. It is like a snapshot of the bridge team interaction at a particular point in time of the UNREP task.

<table>
<thead>
<tr>
<th>Time</th>
<th>Conning Officer</th>
<th>Officer Of The Deck</th>
<th>Helmsman</th>
<th>Lee Helmsman</th>
</tr>
</thead>
<tbody>
<tr>
<td>02:40</td>
<td>4.5.1.5 - Receive Report That Order Was Executed (Lee Helm)</td>
<td>4.4.2 - Monitor Conning Officer During Maneuver</td>
<td>4.1.3 - Report Pitch/RPM Change To Conning Officer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.1.3.1 - Receive Acknowledgement</td>
</tr>
<tr>
<td></td>
<td>4.5.1.5.1 - Acknowledge Report (Lee Helm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.5.2.5 - Receive Report That Order Was Executed (Helm)</td>
<td>4.4.2.1 - Correct Conning Officer As Necessary</td>
<td>2.11.1.2 - Report That The Wheel Is Over To The Conning Officer</td>
<td>4.2 - Maintain Ordered Speed (Loops until new order received)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.2 - Maintain Communications (Periodic Task)</td>
</tr>
<tr>
<td></td>
<td>4.5.2.5.1 - Acknowledge Report (Helm)</td>
<td>2.11.1.2.1 - Receive Acknowledgement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Parallel Task Table of UNREP Task

The index numbers next to each task represent the task's position in the CMN GOMS notation hierarchy. For example, tasks labeled with two digit numbers, such as 4.2, are Functional-Level tasks and other tasks with greater than two digit numbers are sub-tasks of the functional tasks.
IV. TASK OVERVIEW

A. UNDERWAY REPLENISHMENT OVERVIEW

UNREP presents one of the most exhilarating, challenging, and rewarding ship-handling opportunities for a Conning Officer. How precisely a ship can execute an UNREP, both the ship-handling and the deck seamanship aspects of the task, determines what the ship's, as well as the CO's, reputation will become [STAV92].

While on deployment, Navy ships remain at sea for long periods of time ranging from several weeks to several months. Conducting underway replenishments (UNREP), also known as connected replenishments, give the ships the ability to sustain themselves at sea for these long periods by re-supplying fuel, stores, and ammunition. UNREP is a dangerous, but common evolution for Navy ships and is done frequently during deployments, sometimes as often as weekly [NOEL84]. It can also be done at night and in most weather conditions. Essentially, UNREP involves two ships at sea, sometimes three, coming within 90 to 120 feet of each other, while doing 13-15 knots and connecting themselves together with cables that enable stores and fuel to be passed between the ships [CHIE96]. In Figure 6, the replenishment ship is the center ship and is re-fueling the other two ships at the same time.

During a typical UNREP, the replenishment ship is the guide and is charged with maintaining an ordered course and speed; the approach ship initially maneuvers into station 1000 yards astern of the replenishment ship.
However, Aircraft Carriers are a special case. They will normally be the guide ships and therefore the replenishment ship will make the approach on the carrier. The crews of both ships would be working on the decks and at this point would have already spent hours preparing for the cargo transfer portion of the evolution. UNREP is an extremely manpower intensive evolution. The Conning Officer of the approach ship maintains station astern of the replenishment ship as final preparations are done. The Officer of the Deck (OOD) is responsible for ensuring own ship is manned and ready to conduct the UNREP. When all UNREP and engineering stations have reported manned and ready, the OOD will report to the Commanding Officer (CO) and request permission to raise flag ROMEO (for replenishment) to the dip, indicating that the approach ship is
ready to commence the approach. Similar preparation is done on the replenishment ship, however, ROMEO at the dip means that the replenishment ship is steady on ROMEO course and speed and is preparing to receive the approach ship on the side that ROMEO is flying. ROMEO course and speed is the ordered course and speed for the UNREP. The Conning Officer of the approach ship continues to maintain station and observes the course and speed own ship must have ordered to maintain station on the replenishment ship. This course and speed information will be especially useful to the Conning Officer once own ship is alongside the replenishment ship.

When the replenishment ship closes up (raises) flag ROMEO, the Conning Officer of the approach ship receives the cue that it is time to commence the approach. The approach ship must be maneuvered from directly astern of the replenishment ship to a station abreast and parallel to the replenishment ship with between 90 to 120 feet lateral separation. The approach ship must change speed as required to stop on station and to maintain station while alongside. With this goal in mind, the Conning Officer or OOD will order ROMEO closed up on the approach ship to indicate that the ship is commencing its approach. There are several techniques and rules of thumb, for example the Radian Rule, available for the Conning Officer to use to assist in monitoring the ship's progress towards station during the approach phase. Herein the approach phase is defined as the time from when the approach ship starts to move towards station alongside the replenishment ship to when the bow of the approach ship crosses the stern of the replenishment ship. The approach ship's Conning Officer must constantly monitor own
ship's progress and make necessary course and speed corrections. During UNREP it is considered best to control the ship's heading by giving courses to steer in degrees to the Helmsman rather than giving rudder orders [STAV92]. Giving rudder orders is an attempt to do the Helmsman's job and could be dangerous at close ranges. As for speed changes, it is thought to be best for the Conning Officer to give the Lee Helmsman exact revolutions, rather than adding or dropping revolutions [CREN75]. Figure 7 depicts what is known as the coast in method of approach.

![Figure 7: Coast in Approach Method.](image-url)

Once the bow of the approach ship crosses the stern of the replenishment ship, the alongside phase begins. The first priority for the Conning Officer is to slow own ship to
match the speed of the replenishment ship. The Conning Officer must visualize where own ship should be when on station alongside and estimate how far own ship's momentum will carry it forward after the speed is reduced. When it is time, the Conning Officer will reduce the speed and monitor the affect and if required, adjust speed as necessary to maintain own ship's position alongside. Once the approach ship is alongside on a parallel course, the Conning Officer must maneuver the ship to the exact position necessary for UNREP. This is done by making very slight course and speed changes until on station. Flag ROMEO is hauled down on both ships and shot lines are passed between the ships. The first line across is the phone and distance line that is used for communications between the ships. Notice that in Figure 8, the phone and distance line has colored flags on it that are used by the Conning Officer to judge the lateral separation between the ships [DODG81]. The flags are spaced twenty feet apart and are colored in the following sequence: green, red, yellow, blue, and white. At night chemical lights are added and are spaced at twenty foot intervals.
In order to monitor the ships fore and aft motion, the Conning Officer must pick a set of stanchions or a bulkhead to observe for parallax error [DODG81]. Webster's dictionary defines parallax as the apparent change in direction of an object, caused by a change in observational position that provides a new line of sight. The Conning Officer must use the above mentioned cues to monitor own ship's position for the remainder of the alongside phase, which can last up to several hours. When the high-tension lines are hooked up between the ships and ready to be tensioned, the Conning Officer must inform the Helmsman so that the Helmsman can compensate for the additional force pulling the ships together. The Helmsman must also be notified when de-tensioning lines [STAV92].

The Breakaway phase starts when all fuel and stores transfers are complete. While the crew breaks down the riggings, the Conning Officer continues to maintain station. When all lines are reported clear, the Conning Officer must first verify that all lines are
clear, then ask permission from the CO to commence the breakaway. The Conning Officer usually will increase speed by five to ten knots and hold a parallel course to start the breakaway. After the ship starts to pick up speed, the Conning Officer will give a slight, one to two degree, rudder order away from the replenishment ship. The important cue to monitor at this point is the stern of own ship, as it will move towards the replenishment ship as own ship turns. When own ship's stern is clear of the bow of the replenishment ship, it is safe to freely maneuver.

There are three additional factors that can significantly increase the level of difficulty of the alongside phase. First, severe weather conditions make maintaining station extremely difficult. The lateral separation between the ships is normally increased during foul weather and the Helmsman is given more freedom to use the rudder to maintain course. Second, doing a vertical replenishment in conjunction with the connected replenishment adds difficulty. This procedure involves one or two helicopters transferring cargo from the flight deck of the replenishment ship to the vertical replenishment drop zones on the approach ship. Although vertical replenishment does not significantly change the Conning Officer's goals during an UNREP, it does significantly increase the Conning Officer's stress level. And third, it is very difficult and dangerous for the ships to conduct a turn while they are connected. This procedure is not done very often and requires very precise and slow maneuvers and tremendous coordination between the ships.
B. SHIP HYDRODYNAMICS

Developing a realistic ship-handling simulator requires obtaining physically based hydrodynamic models of each of the ships that will be implemented in the simulator's scenarios. The purpose of this thesis is not to describe a hydrodynamic model. However, some of the basics of ship hydrodynamics and environmental factors relevant to ship handling will be discussed. The focus will be on controllable and uncontrollable forces and the venturi effect.

Controllable forces are the forces that the ship's mechanical components can generate and meter. For most ships these components include either one or two rudders and propellers. Thus, a ship can control its speed through the water by increasing either its shafts' RPMs or by increasing its propellers' pitch. A ship can slow by reducing or reversing its shafts' RPMs or decreasing its propellers' pitch. Uncontrollable forces are the external forces that act on the ship. They are usually created by nature and are not controllable by the ship. These forces are the result of the wind, current or tide, and are influenced by characteristics of the ship such as its sail area, draft and displacement. At times, uncontrollable forces can make a ship handler's job very difficult and at other times they can be used to give the ship handler an advantage [CREN75].

One uncontrollable force that is significantly increased as two ships pass or travel abreast at a close distance is known as the venturi effect. The venturi effect is the result of the high-pressure zones that are created at the bow and stern and the low-pressure zone created amidships as the ship moves through the water (Figure 9).
When ships are alongside each other underway, the venturi effect is compounded due to the intermingling of each ship's high and low pressure areas. This creates suction between the ships that is increased as speed increases, as lateral separation decreases, and as the depth of the water decreases. If two ships get too close to each other, the venturi effect can add just enough suction force to pull the ships together and cause a collision [DODG81].

C. BRIDGE WATCH TEAM MEMBERS

The OOD underway has been designated by the CO to be in charge of the ship and is responsible for the ship's safe and proper operation. The OOD's UNREP related duties include:

- Be aware of the tactical situation and geographic factors that may affect safety of navigation and to take the necessary action to avoid grounding or a collision at sea.
• Obey the navigation rules of the road and the CO's standing orders.

• Supervise and train the Junior Officer of the Deck (JOOD). The JOOD is usually also acting as the Conning Officer.

• Ensure orders to the helm and lee helm are correct to avoid danger, to take or keep an assigned station, and to change course and speed in accordance with orders.

• Make required reports to the CO.

• Supervise the bridge watch team to include: JOOD, Quartermaster, Lookouts, Boatswain Mate, Radar Operators and Messenger.

• Maintain communications with the ship's Combat Information Center and Central Control Station.

• Supervise transmissions and acknowledgements on all tactical voice radio circuits.

The Conning Officer's basic function is to control the movement of the ship by issuing orders to the Helmsman and Lee Helmsman. The Conning officer's Duties during UNREP are:

• Be aware of the tactical situation and geographic factors that may affect safety of navigation and to take the necessary action to avoid grounding or a collision at sea.

• Supervise the Helmsman and Lee Helmsman.

• Ensure everyone on the bridge knows who has the Conn.
• Grant or deny permission for the Helmsman or Lee Helmsman to be relieved.

• Issue necessary orders to the helm and/or lee helm to avoid danger, to take or keep an assigned station, and to change course and speed in accordance with orders.

The last two members of the team are the Helmsman and Lee Helmsman. The Helmsman's main function is to steer the courses prescribed by the Conning Officer. The Helmsman must be Personnel Qualifications Standard (PQS) qualified to stand this watch. The Lee Helmsman's main function is to move the ship's throttle as prescribed by the Conning Officer and to ensure that all bells are correctly answered. The Lee Helmsman must also be PQS qualified to stand this watch.

D. STANDARD COMMANDS

Nowhere are terminology and phraseology as important as they are in the commands given to the Helmsman and Lee Helmsman by the Conning Officer. Because misunderstanding or ambiguity can quickly lead to disaster, there must be no possibility of an order being misinterpreted, and there should be no confusion if standard commands are used. Short cuts and individual variations should be avoided; all enlisted personnel who man the ship’s helm or lee helm should become accustomed to receiving commands in the standard format [STAV92].

Standard rudder and engine commands are given in a specific sequence. This sequence is designed to ensure that the order was received correctly and is being carried out. In general, both rudder and engine orders follow this sequence: Command, Reply,
Report and Acknowledgement. Engine orders are simpler than rudder orders, since the only difficult engine order is to have one engine going forward and the other reversed in order to twist the ship. Each class of ship has differences in their engineering plant and thus, requires customized, ship specific, engine orders.

Rudder orders have several variations and the Conning Officer must know which order is required for a given situation. Turns of less than ten degrees are ordered differently than turns greater than ten degrees. Turns can be ordered without the Conning Officer specifying a course to steady on. Again, each class of ship handles differently, and therefore requires some customization as far as degrees of rudder required to turn the ship at various speeds. The Watch Officer's Guide is the best reference for standard commands and should be reviewed to ensure that all combinations of commands are modeled in the VE speech recognition system [STAV92].

E. RESTRICTED MANEUVERING

The ship's Restricted Maneuvering Doctrine is followed when the ship will be restricted in its ability to maneuver due to its proximity to land or other ships. Essentially, restricted maneuvering means that the ship has all its engine rooms and steering control stations manned and that critical equipment, such as main engines and generators, are configured for a graceful degradation and/or a quick restoration in the event of a casualty. The restricted maneuvering instruction also provides guidance on casualty control actions that can be taken and procedures for recovering from casualties. The reasoning behind this guidance is that in some cases, such as UNREP, it would be better to keep an
expensive piece of equipment online and let it catastrophically fail, when normally it would be taken off line. This procedure may cause the ship to lose a shaft, but allow enough time for the ship to do an emergency breakaway that could prevent a collision.

Navy ships are built with several levels of redundancy for control systems and critical equipment. Systems of particular relevance to UNREP operations are the main propulsion engines, shafts, generators, and steering equipment. A failure in any one of these systems could easily cause a collision at sea. Typically, when restricted maneuvering is set, personnel man the engine controls on the bridge, the central control station, and locally in the engine rooms. Generators are configured to automatically start and restore power in the event that an online generator fails. Having all stations manned ensures that if a casualty occurs at one level of control, that there will be personnel at the next level down prepared to take control and/or restore from the casualty. As for steering, personnel will man the steering controls on the bridge and in aft steering for immediate recovery from a steering casualty. Before going alongside for an UNREP, the approach ship is required to test its steering controls in their normal as well as backup configuration to ensure all systems are operational. For example, if steering control were lost on the bridge, control would immediately be taken in aft steering. Personnel in aft steering would first try to take electrical control of the rudders and if that failed they would try to take hydraulic control. How well the ship's crew can execute these emergency procedures could be the difference between a collision and no collision.
F. CASUALTIES

The following list of casualties is limited to those that affect the Conning Officer's ability to control the ship and is intended only to provide ideas for ways to increase the level of difficulty of the UNREP scenario. These casualties are not common however. If one occurs, the Conning Officer must take immediate action to prevent a collision or prepare for a collision. The indicators, effects, and possible corrective actions listed below may not be complete and will vary from ship class to ship class.

- Loss of a shaft

  Indicators: Ship's speed starts to slow, erratic shaft RPM indicator readings, report of loss of one or more engines or a hot line shaft bearing.

  Effects: Ship's max speed may be reduced, responsiveness to speed changes may be reduced.

  Possible corrective action: Increase the RPMs on the remaining shaft and conduct an emergency breakaway. The Helmsman may also have to compensate for the drag of the failing shaft.

- Loss of gyrocompass or repeater

  Indicators: Heading displayed on the gyrocompass does not change or changes erratically, gyrocompass failure alarm sounds.

  Effects: Gyrocompass and repeaters are unavailable for steering the ship.
Possible corrective action: Helmsman and Conning Officer must use the magnetic compass to steer the ship.

- Loss of controllable reversible pitch (CRP) propeller control
  
  Indicators: Report that CRP control was lost, ship does not respond to changes of speed.

  Effects: Ship's max speed may be reduced, responsiveness to speed changes may be reduced.

  Possible corrective action: Change the RPMs on the remaining shaft to control the speed and conduct an emergency breakaway. The Helmsman may also have to compensate for the drag of the failing CRP propeller.

- Loss of steering controls

  Indicators: Ship does not respond to steering changes, steering alarm sounds, report that steering equipment failed.

  Effects: Loss of steering control of the ship.

  Possible corrective action: Steering equipment may be changed to alternate equipment, usually by pushing a button on the bridge. Steering control may be taken in aft steering either electrically or hydraulically. Conduct an emergency breakaway.
• Loss of one or more main engines

Indicators: Ship's speed starts to slow, atic shaft RPM indicator readings, report of loss of one or more engines.

Effects: Ship's max speed may be reduced, responsiveness to speed changes may be reduced.

Possible corrective action: Increase the RPMs on the remaining engines and conduct an emergency breakaway. The Helmsman may also have to compensate for the drag of the slowing shaft.

The standard procedure for any one of the above casualties is to conduct an emergency breakaway, which is the same as a normal breakaway except an emergency breakaway is done faster. The objective of an emergency breakaway is to quickly break down the rigs connecting the ships without severely damaging equipment or injuring personnel. NWP 4-01.4 contains the details of how an emergency breakaway is executed [CHIE96]. Additionally, each ship will have a restricted maneuvering doctrine and engineering casualty control procedures for each of the listed casualties.
V. THE TASK ANALYSIS

A. TASK ANALYSIS OF A CONNING OFFICER DURING UNREP

Analyzing the tasks a Conning Officer must perform during an UNREP was the primary goal of this thesis and therefore receives the most detailed analysis of the bridge team members. The following analysis was constructed in the spirit of CMN GOMS notation. However, the embedded narrative was included to provide an explanation of the tasks and the framework in which they occur. Each goal will be explained in the narrative and the GOMS notation will follow. A copy of the task analysis without the narrative can be found in Appendix A.

The analysis was broken into three levels, first the Unit-Task Level, second the Functional Level and third the Detailed Level (Argument Level). As the analysis progresses from the Unit-Task Level to the Detailed Level, more detail is captured in each successive level.

1. Unit Task Level Analysis

The Unit-Task Level model shows that the primary goal is to execute an UNREP. To accomplish this goal the following four sub-goals must be achieved in order: complete the brief phase, complete the approach phase, complete the alongside phase, and finally completing the breakaway phase. Using CMN GOMS notation these goals are represented as follows:

\[ \text{goal: Execute\_UNREP} \]
2. **Functional Level Analysis**

Decomposing the Unit-Task into its functional components developed the Functional Level model. The functional components are the sub-goals or methods that must be accomplish before higher level goals can be achieved. For example, all the sub-goals below the goal Complete_Approach_Phase, such as Know_UNREP_Plan and Maintain_Communications, must be completed before the higher level Complete_Approach_Phase goal can be achieved.

Contrary to standard CMN GOMS notation, which best represents a serial task sequence, the analysis notation used here does not necessarily represent a serial sequence of sub-goals leading to a higher level goal. Instead, the subtasks in this notation could be accomplished in many different sequences. Some tasks may, and in fact will, loop for a significant period of time while other tasks may be repeated quickly and sporadically throughout a given phase. Situations when a task loops for some period or when a task reoccurs several times will be noted as they occur in the narrative of the detailed level analysis that follows later in this chapter.
. . goal: Know_UNREP_Plan

. . goal: Complete_Approach_Phase

. . . goal: Know_UNREP_Plan

. . . goal: Maintain_Communications

. . . goal: Maintain_Awareness_Of_Third_Party_Ships

. . . goal: Maintain_Station

. . . goal: Receive_Report_Own_Ship_Ready_To_Go_Alongside

. . . goal: Make_Approach

. . goal: Complete_Alongside_Phase

. . . goal: Determine_When_Bow_Crosses_Stern

. . . goal: Watch_For_Bow_To_Be_Pushed_Away_From_Replenishment_Ship

. . . goal: Monitor_Venturi_Effect_Alongside_Replenishment_Ship

. . . goal: Determine_Lateral_Separation

. . . goal: Determine.Range_To_Station_Closing_Rate

. . . goal: Determine_When_To_Match_Speeds

. . . goal: Maneuver_Close_To_Station_Alongside

. . . goal: Get_Phone_And_Distance_Line_Across

. . . goal: Maintain_Station_Alongside

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goal: Complete_Breakaway_Phase
  goal: Maintain_Station_Alongside
  goal: Determine_All_Lines_Clear
  goal: Receive_Breakaway_Order_From_CO
  goal: Breakaway
  goal: Go_To_Next_Station_Or_Duties_Assigned

3. Detailed Level Analysis

The Detailed Level model was developed by further decomposition of the Functional Level methods into smaller more detailed methods that were required to achieve the higher level goal. In many cases, the methods themselves can be viewed as the sub-goals of sub-goals. Throughout this analysis the Conning Officer may, in some cases, choose to select one method or a combination of several methods to achieve a goal. Recall that for this analysis the notation is intended to allow tasks to loop and/or reoccur several times throughout the UNREP. Each Conning Officer develops their driving skills under a different CO's tutelage and encounters various individual experiences throughout their careers that influence the ship handling strategies they develop as well as the cues that they use to drive. It would be exceptionally difficult to analyze every possible sequence of goals that could lead to a successful UNREP. Thus, this analysis documents the general goals that must be accomplished to complete an UNREP regardless of sequence and the cues necessary to achieve these goals.
Some tasks are repeated many times throughout an UNREP. Instead of repeating all of the details related to a particular task over and over in the Detailed Level analysis, the details of a task will appear only once in the analysis. When a task is repeated later in the analysis, the task will have the same goal name. For example, the goal Turn_Ship occurs several times throughout the analysis. However the details related to this task appear only once. All other occurrences are simply references to the Turn_Ship method. The reader can refer back to the first occurrence of a goal as necessary for review.

The goal for a Conning Officer is to safely and efficiently execute an UNREP maneuver. The following analysis and the accompanying narrative documents the sub-goals and methods required to accomplish the Execute_UNREP goal.

goal: Execute_UNREP

The Complete_Brief_Phase was the first goal to be dealt with. This goal is generally accomplished during the operations brief the night before an UNREP or at least there should be a UNREP brief several hours before the UNREP is to occur. All available officers and other personnel who are involved in the UNREP will normally attend these briefs. At a typical UNREP brief, an officer, usually the First Lieutenant, will present a plan detailing what will take place during the UNREP. Details that the Conning Officer must remember are the rendezvous time, ROMEO course and speed, predicted weather, stores and fuel to be transferred, side of approach, and estimated time alongside as well as a picture of the replenishment ship's UNREP stations compared to own ship's UNREP stations. The purpose of the picture is to show the Conning Officer which stations must
be lined up across from each other so that lines and hoses can be passed from station to station between the ships. At this brief, the CO may specify a particular strategy he wants to use during the UNREP maneuver or he may mention particular concerns related to weather or sea-state. Usually the CO will discuss previous experiences he has had while going alongside the replenishment ship or maybe a lack of experience with a particular replenishment ship or ship-class.

Other important information that must be known before going to the bridge to Conn the ship is the engineering plant configuration. Some of the information the Conning Officer should remember about the plant configuration includes the main engines or boilers online, which shafts are turning, which generators are online, as well as the steering motors and cables online. As previously mentioned, in most cases, all engines will be online with all shafts turning so that full power is available. Auxiliary equipment such as generators, motors, and pumps will be configured to provide the quickest casualty recovery time possible. Engineering department personnel will be at restricted maneuvering stations for the entire UNREP to provide immediate casualty recognition and recovery. The Complete_Brief_Phase sub-goals discussed above are represented as follows in CMN GOMS notation:

```
  . goal: Complete_Brief_Phase
    . . goal: Know_UNREP_Plan
      . . [select: Go_To_OPS_Brief
      . .    Go_To_CIC_Before_Watch
```

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Receive_UNREP_Brief_On_Bridge

. . . . goal: Know_Plant_Configuration

. . . . [select: Go_To_OPS_Brief

. . . . Go_To_CCS_Before_Watch

. . . . Receive_UNREP_Brief_on_Bridge]

The goal Complete_Approach_Phase represents the time from when the approach ship arrives at either life guard station 1000 yards astern or waiting station 500 yards astern of the replenishment ship to the time the approach ship's bow crosses the plane perpendicular to the stern of the replenishment ship. By this time, it is critical that the Conning Officer knows the UNREP plan. A well-prepared Conning Officer will have mentally rehearsed the details of the UNREP maneuver before arriving on the bridge. It is always prudent to double-check and ensure that the UNREP plan has not changed and that it is being followed.

For the remainder of the task analysis these assumptions were made:

- An UNREP brief has been completed.
- Restricted maneuvering is set.
- Own ship has just arrived on station astern of the replenishment ship.
- Own ship will approach on the replenishment ship's starboard side.
- ROMEO corpen is 140 degrees true.
- ROMEO speed is 13 knots.
- All engines are online and full power is available.
• The CO, Conning Officer and OOD are on the port bridge wing watching for ROMEO to be closed up on the replenishment ship.

• The Helmsman and Lee Helmsman are fully qualified and standing at the Ship's Control Console in the center of the bridge.

• The sea-state is three and the weather forecast is good.

• The approach ship is an Aegis cruiser with two controllable, reversible pitch propellers.

The above discussion provides all the preliminary information that a Conning Officer should possess prior to conning the ship. The following analysis steps through the approach phase of an UNREP. The Know_UNREP_Plan and Know_Plant_Configuration goals are repeated here because they should be reconfirmed prior to taking the Conn.

  . goal: Complete_Appearance_Phase

  . . goal: Know_UNREP_Plan

  . . . goal: Determine.Side.To_Approach.On

  . . . . [select: Observe_ROMEO.Flag.On_Replenishment.Ship

  . . . . Recall.From_Brief

  . . . . Radio_Communication_with_Replenishment.Ship]

  . . . goal: Know_Plant_Configuration

  . . . . [select: Call_CCS.From_Bridge

  . . . . Ask_Lee_Helm.To_Get_Configuration.From_CCS]

  . . . goal: Go.To.Bridge.Wing
Maintaining communications between the Conning Officer, Helmsman, Lee Helmsman and the CO is very important. Normally, communications between the Conning Officer, the Helmsman, and Lee Helmsman is via an amplified speaker system, however, other methods may be used if this system fails.

- goal: Maintain_Communications ...periodic task
  - [select: Use_Amplified_Communications_System]
  - Yell_Through_Hatch ...if amp fail/not available
  - Visual_Expressions ...for comms. with CO, OOD
  - Verbal_Communications
  - Use_Relay_Person] ... if amp fail/not available
  - Verify_Order_Received

The Conning Officer must periodically visually scan the horizon to detect and track other ships in the area. During an UNREP, the Conning Officer's attention is dedicated to getting to station and/or maintaining station, so the time spent tracking other ships is limited. Thus, the OOD usually maintains the surface contact picture and updates the Conning Officer and CO periodically. This task can usually be accomplished very quickly and is repeated frequently throughout the entire UNREP as often as other tasks permit.

- goal: Maintain_Awareness_Of_Third_Party_Ships ...periodic task
One distinguishing characteristic of a good Conning Officer is the ability to precisely maintain an ordered station. Constant vigilance is required to maintain station. Therefore, the Conning Officer must constantly observe own ship's position relative to the guide ship (the replenishment ship in this case) and make the necessary speed and course corrections to stay on station. How does one know when to make a correction? By observing cues that answer questions such as: Is own ship closing/opening the range to the replenishment ship? Is own ship drifting to the right or left of station? In order to detect these cues, the Conning Officer must maintain an up to date range by regularly requesting the range from the stadometer operator or radar operator and frequently shoot bearings to the replenishment ship. Once on station, it is important that the Conning Officer remember the speed and RPMs required to maintain the exact speed of the replenishment ship. This information will be important when own ship is alongside trying to match the replenishment ship's speed. Other cues available include observing the masts of the replenishment ship; they should line up if own ship is directly astern. At night a similar cue can be used except in this case the masthead lights should line up. Another cue to watch is the wake of the replenishment ship; own ship should be centered in the wake if it is directly astern. If own ship is more than a couple of degree left/right or 20
yards out of station, the Conning Officer should take action (turn or change speed) to get back to station.

. . . goal: Maintain_Station ...loops until Make_Approach executed

. . . goal: Shoot_Bearing_To_Replenishment_Ship ...frequently until alongside

. . . [select: Use_Alidade_On_Bridge_Wing

. . . Use_Radar_Bearing_To_Replenishment_Ship

. . . Replenishment_Ship's_Masts_Lineup

. . . Masthead_Lights_Of_Replenishment_Ship_Lineup ...at night

. . . Own_Ship_In_Wake_Of_UNREP_Ship] ...at night/low vis

. . . goal: Get_Range_To_Replenishment_Ship ...frequently until alongside

. . . [select: Get_Range_From_Stadimeter

. . . Call_For_Radar_Range ...anytime and at night/low visibility

. . . Visual_Estimate] ...in between updates

. . . goal: Determine_If_On_Station

. . . goal: Determine_If_Range_To_Replenishment_Ship_Correct

. . . Compare_Range_With_Ordered_Range

. . . goal: Determine_If_Bearing_To_Replenishment_Ship_Correct

. . . Compare_Bearing_With_Ordered_Bearing

. . . Verify_On_Station

If own ship is not on station, the Conning Officer must change course and speed as required to get to station and stay there. The methods required to Turn_Ship, Change_
Speed_of_Ship and Monitor_Helm are explained later in the Detailed Level analysis of the Complete_Approach_Phase.

... goal: Make_Necessary_Corrections ...loop back to Maintain_Station

... [select goal: Turn_Ship ...see page 58

... goal: Change_Speed_Of_Ship] ...see page 55

The ready to go alongside report is important since it determines when own ship can hoist ROMEO at the dip, indicating it is ready to commence its approach. Since flag signals are the normal mode of communications, it is essential that own ship expediently hoist flag ROMEO to the dip when it is ready to make its approach.

... goal: Receive_Report_Own_Ship_Ready_To_Go_Alongside

... Receive_Verbal_Report_From_OOD

... goal: Acknowledge_Receiving_Report

... Verbally_Repeat_Order_Received

... goal: Order_ROMEO_Raised_On_The_Side_To_Go_Alongside

... Order_Signalman_To_The_Dip_ROMEO ...OOD may do this

The next signal that must be received from the replenishment ship is ROMEO close up on the side own ship is to approach. On the CO's order, own ship would answer by closing up ROMEO and commencing its approach. At night, flashing light signals will be used and in a few cases, normally only emergencies, a radio may be used.

... goal: Make_Approach

... goal: Observe_ROMEO_Close-up_On_Replenishment_Ship
Since it is a good rule of thumb to increase speed first before turning, the Conning Officer will first verbally issue an engine order that will increase the speed of the ship [STAV92]. Generally, the CO will prescribe the approach speed. However, NWP 4-01.4 recommends using five knots over the speed of the replenishment ship. As previously mentioned, the Conning Officer, Helmsman, and Lee Helmsman must follow a very specific standard command sequence when issuing engine and rudder orders.
There are a number of cues that can be used to determine that an order is being executed. For example, if the ship's speed is being increased, there may be a noticeable change in the sound of the turbines. If the increase in speed was significant, an increase of the relative wind speed felt on the bridge wing or a change in the feel of the ship's hull cutting through the water may be noticed. As a last resort, speed indicators are usually located on the bridge as well as on each of the bridge wings so that the Conning Officer can monitor changes in speed.
When turning the ship, it is particularly important to be aware of what other ships in the area are doing. The Conning Officer should personally visually verify the water in the direction own ship will turn is clear of other shipping or request that someone else verify the area is clear [STAV92]. Next, the Conning Officer must consider several questions before issuing a rudder order. What direction to turn? How quickly should the ship turn? How many degrees will the ship's heading change during the turn? How fast is the ship moving? The answers to these questions will help the Conning Officer determine how much rudder is required to achieve the intended result. With experience, answering these questions for oneself becomes almost automatic. There are two philosophies on how a Conning Officer should turn a ship. When using the first method, the Conning
Officer tries to control the rudder by issuing specific rudder orders to the Helmsman such as, "Right five degrees rudder". This method, in effect, takes control of the rudder from the Helmsman since the Helmsman must follow the Conning Officer's orders exactly and can not automatically counter the swing of the ship or decrease the amount of rudder to slow the turn of the ship. To execute this method well requires a great deal of experience. When using the second method, the Conning Officer typically issues new courses for the Helmsman to steer. For example, "Come right, steer course 145". This method usually decreases the chances that the Conning Officer will over shoot an intended course by leaving the rudder over for too long. In this case, the Helmsman knows what heading to go to and has more freedom to use the rudder to check the swing in time to stop on the ordered course [STAV92]. Most Conning Officers probably use a method somewhere in between these two extremes.

For analysis purposes, at this point, assume the Conning Officer has increased speed by five knots and issued a rudder order such as "Come right, steer course 145". The Helmsman immediately repeats the order back to the Conning Officer and later reports when the order is completed. Own ship has started to slowly pull out to the right and has closed to 900 yards astern of the replenishment ship. Another rule of thumb that can be used is called the rule of thirty, which means that the total of the ship's speed, in knots, and the degree of rudder ordered should not exceed thirty. This should prevent the ship from heeling over excessively during turns.

... goal: Turn_Ship ...to change lateral separation
goal: Visually_Verify_Direction_Of_Turn_Clear

[select: Walk_To_Bridge_Wing_Of_The_Direction_Of_Turn_To_Look

Request_Another_Watch_Team_Member_Visually_Check]

gain: Issue_Rudder_Order ...to helmsman

[select goal: Starboard_Turn

. goal: Determine_How_Far_To_Turn

. [select: Use_Prior_Experience_To_Estimate_Distance

. Use_Radian_Rule_To_Monitor_Turn

. Follow_CO's_Orders]

. goal: Determine_Degree_of_Rudder_To_Use

. [select: Use_The_Rule_Of_Thirty_To_Determine_Amount

. Use_Prior_Experience_To_Estimate_Amount

. Follow_CO's_Orders]

. goal: Give_Verbal_Order_To_Helm

goal: Port_Turn

. goal: Determine_How_Far_To_Turn

. [select: Use_Prior_Experience_To_Estimate_Distance

. Use_Radian_Rule_To_Monitor_Turn

. Follow_CO's_Orders]

. goal: Determine_Degree_of_Rudder_To_Use

. [select: Use_The_Rule_Of_Thirty_To_Determine_Amount

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Use_Prior_Experience_To_Estimate_Amount

Follow_CO's_Orders]

goal: Give_Verbal_Order_To_Helm

goal: Receive_Repeat-back_From_Helm

Listen_For_Report_From_Helm

[select goal: Acknowledge_Repeat-back ...if received

goal: Repeat_Order] ...if not received

The Conning Officer monitors the Helmsman and the turn in progress by watching the rudder angle indicator to see that the rudder was turned in the correct direction by the ordered amount. Additional cues that can be used to monitor a turn include observing the feeling of the ship starting to heel, the wake of the replenishment ship, the gyrocompass heading change, the feeling that the ship is turning, and the rate at which the ship is turning. The rate at which the ship is turning is important because if the ship is turning quickly as it is approaching the ordered course, the Helmsman may need to be reminded not to let the ship stray past the ordered heading. Notice that many of the cues used to detect that a turn order has been executed are identical to the cues used to monitor a turn.

goal: Determine_If_Order_Was_Executed

[select: Observe_Rudder_Angle_Indicator

Observe_Wake_Of_Replenishment_Ship

Observe_Feeling_Ship_Heel

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Observe_Target_Angle_Of_Replenishment_Ship_Change
Observe_Horizon
Observe_Wake_Of_Own_Ship
Observe_Gyrocompass_Heading_Change
Observe_Feeling_That_Ship_Is_Turning

goal: Receive_Report_That_Order_Was_Executed
Listen_For_Report_From_Helmsman
[select goal: Acknowledge_Report ...if received

goal: Request_Status_Of_Order_Execution] ...if not received

goal: Monitor_Ship's_Turn
[select: Observe_Rudder_Angle_Indicator

Observe_Feeling_Ship_Heel
Observe_Wake_Of_Replenishment_Ship
Observe_Wake_Of_Own_Ship
Observe_Horizon
Observe_Gyrocompass_Heading_Change
Observe_Feeling_That_Ship_Is_Turning
Observe_Rate_Of_Turn_Increase/Decrease

goal: Monitor_Helmsman
[select: Observe_Turn_Progress_On_Gyrocompass

Observe_Rudder_Angle_Indicator]
While monitoring the turn, the Conning Officer may find it necessary to make corrections. For instance, the previous order may not have caused the intended result or the desired outcome may have changed. The goals discussed in the above analysis provide insight into the methods used to determine if a correction is required. All that is left is to issue another engine/rudder order and monitor for the desired result. This process of giving orders and waiting to see the result is repeated throughout the approach.

... goal: Make_Necessary_Corrections

.... [select goal: Turn_Ship

.... goal: Change_Speed_Of_Ship]

The Helmsman reports to the Conning Officer when the ship is steady on the ordered course. As the range to the replenishment ship continues to close, the Conning Officer must frequently update range and bearing as well as monitor the lateral separation. The most common tool used to determine lateral separation is the Radian Rule. By using the Radian Rule, the Conning Officer can quickly determine if own ship has progressed towards or over shot the desired lateral separation. On the other hand, some Conning Officers may choose to simply use seaman's eye to judge lateral separation.

... goal: Receive_Steady_On_Course_Report

... Listen_For_Steady_On_Course_Report

.... [select goal: Acknowledge_Report ...if received

.... goal: Request_Status_Of_Order_Execution] ...if not received
As the range to the replenishment ship decreases to within the last hundred yards, it is paramount that the Conning Officer accurately judges that the lateral separation is enough to safely proceed alongside. At this point, a minimum of eighty feet lateral separation is comfortable. If the lateral separation becomes too narrow it would be prudent for the approach ship to slow and increase the lateral separation before crossing the stern of the replenishment ship. Rather than approaching too close, it is safer to end up alongside with too much lateral separation and have to slowly close to within the desired separation.

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Estimate_Closing_Rate]

... goal: Shoot_Bearing_To_Replenishment_Ship

... [select: Use_Alidade_On_Bridge_Wing

... Call_For_Radar_Bearing] ...at night/low visibility

... goal: Determine_If_Lateral_Separation_Closing/Opening/Maintaining

... [select: Use_Radian_Rule_Method

... Use_Table_Of_Radian_Rule_Values_Method

... Observe_Distance_Between_Wakes

... Use_Seaman’s_Eye_Method ...requires experience

... Use_Combination_Of_The_Above]

... goal: Determine_If_Lateral_Separation_Too_Close/Far

... [select: Use_Radian_Rule_Method

... Use_Table_Of_Radian_Rule_Values_Method

... Observe_Distance_Between_Wakes

... Use_Seaman’s_Eye_Method ...requires experience

... Use_Combination_Of_The_Above]

... goal: Make_Necessary_Corrections

... [select goal: Turn_Ship

... goal: Change_Speed_Of_Ship]}

The last chance to determine that the lateral separation is safe is right before the bow of own ship crosses the stern of the replenishment ship. This is also the beginning of
the alongside phase of the UNREP. There are no instruments available that accurately
determine distance this close. The Conning Officer must rely on past experience and
depth perception to estimate the distance between the ships.

. . . . goal: Determine_If_Lateral_Separation_Is_Safe_To_Go_Alongside
. . . . Visually_Estimate_Lateral_Separation
. . . . goal: Make_Necessary_Corrections ...if not safe
. . . . . [select goal: Turn_Ship
. . . . . . goal: Change_Speed_Of_Ship]
. . . . goal: Monitor_Bow_As_It_Approaches_Replenishment_Ship's_Stern
. . . . Watch_For_Pressure_To_Push_Bow_Away_From_Stern

Water pressure at the stern of the replenishment ship and the bow of own ship
causes a high-pressure area that may initially cause the bow of own ship to be pushed
away from the stern of the replenishment ship. However, as own ship continues to gain
on the replenishment ship, the high-pressure zones interact and cause a venturi effect
between the ships. The venturi effect causes a suction to form that tends to pull the ships
together. The closer the ships are, the stronger the suction force between them. Thus, it is
extremely important to observe the lateral separation between the ships, particularly
watching for a decreasing trend. Again, there are no instruments used to monitor
separation other than the Conning Officer's eye.

. . goal: Complete_Alongside_Phase
. . . . goal: Determine_When_Bow_Crosses_Stern
. . . Visually_Estimate
. . . goal: Watch_For_Bow_To_Be_Pushed_Away_From_Replenishment_Ship
. . . Observe_Bow_Motion  ...high pressure area between bow and stern
. . . goal: Monitor_Venturi_Effect_Alongside_Replenishment_Ship  ...< 80 feet
. . . goal: Monitor_Lateral_Separation_Distance
. . . [select: Observe_Wake_Action_Between_Ships
. . . Visually_Estimate_Opening/Closing_Trend
. . . Visually_Estimate_Lateral_Separation]
. . . goal: Make_Necessary_Corrections  ...if too far or close
. . . [select goal: Turn_Ship
. . . goal: Change_Speed_Of_Ship]

The next major step for the Conning Officer is to determine when to match the replenishment ship's speed. Previous experience with the same replenishment ship is very helpful here, otherwise, one must estimate when to cut own ship's speed. The main thing to consider is how far will own ship surge (continue to move ahead) after its speed has been reduced. Again, experience is crucial. If the speed is reduced too early, the Conning Officer will have to try to catch-up to get into station. On the other hand, if the speed is left on too long, own ship will shoot past the intended station and have to slowly fall back to get into station. A cue that can be used to help judge the relative speed between the ships is the speed at which items on the replenishment ship appear to pace. Using this cue
makes it easier to detect when own ship is moving too fast or too slow. The process of initially getting into station typically requires several slight speed and course changes.

. . goal: Determine_Lateral_Separation ...>90 feet

. . . [select: Observe_Wake_Action_Between_Ships

. . . Visually_Estimate_Lateral_Separation_Distance]

. . . goal: Make_Necessary_Correction ...if too far or close

. . . . [select goal: Turn_Ship

. . . . goal: Change_Speed_Of_Ship]

. . . goal: Determine_Range_To_Station_Closing_Rate

. . . goal: Determine_Range_To_Station

. . . . [select: Visually_Estimate_Distance

. . . . Observe_Rate_Which_Features_On_Replenishment_Ship_Pass]

. . . . goal: Make_Necessary_Correction ...if too fast or slow

. . . . [select goal: Turn_Ship

. . . . . goal: Change_Speed_Of_Ship]

. . . . goal: Determine_When_To_Match_Speeds

. . . . Compare_Speed_Between_Ships_Estimate_When_To_Match_Speed

. . . . . goal: Change_Speed_Of_Ship

. . . . goal: Maneuver_Close_To_Station_Alongside

. . . . goal: Monitor_Ships_Heading_On_Gyrocompass ...repeats frequently

. . . . . . Observe_Bridge_Wing_Gyrocompass
goal: Monitor_Lateral_Separation

[select: Observe_Wake_Between_Ships
   Visually_Estimate_Opening/Closing_Trend]

goal: Monitor_Fore_And_Aft_Motion

[select: Use_Replenishment_Ship's_Riggings_As_Range
   Use_Replenishment_Ship's_Bulkhead_As_Range]

goal: Make_Necessary_Correction...to move towards station

[select goal: Turn_Ship

gold: Change_Speed_Of_Ship]

When own ship is close to station, it is time to have the phone and distance line passed. Once the phone and distance line is in place, it becomes much easier to determine the lateral separation. The Conning Officer should use the flags on the phone and distance line to determine the necessary course changes required to maneuver own ship to the ordered lateral separation. Next, or at the same time, the Conning Officer should maneuver the ship as required to ensure that the UNREP stations on each of the ships are across from each other. When the UNREP stations are inline, the Conning Officer should look for riggings or a bulkhead on the replenishment ship to use as a cue to maintain station. For example, the Conning Officer may pick two rigs on the replenishment ship to line up and then watch for parallax error to occur. This would indicate that own ship has pulled ahead of the replenishment ship or fallen behind. Once own ship is on station, the Conning Officer must constantly monitor the flags on the phone and distance line and the
rigs on the replenishment ship in order to maintain station. Whenever lines are tensioned or de-tensioned, the Conning Officer should inform the Helmsman, so that the Helmsman is ready to compensate for the increased force of the lines pulling own ship towards the replenishment ship. The process described for maintaining station would be repeated for hours. Normally, while alongside, the Conning Officer will be replaced several times. This provides experience for more officers and is meant to keep the Conning Officer alert.

- . . . goal: Get_Phone_And_Distance_Line_Across ...when near station
- . . . Give_Order_To_Send_Phone_And_Distance_Line_Across
- . . . goal: Maintain_Station_Alongside ...loop until All Lines Clear
- . . . goal: Monitor_Lateral_Separation
- . . . [select: Observe.Flags_On_Phone_And_Distance_Line_Open/Close
- . . . Visually_Estimate_Opening/Closing_Trend
- . . . Observe_Chemical_Lights_On_Phone_And_Distance_Line]
- . . . goal: Monitor_Fore_And_Aft_Motion
- . . . [select: Use_Replenishment_Ship's_Riggings_As_Range
- . . . Use_Replenishment_Ship's_Bulkheads_As_Range
- . . . Observe_Angle_Of_Phone_And_Distance_Line]
- . . . goal: Make_Necessary_Correction ...to stay on station
- . . . [select goal: Turn_Ship
- . . . goal: Change_Speed_Of_Ship]
After a few hours of receiving stores and fuel, the time comes to breakaway. This involves the crew breaking down rigs that were setup to facilitate passing fuel and stores between the ships. When all the lines between the ships are clear and the CO gives the okay, it is safe for own ship to breakaway.

- goal: Complete_Breakaway_Phase
- goal: Maintain_Station_Alongside ...same loop as above
- goal: Monitor_Lateral_Separation
- [select: Observe_Wake_Between_Ships
  - Visually_Estimate_Opening/Closing_Trend]
- goal: Monitor_Fore_And_Aft_Motion
- [select: Use_Replenishment_Ship's_Riggings_As_Range
  - Use_Replenishment_Ship's_Bulkhead_As_Range]
- goal: Make_Necessary_Correction ...to move towards station
- [select goal: Turn_Ship
  - goal: Change_Speed_Of_Ship]
- goal: Inform_Helmsman_Before_Lines_Are_De-tensioned
Receive_Report_That_Lines_Are_Being_De-tensioned

goal: Inform_Helmsman_To_That_Lines_Are_Being_De-tensioned

[select goal: Receive_Repeat-back ...if received
goal: Repeat_Order] ...if not received

goal: Determine_All_Lines_Clear

[select: Visually_Verify_All_Lines_Clear

Receive_Report_All_Lines_Clear]

goal: Receive_Breakaway_Order_From_CO

Receive_Verbal_Order_From_CO

goal: Acknowledge_Receiving_Order

Verbally_Repeat_Order_Received

The Conning Officer increases own ship's speed by five to ten knots to pull ahead of the replenishment ship. Traditionally, the ship breaking away plays a breakaway song at this point. As own ship starts to gain speed, the Conning Officer's primary concern is the stern of own ship hitting the replenishment ship. As during the approach, the venturi between the ships fluctuates causing a stronger suction to occur during the breakaway. The Conning Officer should use small course changes, of one or two degrees, to maneuver own ship away until its stern is clear of the replenishment ship's bow. After the stern has cleared the bow, the Conning Officer is free to change speed and course as required in route to the next ordered station. However, it is not a good idea to cross the bow of the replenishment ship during the breakaway.
... goal: Breakaway ...start breakaway
... goal: Change_Speed_Of_Ship ...increase speed to pull away
... goal: Turn_Ship ...done in small increments until stern is clear
... goal: Monitor_Ship's_Turn ...until stern clear
... . . . Observe_Ship's_Stern_Does_Not_Move_Towards_Replenishment_Ship
... . . . goal: Make_Necessary_Correction
... . . . [select goal: Turn_Ship ...see repeated methods
... . . . goal: Change_Speed_of_Ship] ...see repeated methods
... . . . goal: Determine_Stern_Is_Clear
... . . . Observe_Stern_Clear_Of_Replenishment_Ship's_Bow
... . goal: Go_To_Next_Station_Or_Duties_Assigned

B. TASK ANALYSIS OF AN OFFICER OF THE DECK DURING UNREP

The tasks the Officer of the Deck (OOD) performs during an UNREP differ from ship to ship. In most cases, once the approach starts, the CO personally supervises the Conning Officer until the ship is safely alongside the replenishment ship. This allows the CO and Conning Officer to concentrate on driving the ship while the OOD does most of the supporting administrative duties associated with the watch, such as: monitoring third party shipping, supervising the bridge watch team, and managing communications. This analysis assumes that the OOD will primarily organize and manage the internal operations of the ship, as well as provide support to the CO and Conning Officer during the UNREP.
The analysis was broken into three levels, first the Unit-Task Level, second the Functional Level and third the Detailed Level (Argument Level). As the analysis progresses from the Unit-Task Level to the Detailed Level, more detail is captured in each successive level.

1. **Unit Task Level Analysis**

   The Unit-Task indicates that the top-level goal was to execute an UNREP. How does the OOD fit into this Unit-Task? The OOD is responsible for coordinating the whole team. This means the OOD must know what everyone else is suppose to be doing and must ensure that they do their jobs effectively. The OOD is directly responsible to the CO for the operation and safety of the ship. The GOMS representation of the Unit-Task remains unchanged.

   goal: Execute_UNREP
   . goal: Complete_Brief_Phase
   . goal: Complete_Approach_Phase
   . goal: Complete_Alongside_Phase
   . goal: Complete_Breakaway_Phase

2. **Functional Level Analysis**

   The Functional Level was developed by decomposing the tasks the OOD would typically have to accomplish during an UNREP. Most of the OOD's tasks closely parallel the tasks the Conning Officer must accomplish with more of an emphasis on supervision.

   goal: Execute_UNREP

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. goal: Complete_Brief_Phase

  . goal: Know_UNREP_Plan

. goal: Complete_Approach_Phase

  . goal: Know_UNREP_Plan

  . goal: Supervise_Bridge_Watch_Team

  . goal: Maintain_Communications

  . goal: Ensure_Safety_Of_Own_Ship

  . goal: Maintain_Awareness_Of_Third_Party_Ships

  . goal: Ensure_Own_Ship_Ready_To_Go_Alongside

  . goal: Ensure_Conning_Officer_Maintains_Station

  . goal: Supervise_Conning_Officer_During_Approach

. goal: Complete_Alongside_Phase

  . goal: Supervise_Conning_Officer_While_Alongside

  . goal: Determine_When_Bow_Crosses_Stern

  . goal: Watch_For_Bow_To_Be_Pushed_Away_From_Replenishment_Ship

  . goal: Monitor_Venüri_Effect_Alongside_Replenishment_Ship

  . goal: Determine_Lateral_Separation

  . goal: Determine_Range_To_Station_Closing_Rate

  . goal: Determine_When_To_Match_Speed
. . goal: Maneuver_Close_To_Station_Alongside
. . goal: Get_Phone_And_Distance_Line_Across
. . goal: Maintain_Sation_Alongside ...loop until UNREP complete
. . goal: Supervise_Bridge_Watch_Team
. . goal: Maintain_Awareness_Of_Third_Party_Shipping
. . goal: Maintain_Communications

. . goal: Complete_Breakaway_Phase
. . goal: Supervise_Conning_Office_While_Alongside
. . goal: Supervise_Bridge_Watch_Team
. . goal: Maintain_Awareness_Of_Third_Party_Shipping
. . goal: Know_Where_To_Go_Next
. . goal: Maintain_Communications

3. Detailed Level Analysis

As before, the Detailed Level analysis was created by further decomposing the tasks outlined in the Functional Level analysis. Throughout the analysis, remember that the OOD may choose to select one of several methods to accomplish a goal. Some tasks may be repeated often while others may loop several times to show that the task is done frequently to monitor the progress towards achieving a goal. The sequence of the goals presented in the analysis will vary from UNREP to UNREP as well as from OOD to OOD.
The OOD attends the same briefs and records the same information as the Conning Officer. Since the OOD is in charge of the bridge watch team, it is equally important for the OOD to know the UNREP plan and engineering plant status as it is for the Conning Officer. The OOD is typically senior to the Conning Officer and has more influence in formulating the UNREP plan. The OOD and CO will discuss the UNREP plan in detail during the brief. The Unit-Task remains unchanged.

goal: Execute_UNREP
  . goal: Complete_Brief_Phase
  . . goal: Know_UNREP_Plan
  . . . [select: Go_To_OPS_Brief
  . . . . Go_To_CIC_Before_Watch
  . . . . Receive_UNREP_Brief_on_Bridge
  . . . . Talk_To_Operations_Officer_About_Changes
  . . . . Talk_To_CO_About_Plan]
  . . goal: Know_Plant_Configuration
  . . . [select: Go_To_OPS_Brief
  . . . . Go_To_CCS_Before_Watch
  . . . . Receive_UNREP_Brief_on_Bridge
  . . . . Talk_To_Chief_Engineer_About_Plant_Status]

Once on the bridge, it is the OOD's duty to coordinate the preparation necessary to conduct an UNREP. Personnel must be on station throughout the ship and numerous
communication circuits must be established and checked before the ship is ready to UNREP. A checklist is kept on the bridge to aid in keeping track of all the tasks that must be accomplished throughout the ship before it goes alongside. As crewmembers complete tasks, they call the bridge to report that they have accomplished a required task. The OOD then records that the task has been completed. By reviewing the checklist periodically, the OOD can determine what remains to be done. If required, the OOD can contact the department responsible for a task on the checklist to expedite its completion.

The OOD is the center of the operation. The OOD must know the big picture as well as who is responsible for the little details. If something is not right and the OOD can not fix the problem, the OOD must know who to contact to get the problem solved immediately.

To become an excellent OOD takes years of experience beyond initial qualification.

The OOD plays a major part in getting the ship positioned astern the replenishment ship and up to this point the OOD and Conning Officer act as a team. The OOD monitors the Conning Officer's actions and makes necessary corrections to ensure the safety of own ship. However, from the start of the approach and until the UNREP is complete, the CO and Conning Officer go to the bridge wing and work together to maneuver the ship alongside and on a parallel course with the replenishment ship. The OOD provides support by organizing the bridge watch team to ensure none of the supporting tasks, i.e. communications, are missed or delayed.

- goal: Complete Approach Phase
- goal: Know UNREP Plan
[select: Receive_UNREP_Brief_On_Bridge]

Talk_To_Operations_Officer_About_Changes

Talk_To_CO_About_Plan]

goal: Know_Plant_Configuration

[select: Call_CCS_From_Bridge]

Ask_Lee_Helm_To_Get_Configuration_From_CCS

Talk_To_Chief_Engineer_About_Plant_Status]

goal: Determine_Side_To_Approach_On

[select: Observe_ROMEO_Flag_On_Replenishment_Ship]

Radio_Communication_With_Replenishment_Ship]

Supervising the bridge watch team involves ensuring each team member is equipped to do their job and is doing what they are suppose to be doing. To keep watch standers well rested and alert, they are rotated several times during an UNREP. This includes the Conning Officer's position, which is frequently rotated to provide an opportunity for more than one officer to drive. The OOD must monitor personnel and coordinate watch relief. Additionally, the OOD is responsible for executing the ship's communications plan, which include monitoring several phone and radio channels simultaneously.

goal: Supervise_Bridge_Watch_Team

goal: Ensure_Bridge_Manned_Ready before starting approach

Observe_Each_Station_Manned
Each of the UNREP stations, phone and distance line station, Central Control Station, Aft Steering, and Combat Information Center has manned phone circuits directly to the bridge. This provides immediate access to information in both directions. The phone talkers who man these circuits relay all reports to the OOD. The OOD also must monitor several radios used to communicate with other ships in the group. Flag hoists, flashing light signals, and semaphore signals are other methods used to pass messages between ships at sea. All incoming and outgoing messages should be reviewed by the OOD.

. . . goal: Ensure_All_Communications_Equipment_Operational

. . . Order_All_Watch_Standers_To_Do_Phone_Check

. . . goal: Correct_Discrepancies ...if not operational

. . . . . . Contact_Responsible_Department

. . . goal: Ensure_Signalman_Has_Correct_Flags_Displayed

. . . Observe_Flags_From_Bridge_Wing

. . . . . . goal: Correct_Discrepancies ...if not correct

. . . . . . Contact_Signalman

During an UNREP, own ship will display the ball diamond ball day shapes and at night or in low visibility three red lights on its mast to inform all third party shipping that it is restricted in its maneuverability [CHIE96]. At night, as well as in low visibility, other
running lights will be illuminated to provide increased visibility. Running lights and day shapes enable distant ships to determine who has the right of way and in which direction a vessel is headed. The OOD must ensure the correct lights and day shapes are displayed.

. . . goal: Ensure_Quartermaster_Has_Correct_Lights_Displayed

. . . . Observe_Masthead_Lights_From_Bridge_Wing

. . . . . goal: Correct_Discrepancies ...if not correct

. . . . . . Contact_Quartermaster

Normally, an electronics technician is available on the bridge to make quick repairs or assist in the setup of radar and communications equipment. The OOD and Conning Officer are required to know what each piece of equipment does and where it is located on the bridge.

. . . goal: Ensure_All_Bridge_Equipment_Setup_And_Operational

. . . . Check_Radar_Display

. . . . Check_Radios

. . . . Check_Miscellaneous_Equipment

. . . . . goal: Correct_Discrepancies ...if not operational

. . . . . . Contact_Problem

. . . goal: Ensure_Bridge_Watch_Standers_Remain_Alert

. . . . Monitor_Behavior_Of_Watch_Standers

. . . . Control_Noise_Level_On_Bridge

. . . . . goal: Correct_Discrepancies ...if not alert
Contact_Problem

. . goal: Maintain_Communications ...with CO, Conn, Helm and Lee helm

. . . [select goal: Communicate_with_Watch_Team

. . . . . [select: Yell_Through_Hatch

. . . . Visual_Expression

. . . . Verbal_Communications]

. . . goal: Communicate_with_Other_Ships

. . . . [select: Use_Bridge_to_Bridge_Radio

. . . . Use_Secure_Radio

. . . . Use_Flag_Signals

. . . . Use_Flashing_Light_Signals]

. . . Verify_Message_Received]

As each station becomes manned and phone communications are established, manned and ready reports are sent to the bridge where they are recorded. Once all stations report manned and ready and restricted maneuvering is set, the ship is ready to make its approach. Flag ROMEO is hoisted to the dip to indicate the ship is ready to make its approach. At this time the Conning Officer should see ROMEO at the dip on the replenishment ship.

. . goal: Ensure_Own_Ship_Ready_to_Go_Alongside

. . . Monitor_UNREP_Checklist

. . . goal: Ensure_All_Personnel_On_Station
Receive_Manned_Ready_Reports_From_UNREP_Stations
Receive_Manned_Ready_Reports_From_All_Department_Heads

goal: Contact_Department_Head_Of_Delinquent_Department

Call_Department_Head

goal: Set_Restricted_Maneuvering

goal: Get_Permission_To_Set_Restricted_Maneuvering_From_CO

goal: Pass_The_Word_That_Restricted_Maneuvering_Is_Set

Announce_That_Restricted_Maneuvering_Is_Set

goal: Inform_CO_Ship_Is_Manned_Ready_To_Go_Alongside

Make_Verbal_Report_To_CO

goal: Raise_ROMEO_On_The_Side_To_Go_Alongside

Order_Signalman_To_Close-up_ROMEO

The OOD must frequently visually scan the horizon for new contacts and monitor contacts that have already been reported. Additionally, the OOD will use the radar display to detect and track contacts. The OOD will report only those contacts that are predicted to close within a range specified by the CO, typically around ten thousand yards. Ships closing within five thousand yards may be hailed on the bridge to bridge radio to determine its intentions.

goal: Maintain_Awareness_Of_Third_Party_Ships ...done frequently

[select: Visually_Scan_Horizon

Observe_Radar_Display
Communicate_With_Ship's_Combat_Information_Center

Receive>Contact_Reports]

goal: Ensure_Safety_Of_Own_Ship

Monitor_Third_Party_Shipping

Make_Contact_Reports_To_CO

Observe_Everything_In_Sight_And_Sound

Unless the CO is supervising the Conning Officer, the OOD should monitor the Conning Officer's actions. An experienced OOD can be a tremendous aid to a relatively inexperienced Conning Officer by providing helpful tips that prevent embarrassing zigzag maneuvers on the way to station. The OOD's main concern is the safety of own ship, specifically, not hitting anything. A secondary concern is the ship's reputation. If a Conning Officer can not precisely maintain a station or is unable to make very smart, military, and efficient maneuvers to get to station, the ship will earn a bad reputation for the CO.

goal: Ensure_Conning_Officer_Maintains_Station

goal: Get_Bearing_And_Range_To_Replenishment_Ship

[select goal: Get_Bearing_To_Replenishment_Ship

[select: Request_Bearing_From_Conning_Officer

Use_Alidade_On_Bridge_Wing

Replenishment_Ship's_Masts_Lineup

Observe_Radar_Display
In order to monitor the Conning Officer, the OOD must compare the actual range and bearing to the replenishment ship with the ordered range and bearing, as well as consider if the Conning Officer is taking action to correct discrepancies in a timely fashion. Essentially, the OOD must detect and monitor the same visual and audible cues as the Conning Officer in order to ensure the correct actions are being taken. If the OOD determines the Conning Officer is not taking the correct actions, the OOD should provide help by giving suggestions or giving specific orders to the Conning Officer. In the rare case when a Conning Officer is unable to drive the ship even with the OOD's help, or in an emergency, the OOD may take the conn from the Conning Officer and drive the ship until a new Conning Officer is assigned.

... goal: Determine_If_Conning_Officer_Is_Conning_Safely

... Compare_Current_Range_&_Bearing_To_Ordered_Range_&_Bearing

... goal: Correct_Conning_Officer_As_Necessary
... select goal: Coach_Conning_Officer

... Make_Helpful_Course_Speed_Recommendations

group: Order_Conning_Officer
... goal: Order_Conning_Officer_To_Correct_Problem
... Give_Conning_Officer_Engine_Orders
... Give_Conning_Officer_Rudder_Orders

group: Supervise_Conning_Officer
... goal: Supervise_Conning_Officer_During_Approach  CO does this

... goal: Observe_ROMEO_Close-up_On_Replenishment_Ship

... select: Observe_ROMEO_On_The_Side_Own_Ship_Will_Approach

... Observe_Flashing_Light_Signal  at night/low visibility
... Receive_Radio_Transmission]  at night/low visibility

... goal: Receive_Approach_Order_From_CO

... select: Receive_Verbal_Order_From_CO_To_Commence_Approach

... Receive_Verbal_Order_Via_XO_To_Commence_Approach]

... goal: Acknowledge_Receiving_Order

... Verbally_Repeat_Order_Received

... goal: Order_Conning_Officer_To_Comence_Approach

... Verbally_Order_Conning_Officer

... goal: Monitor_Ship's_Turn  may use multiple methods

... select: Observe_Rudder_Angle_Indicator

... Observe_Feeling_Ship_Heel
... Observe_Wake_Of_Own_Ship

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Observe_Horizon
Observe_Gyrocompass_Heading_change
Observe_Feeling_That_Ship_Is_Turning
Observe_Rate_Of_Turn_Increase/Decrease

goal: Monitor_Helm

Observe_Turn_Progress_On_Gyrocompass
Observe_Rudder_Angle_Indicator

goal: Monitor_Conning_Officer_During_Maneuver

goal: Correct_Conning_Officer_As_Necessary

goal: Determine_Range_To_Replenishment_Ship

[select: Get_Range_From_Stadimeter
Call_For_Radar_Range]

goal: Determine_Range_Closing/Opening_Rate

[select: Call_For_Current_Speed
Observe_Speed_Indicator
Estimate_Closing_Rate]

goal: Determine_Lateral_Separation_Closing/Opening

goal: Shoot_Bearing_To_Replenishment_Ship

[select: Use_Alidade_On_Bridge_Wing
Call_For_Radar_Bearing] ...at night/low vis

goal: Determine_If_Lateral_Separation_Too_Close/Far
[select: Use_Radian_Rule_Method
Use_Table_Of_Radian_Rule_Values_Method
Observe_Distance_Between_Wakes
Use_Seaman's_Eye_Method ...requires experience
UseCombination_Of_The_Above]

g. goal: Monitor_Conning_Officer_During_Maneuver

g. goal: Correct_Conning_Officer_As_Necessary

In the unlikely event that the CO is not supervising the Conning Officer at the point of the approach when the bow is about to cross the stern, the OOD should closely monitor own ship's position relative to the replenishment ship and take action as required to ensure that there is not a collision. For example, if the OOD thinks own ship is too close and the Conning Officer is continuing the approach, the OOD must give the Conning Officer instructions to slow or turn away to prevent an accident.

g. goal: Monitor_Bow_As_It_Approaches_Replenishment_Ship's_Stern

g. Watch_For_Pressure_To_Push_Bow_Away_From_Stern

g. goal: Determine_If_Lateral_Separation_Is_Safe_To_Go_Alongside

g. Visually_Estimate_Lateral_Separation

g. goal: Monitor_Conning_Officer_During_Maneuver

g. Determine_If_Order_From_Conning_Officer_Correct_For_Situation

g. goal: Correct_Conning_Officer_As_Necessary

g. [select goal: Coach_Conning_Officer

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Once alongside, the OOD must continue to closely monitor the Conning Officer until own ship has settled into station and the phone and distance line is across. The alongside phase is a good officer training opportunity and usually many officers are allowed to drive the ship. Some COs may enjoy personally instructing the junior officers as they take their turns conning and others may want to observe the XO or let the OOD train the officers, so the OOD's role can vary.

- goal: Complete_Alongside_Phase
- goal: Supervise_Conning_Officer_While_Alongside ...
- goal: Monitor_Conning_Officer_During_Maneuver
- goal: Determine_If_Order_From_Conning_Officer_Correct_For_Situation
- goal: Correct_Conning_Officer_As_Necessary
- [select goal: Coach_Conning_Officer]
- . Make_Helpful_Course_Speed_Recommendations
- goal: Order_Conning_Officer_To_Correct_Problem
- . Give_Conning_Officer_Engine_Orders
- . Give_Conning_Officer_Rudder_Orders]
goal: Ensure All Personnel Are Alert

Observe Bridge Watch Standers

goal: Ensure All Equipment Failures Are Immediately Corrected

Immediately Contact Responsible Department

group: Ensure Quarter Master Maintains Correct Track

[select: Observe Ship's Track On Chart

Discuss Ship's Track With Quarter Master]

group: Maintain Quiet Bridge

Monitor Conversation And Noise Level On Bridge

group: Determine When Bow Crosses Stern

Visually Estimate

group: Watch For Bow To Be Pushed Away From Replenishment Ship

Observe Bow Motion

group: Monitor Venturi Effect Alongside Replenishment Ship ...
< 80 feet

Observe Wake Action Between Ships

group: Monitor Lateral Separation Distance

Visually Estimate Opening/Closing Trend ...... depth perception

Visually Estimate Lateral Separation ...... depth perception

group: Monitor Conning Officer During Maneuver

Correct Conning Officer As Necessary

group: Determine Lateral Separation ...
> 80 feet
... [select: Observe_Wake_Action_Between_Ships
... Visually_Estimate_Lateral_Separation_Distance]
... goal: Monitor_Conning_Officer_During_Maneuver
... . goal: Correct_Conning_Officer_As_Necessary
... . goal: Determine_Range_To_Station_Closing_Rate
... . goal: Determine_Range_To_Station
... . . [select: Visually_Estimate_Distance
... . . Observe_Rate_At_Which_Items_On_Replenishment_Ship_Pass]
... . . goal: Monitor_Conning_Officer_During_Maneuver
... . . goal: Correct_Conning_Officer_As_Necessary
... . . goal: Determine_When_To_Match_Speed
... . . Compare_Relative_Speed_Of_Ships_Estiniate_When_To_Match_Speed
... . . goal: Change_Speed_of_Ship
... . . goal: Maneuver_Close_To_Station_Alongside
... . . goal: Monitor_Ships_Heading_On_Gyrocompass
... . . Observe_Bridge_Wing_Gyrocompass
... . . goal: Monitor_Lateral_Separation
... . . Observe_Wake_Between_Ships
... . . Visually_Estimate_Opening/Closing_Trend
... . . goal: Monitor_Fore_And_Aft_Motion
... . . . [select: Use_Replenishment_Ship's_Riggings_As_Range
... Use_Replenishment_Ship's_Bulkhead_As_Range
... goal: Monitor_Conning_Officer_During_Maneuver
... goal: Correct_Conning_Officer_As_Necessary
... goal: Get_Phone_And_Distance_Line_Across ...when on station
... Give_Order_To_Send_Phone_And_Distance_Line_Across
... goal: Maintain_Station_Alongside ...loop until UNREP complete
... goal: Monitor_Lateral_Separation
... [select: Observe_FLAGS_On_Phone_And_Distance_Line
... Visually_Estimate_Opening/Closing_Trend
... Observe_Chemical_Lights_On_Phone_And_Distance_Line]
... goal: Monitor_Fore_And_Aft_Motion
... [select: Use_Replenishment_Ship's_Riggings_As_Range
... Use_Replenishment_Ship's_Bulkheads_As_Range
... Observe_Angle_Of_Phone_And_Distance_Line]
... goal: Monitor_Conning_Officer_During_Maneuver
... goal: Correct_Conning_Officer_As_Necessary
... goal: Determine_Where_Own_Ship_Will_Go_After_UNREP
... Discuss_Plans_With_Operations_Officer
... Discuss_Plans_With_Combat_Information_Center_Watch_Officer
... Discuss_Plans_With_CO
... goal: Monitor_Progress_Of_Stores_And_Fuel_Transfer
. . . . Receive_Progress_Reports_Form_UNREP_Stations

. . . . goal: Report_Progress_To_CO

. . . . . . Make_Verbal_Report_To_CO

Own ship remains stationed alongside until all lines are clear and the CO gives the
okay to breakaway. During the breakaway, it is important that the OOD know where the
ship is headed next. Usually, if own ship is in a formation with the replenishment ship as
the guide, own ship will receive a tactical command to take a new station relative to the
guide. On the other hand, if own ship meets with the replenishment ship solely for
UNREP purposes, own ship will likely be released to continue on duties assigned.

. . goal: Complete_Breakaway_Phase

. . goal: Maintain_Station_Alongside

. . goal: Determine_All_Lines_Clear

. . . [select: Visually_Verify_All_Lines_Clear

. . . . Receive_Report_All_Lines_Clear]

. . goal: Receive_Breakaway_Order_From_CO

. . . Receive_Verbal_Order_From_CO

. . . goal: Acknowledge_Receiving_Order

. . . . Verbally_Repeat_Order_Received

. . goal: Breakaway

. . . goal: Ensure_Conning_Officer_Commences_Breakaway_Maneuver

. . . . Observe_Conning_Officers_Actions

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The OOD's, as well as the Conning Officer's, primary concern during the breakaway is that own ship's stern will clear the replenishment ship's bow. The OOD should monitor the stern as the Conning Officer increases own ship's speed and gives slight, one or two degree, course changes until the stern is clear. After the stern is clear, own ship will head towards its new station, if given, or proceed on duties assigned.
C. TASK ANALYSIS OF A HELMSMAN DURING UNREP

The tasks a Helmsman must perform during an UNREP are presented below to show the teamwork involved in conducting an UNREP, specifically the ship-handling element of an UNREP. Since the Helmsman's tasks are intentionally very specific and kept to a minimum, analyzing the Helmsman was much simpler than analyzing the Conning Officer. The Helmsman's tasks are relatively easy to distinguish and are routinely repeated. An inexperienced observer could watch a Helmsman at work for a short period of time, say fifteen minutes, and make a reasonable analysis of the tasks the Helmsman must perform. The same is not true for the Conning Officer or the OOD.

The analysis was broken into three levels, first the Unit-Task Level, second the Functional Level and third the Detailed Level (Argument Level). As the analysis progresses from the Unit-Task Level to the Detailed Level, more detail is captured in each succeeding level.

1. Unit Task Level Analysis

The Unit-Task indicates that the top-level goal was to execute an UNREP. How does the Helmsman fit into this Unit-Task? Would not the Helmsman's Unit-Task be better stated as Steer_Ship? Yes, however, the primary goal of the team is to execute an UNREP and the Helmsman plays a significant role in accomplishing this task. Thus the Unit-Task remains Execute_UNREP. The Steer_Ship task appears later in the Functional Level analysis. The GOMS representation of the Unit-Task remained unchanged.
2. **Functional Level Analysis**

The Functional Level analysis showed that during all phases of an UNREP the Helmsman's goal was to steer the ship as ordered. The Functional Level GOMS notation follows:

```
goal: Execute_UNREP
  . goal: Complete_Approach_Phase
  . goal: Complete_Alongside_Phase
  . goal: Complete_Breakaway_Phase

  . . goal: Maintain_Ordered_Course
  . . goal: Turn_Ship_As_Ordered

  . . goal: Maintain_Ordered_Course
  . . goal: Turn_Ship_As_Ordered

  . goal: Complete_Breakaway_Phase
  . . goal: Maintain_Ordered_Course
  . . goal: Turn_Ship_As_Ordered
```
3. **Detailed Level Analysis**

During the Detailed Level analysis, the Steer_Ship goal was broken into its subtasks and methods. The Helmsman must accomplish the subtasks and methods detailed below to satisfactorily steer the ship.

**goal: Execute_UNREP**

The sequence of events the Helmsman performs during the approach is quite limited when compared to that of the Conning Officer. The Helmsman would likely receive numerous orders to turn the ship while the Conning Officer attempts to maintain station astern of the replenishment ship. When given a course to steer, the Helmsman is free to use the steering wheel to control the rudder in order to maintain the ordered course. Generally, there are limits placed on how much rudder the Helmsman can use without first getting permission from the Conning Officer. For example, in most cases, no more than ten degrees rudder in either direction is allowed without first requesting permission from the Conning Officer. The primary reason the Helmsman would need to use more than ten degrees rudder to maintain a course is a high sea-state. In this case, the Helmsman requests permission to use more than ten degrees rudder to maintain course. The Conning Officer would likely grant permission, and then the Helmsman would be free to use the rudder as required.

**goal: Complete_Approach_Phase**

**goal: Maintain_Ordered_Course**

...normal condition loop

**goal: Observe_Changes_In_Gyrocompass_Heading**
At some point, soon after the Conning Officer decides to commence the approach, a turn order will be verbally given to the Helmsman. The alert Helmsman would receive the order, repeat it back, and turn the wheel in the ordered direction the ordered number of degrees. The Helmsman will report to the Conning Officer when the rudder is over the ordered amount. Note that the Conning Officer should monitor the Helmsman by observing the Rudder Angle Indicator and Gyrocompass Repeater on the bridge wing. If the order included a course to steady on, the Helmsman will initially turn the rudder the ordered amount. However, as the ship approached the ordered course, the Helmsman should automatically reduce the rudder and counter steer as required to stop the swing of the ship on the ordered course without over shooting. The other scenario would be that no course was given with the initial order. For example, "Right Full Rudder" in this case the Helmsman must put the rudder over right full, do the required reports, and wait for the Conning Officer to order a course. When a course is ordered, the Helmsman would follow the same process stated previously to stop the ship on the ordered course.

   . . . goal: Turn_Ship_As_Ordered

   . . . . goal: Receive_Order_From_Conning_Officer

   . . . . . . Listen_For_Order

   . . . . . . . goal: Repeat_Order_Back_To_Conning_Officer

   . . . . . . . . . goal: Receive_Acknowledgement
For the Helmsman to quickly steady the ship on a course without zigzagging takes a great deal of experience. Essentially, the Helmsman must monitor the gyrocompass and rudder angle indicator constantly throughout the turn. The gyrocompass helps the Helmsman determine the rate at which the ship is turning, enabling the Helmsman to estimate when to decrease the rudder and/or counter steer.

... goal: Monitor_Turn

... [select: Observe_Changes_In_Gyrocompass_Heading

... Observe_Rate_Of_Ships_Turn

... Observe_Rudder_Angle_Indicator

... Observe_Feel_Of_Ship_Turn

... Observe_Horizon]

... goal: Stop_Ships_Turn_On_Ordered_Course

... Estimate_When_To_Reduce_Degree_Of_Rudder

... goal: Reduce_Rudder_To_Slow_Swing_Of_Ship

... Turn_Wheel_As_Required

... goal: Stop_The_Swing_Of_The_Ship

... Estimate_Degree_Of_Counter_Rudder_To_Stop_Swing_Of_Ship

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Since the Conning Officer is able to see the Ship's Control Console and associated alarms from the bridge wing, the Helmsman must know the immediate actions to take in the event of a steering equipment casualty. A steering equipment casualty is one of the most dangerous casualties that can occur during a UNREP. One of several events should alert the Helmsman that a steering casualty has occurred; the rudder angle indicator does not move in the direction the rudder was turned or a steering cable or motor alarm goes off. Steering casualties are discussed in detail in Chapter Four.

As previously explained, the Helmsman alerts the Conning Officer of difficulties maintaining course by requesting permission to use greater than ten degrees rudder to maintain course.
The Helmsman must be alert and standing by to receive orders at all times. All other communications with the Helmsman are minimized. However, in case of emergency, the Helmsman must maintain communications with aft steering over a phone circuit. This procedure allows aft steering to communicate with the bridge and receive rudder orders in the event of a steering casualty.

The subtasks and method associated with the Complete_Alongside_Phase as well as the Complete_Breakaway_Phase are, with few exceptions, identical to those discussed for the Complete_Approach_Phase. The only exceptions are that during the Complete_Alongside_Phase, the Helmsman must be particularly diligent when monitoring the ship's heading to ensure it does not stray off course and while trying to maintain ordered course, the Helmsman must use precise rudder control. While alongside, there is very little room for error.
D. TASK ANALYSIS OF A LEE HELMSMAN DURING UNREP

The tasks a Lee Helmsman must perform during an UNREP are presented below to show the teamwork involved in conducting an UNREP, specifically the ship-handling element of an UNREP. Since the Lee Helmsman's tasks are intentionally very specific and kept to a minimum, analyzing the Lee Helmsman was as straightforward as the analysis of the Helmsman. The Lee Helmsman's tasks are relatively easy to distinguish and routinely repeated. As with the Helmsman, an inexperienced observer could watch a Lee Helmsman at work for a short period of time and make a reasonable analysis of the tasks that must be performed.

Again, the analysis was broken into three levels, first the Unit-Task Level, second the Functional Level and third the Detailed Level (Argument Level). As the analysis progresses from the Unit-Task Level to the Detailed Level, more detail is captured in each succeeding level.

1. Unit Task Level Analysis

The Unit-Task remains unchanged to maintain the same frame of reference throughout the analysis of each team member.

  goal: Execute_UNREP

  . goal: Complete_Approach_Phase

  . goal: Complete_Alongside_Phase

  . goal: Complete_Breakaway_Phase
2. **Functional Level Analysis**

The Functional Level analysis showed that during all phases of an UNREP the Lee Helmsman's goal was to change the ship's speed as ordered. The Functional Level GOMS notation follows:

```
  goal: Execute_UNREP
    . goal: Complete_Approach_Phase
      . . goal: Maintain_Ordered_Speed
      . . goal: Change_Speed_As_Ordered

    . goal: Complete_Alongside_Phase
      . . goal: Maintain_Ordered_Speed
      . . goal: Change_Speed_As_Ordered

    . goal: Complete_Breakaway_Phase
      . . goal: Maintain_Ordered_Speed
      . . goal: Change_Speed_As_Ordered
```

3. **Detailed Level Analysis**

During the Detailed Level analysis, the Maintain_Ordered_Speed goal was broken into its subtasks and methods. The Lee Helmsman must accomplish the subtasks and methods detailed below to satisfactorily change the ship's speed.

```
  goal: Execute_UNREP
```

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The tasks required to maintain ordered speed are identical during the Complete_Approach_Phase, Complete_Alongside_Phase, and Complete_Breakaway_Phase, therefore, the detailed analysis is presented only once. As with the Helmsman, the only difference for the Lee Helmsman is that while alongside, increased attention to detail and precision is required.

The Lee Helmsman controls the ship's throttles at the Ship's Control Console during UNREP on the bridge. The Lee Helmsman must maintain control of the throttles, remain alert to receive orders, change the throttle position when ordered, and maintain communications with the Central Control Station (CCS). Throughout the UNREP the Conning Officer will likely make many speed changes. For the Lee Helmsman, the GOMS notation is straightforward.

. goal: Complete_Approach_Phase
  . . goal: Maintain_Ordered_Speed ...normal condition loop
  . . . [select: Observe_Throttle ...ensure it is not moved
  . . . Observe_RPM_Indicator
  . . . Observe_Pitch_Indicator
  . . . Observe_Speed_Indicator]
  . . goal: Change_Speed_As_Ordered
  . . . goal: Receive_Engine_Order
  . . . . . . Listen_For_Order_From_Conning_Officer
  . . . . . . goal: Repeat_Order_Back_To_Conning_Officer
goal: Change_Throttle_To_Ordered_Speed

[select: Change_Throttle_To_Match_RPM_Of_Ordered_Speed
Change_Throttle_To_Match_Pitch_Of_Ordered_Speed]

goal: Report_Pitch/RPM_Change_Complete_To_Conning_Officer

The Lee Helmsman should continuously monitor the RPM indicators for both
shafts, and the ship's speed indicator for abnormal fluctuations. Any abnormal conditions
should be immediately reported to the Conning Officer. Since the Lee Helmsman
maintains a communication circuit with CCS, it is likely that the Lee Helmsman will be
the first person on the bridge to know when an engineering casualty occurs. The Lee
Helmsman may alert the OOD that a casualty has occurred, but all such reports should be
verified by contacting the Engineering Officer of the Watch in CCS before any action is
taken.

goal: Inform_Conning_Officer_Of_Engineering_Problems

goal: Detect_Unusual_Changes_In_RPM

Observe_RPM_Indicator

Report_Problem_To_Conning_Officer

goal: Detect_Unusual_Changes_In_Pitch

Observe_Pitch_Indicator

Report_Problem_To_Conning_Officer

goal: Detect_No/Slow_Response_To_Throttle_Changes

Report_Problem_To_Conning_Officer
E. ANALYSIS OF PARALLEL TASKS DURING UNREP

One of the goals of this research was to show the parallelism between the tasks that each of the bridge watch team members must perform during an UNREP. Since bridge teams normally consist of approximately ten or more personnel, most evolutions are accomplished with teamwork. While one team member is performing task A, another member may be working on task B and task B may require task A to be completed prior to task B being completed. In other words, many tasks are executed in parallel. In an effort to capture this parallelism, several parallel programming and task analysis notations were considered, but none of them quite captured the parallel nature of the tasks. For instance, CPM GOMS was strongly considered. However, it is normally used to show the parallelism between tasks within a single person. Thus, the table below was created to capture the sequential as well as parallel aspects of the UNREP task. Sequential tasks required of each watch stander are listed by column from top to bottom. On the other hand, when the table is read by row across each watch stander, the parallelism of task execution can be easily understood. The outline numbers associated with the tasks indicate what level the task would be in CMN GOMS notation. For instance, a two-digit
(0.0) numbered task in the table would be a functional level task in CMN GOMS notation and tasks with three or more digit number are the subtasks of functional tasks.

<table>
<thead>
<tr>
<th>Time</th>
<th>Conning Officer</th>
<th>Officer Of The Deck</th>
<th>Helmsman</th>
<th>Lee Helmsman</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 – Complete Brief Phase</td>
<td>1.0 - Complete Brief Phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 – Know UNREP Plan</td>
<td>1.1 - Know UNREP Plan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2 – Know Plant Configuration</td>
<td>1.2 - Know Plant Configuration</td>
<td>1.0 - Take Helmsman Watch</td>
<td>1.0 - Take Lee Helmsman Watch</td>
<td></td>
</tr>
<tr>
<td>2.0 - Complete Approach Phase</td>
<td>2.0 - Complete Approach Phase</td>
<td>2.0 - Complete Approach Phase</td>
<td>2.0 - Complete Approach Phase</td>
<td></td>
</tr>
<tr>
<td>2.1 – Know UNREP Plan</td>
<td>2.1 - Know UNREP Plan</td>
<td>2.1 Maintain Ordered Course</td>
<td>2.1 Maintain Ordered Speed</td>
<td></td>
</tr>
<tr>
<td>2.1.1 - Know Plant Configuration</td>
<td>2.1.1 - Know Plant Configuration</td>
<td>(Loops until new order received)</td>
<td>(Loops until new order received)</td>
<td></td>
</tr>
<tr>
<td>2.1.2 - Determine Side To Approach On</td>
<td>2.1.2 - Determine Side To Approach On</td>
<td>2.1.1 - Steer To Maintain Ordered Course</td>
<td>2.2 – Maintain Communications (Periodic Task)</td>
<td></td>
</tr>
<tr>
<td>2.1.3 - Go To Appropriate Bridge Wing</td>
<td>2.2 - Supervise Bridge Watch Team</td>
<td>2.2 Maintain Communications (Periodic Task)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2 – Maintain Communications (Periodic Task)</td>
<td>2.2.1 - Ensure Bridge Manned &amp; Ready</td>
<td>2.2.1.1 - Correct Discrepancies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3 – Maintain Awareness Of Third Party Ships (Periodic Task)</td>
<td>2.2.2 - Ensure All Communications Equipment Operational</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Parallel Task Table for UNREP Watch Team
<table>
<thead>
<tr>
<th>Time</th>
<th>Conning Officer</th>
<th>Officer Of The Deck</th>
<th>Helmsman</th>
<th>Lee Helmsman</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:05</td>
<td>2.4 – Maintain Station (Loops until approach starts)</td>
<td>2.2.3 - Ensure All Bridge Equipment Setup and Operational</td>
<td>2.2.4 - Ensure All Bridge Watch Standers Remain Alert (Periodic Task)</td>
<td>2.3 - Maintain Communications (Periodic Task)</td>
</tr>
<tr>
<td></td>
<td>2.4.1 - Shoot Bearings To Replenishment Ship</td>
<td>2.4 - Ensure Own Ship Ready To Go Alongside</td>
<td>2.5 - Maintain Awareness Of Third Party Ships (Periodic Task)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.4.2 - Get Range To Replenishment Ship</td>
<td>2.4.3 - Determine If On Station</td>
<td>2.6 – Ensure Conning Officer Maintains Station</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.4.3 – Determine If Range To Replenishment Ship Correct</td>
<td>2.4.3.1 – Determine If Range To Replenishment Ship Correct</td>
<td>2.4.3.2 – Determine If Bearing To Replenishment Ship Correct</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.4.4 - Make Necessary Corrections (Assume On Station, No Corrections Required)</td>
<td>2.4.4 - Make Necessary Corrections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:10</td>
<td>2.5 – Receive Report Own Ship Ready To Go Alongside</td>
<td>2.4.1 – Inform CO Ship Is Manned And Ready To Go Alongside</td>
<td>2.5.1 – Acknowledge Receiving Report</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5.1 – Acknowledge Receiving Report</td>
<td>2.5 – Receive Report Own Ship Ready To Go Alongside</td>
<td>2.3 – Maintain Awareness Of Third Party Ships (Periodic Task)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5.2 – Order ROMEO Close-up On The Side That Will Go Alongside (OOD may do this)</td>
<td>2.5.2 – Order ROMEO Close-up On The Side That Will Go Alongside</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:15</td>
<td>2.6 – Make Approach</td>
<td>2.6 – Supervise Make Approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.6.1 - Observe ROMEO Close-up On Replenishment Ship</td>
<td>2.6.1 - Observe ROMEO Close-up On Replenishment Ship</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.6.2 – Receive Approach Order From CO</td>
<td>2.6.2 Order Conning Officer To Commence Approach (From CO)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Parallel Task Table for UNREP Watch Team (Continued)
<table>
<thead>
<tr>
<th>Time</th>
<th>Conning Officer</th>
<th>Officer Of The Deck</th>
<th>Helmsman</th>
<th>Lee Helmsman</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.6.2.1</td>
<td>Acknowledge Receiving Order</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.3</td>
<td>Change Speed Of Ship</td>
<td>2.6.3 - Monitor Conning Officer During Maneuver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.3.1</td>
<td>Issue Engine Order</td>
<td>2.6.3.1 - Correct Conning Officer As Necessary</td>
<td>2.3</td>
<td>Change Speed As Ordered</td>
</tr>
<tr>
<td>2.6.3.1.1</td>
<td>Increase Speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.3.1.1.1</td>
<td>Determine Desired Speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.3.1.1.2</td>
<td>Give Verbal Order To Lee Helm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.3.2</td>
<td>Receive Repeat-back (Lee Helm)</td>
<td></td>
<td></td>
<td>2.3.2</td>
</tr>
<tr>
<td>2.6.3.2.1</td>
<td>Acknowledge Repeat-back (Lee Helm)</td>
<td></td>
<td>2.3.3</td>
<td>Change Throttle To Match RPM of Ordered Speed</td>
</tr>
<tr>
<td>2.6.4</td>
<td>Turn Ship</td>
<td>2.3</td>
<td>Turn Ship As Ordered</td>
<td></td>
</tr>
<tr>
<td>2.6.4.1</td>
<td>Visually Verify Direction Clear</td>
<td></td>
<td>2.3.1</td>
<td>Receive Order From Conning Officer</td>
</tr>
<tr>
<td>2.6.4.2</td>
<td>Issue Rudder Order</td>
<td>2.3.1.1</td>
<td>Receive Acknowledgement</td>
<td></td>
</tr>
<tr>
<td>2.6.4.2.1</td>
<td>Starboard Turn</td>
<td>2.3.1.1.1</td>
<td>Receive Acknowledgement</td>
<td></td>
</tr>
<tr>
<td>00:20</td>
<td>2.6.4.2.1.1</td>
<td>Determine How Far To Turn</td>
<td>2.3</td>
<td>Turn Ship As Ordered</td>
</tr>
<tr>
<td></td>
<td>2.6.4.2.1.2</td>
<td>Determine Degree Of Rudder To Use</td>
<td>2.3.1</td>
<td>Receive Order From Conning Officer</td>
</tr>
<tr>
<td></td>
<td>2.6.4.2.1.3</td>
<td>Give Verbal Order To Helm</td>
<td>2.3.2</td>
<td>Turn The Wheel</td>
</tr>
<tr>
<td></td>
<td>2.6.4.3</td>
<td>Receive Repeat-back (Helm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.6.4.3.1</td>
<td>Acknowledge Repeat-back (Helm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.3.1.1.1</td>
<td>Receive Acknowledgement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Parallel Task Table for UNREP Watch Team (Continued)
<table>
<thead>
<tr>
<th>Time</th>
<th>Conning Officer</th>
<th>Officer Of The Deck</th>
<th>Helmsman</th>
<th>Lee Helmsman</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5.3.3 – Determine If Order Was Executed (Engine)</td>
<td>2.6.4 - Determine Range To Replenishment Ship</td>
<td>2.6.5 – Determine Range Closing/Opening Rate</td>
<td>2.3.3.1.1 - Report Pitch/RPM Change To Conning Officer</td>
<td>2.3.3.1.1.1 - Receive Acknowledgement</td>
</tr>
<tr>
<td>2.5.3.4 – Receive Report Order Was Executed (Lee Helm)</td>
<td>2.6.4.4 - Determine If Order Was Executed (Turn)</td>
<td>2.5 - Maintain Awareness Of third Party Ships (Periodic Task)</td>
<td>2.6.6 - Monitor Ship's Turn On Ordered Course</td>
<td>2.2 - Maintain Communications (Periodic Task)</td>
</tr>
<tr>
<td>2.5.3.4.1 – Acknowledge Report (Lee Helm)</td>
<td>2.6.6.1 - Shoot Bearing To Replenishment Ship</td>
<td>2.3.1.2 - Report That The Wheel Is Over To The Conning Officer</td>
<td></td>
<td>2.3.1.2.1 - Receive Acknowledgement</td>
</tr>
<tr>
<td>2.6.4.4 – Determine If Order Was Executed (Turn)</td>
<td>2.6.6 - Monitor Helmsman</td>
<td>2.3.3.1 - Reduce Degree Of Rudder To Slow Swing Of Ship</td>
<td>2.3.3.1.1 - Report Steady On Ordered Course To Conning Officer</td>
<td></td>
</tr>
<tr>
<td>2.6.4.5 – Receive Report That Order Was Executed (Helm)</td>
<td>2.6.6 - Monitor Helmsman</td>
<td>2.3.3.2 - Stop The Swing Of The Ship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.4.5.1 – Acknowledge Report (Helm)</td>
<td>2.6.6.1 - Shoot Bearing To Replenishment Ship</td>
<td>2.3.3.2.1 - Counter Steer To Stop Swing Of The Ship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.5 – Monitor Ship's Turn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.6 - Monitor Helmsman</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.6.1 – Shoot Bearing To Replenishment Ship</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3 – Maintain Awareness Of third Party Ships (Periodic Task)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3.1.2 - Report That The Wheel Is Over To The Conning Officer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3.3.1 - Reduce Degree Of Rudder To Slow Swing Of Ship</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3.3.2 - Stop The Swing Of The Ship</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3.3.2.1 - Counter Steer To Stop Swing Of The Ship</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3.3.3 – Report Steady On Ordered Course To Conning Officer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Parallel Task Table for UNREP Watch Team (Continued)
<table>
<thead>
<tr>
<th>Time</th>
<th>Conning Officer</th>
<th>Officer Of The Deck</th>
<th>Helmsman</th>
<th>Lee Helmsman</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.6.7.1 - Acknowledge Report (Helm)</td>
<td></td>
<td></td>
<td>2.3.3.3.1 - Receive Acknowledgement</td>
<td></td>
</tr>
<tr>
<td>2.6.8 - Make Necessary Corrections (Assume Lateral Separation Must be Increased)</td>
<td></td>
<td></td>
<td>2.4 - Maintain Ordered Course (Loops until new order received)</td>
<td></td>
</tr>
<tr>
<td>2.6.9 - Turn Ship</td>
<td></td>
<td></td>
<td>2.4.1 - Steer To Maintain Ordered Course 2.2 - Maintain Communications (Periodic Task)</td>
<td></td>
</tr>
<tr>
<td>2.6.9.1 - Visually Verify Direction Clear</td>
<td>2.6.7 - Monitor Conning Officer During Maneuver</td>
<td></td>
<td>2.5 - Turn Ship As Ordered 2.5.1 - Receive Order From Conning Officer</td>
<td></td>
</tr>
<tr>
<td>2.6.9.2 - Issue Rudder Order</td>
<td></td>
<td></td>
<td>2.5.2 - Turn The Wheel</td>
<td></td>
</tr>
<tr>
<td>2.6.9.2.1 - Starboard Turn</td>
<td></td>
<td></td>
<td>2.6.9.3 - Receive Repeat-back (Helm)</td>
<td></td>
</tr>
<tr>
<td>2.6.9.2.1.1 - Determine How Far To Turn 2.6.9.2.1.2 - Determine Degree Of Rudder To Use 2.6.9.2.2 - Give Verbal Order To Helm</td>
<td></td>
<td></td>
<td>2.5 - Maintain Awareness Of third Party Ships (Periodic Task)</td>
<td></td>
</tr>
<tr>
<td>2.6.9.3.1 - Acknowledge Repeat-back (Helm)</td>
<td></td>
<td></td>
<td>2.5.1.1 - Repeat Order Back To Conning Officer 2.5.2 - Turn The Wheel</td>
<td></td>
</tr>
<tr>
<td>2.6.9.4 - Determine If Order Was Executed (Turn)</td>
<td></td>
<td></td>
<td>2.5.1.2 - Report That The Wheel Is Over To The Conning Officer</td>
<td></td>
</tr>
<tr>
<td>2.6.9.5 - Receive Report That Order Was Executed (Helm)</td>
<td></td>
<td></td>
<td>2.5.1.2.1 - Receive Acknowledgement</td>
<td></td>
</tr>
<tr>
<td>2.6.9.5.1 - Acknowledge Report (Helm)</td>
<td></td>
<td></td>
<td>2.5.2 - Monitor Turn 2.5.3 - Stop Ship's Turn On Ordered Course</td>
<td></td>
</tr>
<tr>
<td>2.6.10 - Monitor Ship's Turn</td>
<td>2.6.8 - Monitor Ship's Turn</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Parallel Task Table for UNREP Watch Team (Continued)
<table>
<thead>
<tr>
<th>Time</th>
<th>Conning Officer</th>
<th>Officer Of The Deck</th>
<th>Helmsman</th>
<th>Lee Helmsman</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.6.10.1 – Monitor Helmsman</td>
<td>2.6.9 - Monitor The Conning Officer 2.6.9.1 - Correct Conning Officer As Necessary</td>
<td>2.5.3.1 - Reduce Degree Of Rudder To Slow Swing Of Ship 2.5.3.2 - Stop The Swing Of The Ship 2.5.3.2.1 - Counter Steer To Stop Swing Of The Ship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.11 - Make Necessary Corrections (Assume No Corrections Required)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.12 – Receive Steady On Course Report</td>
<td></td>
<td>2.5.3.3 – Report Steady On Ordered Course To Conning Officer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.12.1– Acknowledge Receiving Report</td>
<td></td>
<td>2.5.3.4 – Receive Acknowledgement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.13 – Get Range To Replenishment Ship</td>
<td></td>
<td>2.6 Maintain Ordered Course (Loops until new order received)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.13.1 – Determine Range Opening/Closing Rate</td>
<td></td>
<td>2.6.1 - Steer To Maintain Ordered Course 2.2 – Maintain Communications (Periodic Task)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.14 - Shoot Bearing To Replenishment Ship</td>
<td>2.5 – Maintain Awareness Of third Party Ships (Periodic Task)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.15 – Determine If Lateral Separation Closing/Opening</td>
<td>2.6.10 – Determine If Lateral Separation Closing/Opening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.16 – Determine If Lateral Separation Too Close/Far</td>
<td>2.6.11 – Determine If Lateral Separation Too Close/Far</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.16.1 - Make Necessary Corrections (Assume No Corrections Required)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.17 - Determine If Lateral Separation Is Safe To Go Alongside</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 2: Parallel Task Table for UNREP Watch Team (Continued)
<table>
<thead>
<tr>
<th>Time</th>
<th>Conning Officer</th>
<th>Officer Of The Deck</th>
<th>Helmsman</th>
<th>Lee Helmsman</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.6.17.1 - Make Necessary Corrections <em>(Assume No Corrections Required)</em></td>
<td>2.6.12 - Monitor Bow As It Approaches Replenishment Ship's Stern</td>
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<td>2.6.18 - Monitor Bow As It Approaches Replenishment Ship's Stern</td>
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<tr>
<td>00:25</td>
<td>3.0 - Complete Alongside Phase</td>
<td>3.0 - Complete Alongside Phase</td>
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<tr>
<td>3.1 - Determine When Bow Crosses Stern</td>
<td>3.1 - Determine When Bow Crosses Stern</td>
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<td>3.2 - Watch For Bow To Be Pushed Away From Replenishment Ship</td>
<td>3.2 - Supervise Bridge Watch Team</td>
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<td>3.2.1 - Ensure All Personnel Are Alert</td>
<td>3.2.2 - Maintain Quiet Bridge</td>
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<tr>
<td>3.3 - Monitor Venturi Effect Alongside Replenishment Ship</td>
<td>3.3 - Monitor Venturi Effect Alongside Replenishment Ship</td>
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<td>3.3.1 - Monitor Lateral Separation</td>
<td>3.3.1 - Monitor Lateral Separation</td>
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<td>3.3.1.1 - Make Necessary Corrections <em>(Assume Too Close)</em></td>
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<td>3.3.1.1.1 - Turn Ship</td>
<td>3.4 - Supervise Conning Officer While Alongside Replenishment Ship</td>
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<td>3.3.1.1.1.1 - Issue Rudder Order</td>
<td>3.4.1 - Monitor Conning Officer During Maneuver</td>
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<td>3.3.1.1.1.1 - Starboard Turn</td>
<td>3.4.1.2 - Correct Conning Officer As Necessary</td>
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<td>3.3.1.1.1.1.1 - Determine How Far To Turn</td>
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<td>3.3.1.1.1.1.2 - Determine Degree Of Rudder To Use</td>
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<td>3.3.1.1.1.1.3 - Give Verbal Order To Helm</td>
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<tr>
<td>2.7 - Turn Ship As Ordered</td>
<td>2.7.1 -Receive Order From Conning Officer</td>
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<th>Officer Of The Deck</th>
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<th>Lee Helmsman</th>
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<tbody>
<tr>
<td>3.3.1.2 – Receive Repeat Back (Helm)</td>
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<td>2.7.1.1 - Repeat Order Back To Conning Officer</td>
<td>2.7.2 - Turn The Wheel</td>
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<td>3.3.1.2.1 – Acknowledge Repeat-back</td>
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<td>2.7.1.2 - Report That The Wheel Is Over To The Conning Officer</td>
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<td>3.3.1.4 – Receive Report That Order Was Executed (Helm)</td>
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<td>3.3.1.4.1 – Acknowledge Report</td>
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<td>3.3.1.2 – Monitor Ship's Turn</td>
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<td>2.7.1.3 - Report Steady On Ordered Course To Conning Officer</td>
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<td>3.3.1.2.1 – Monitor Helmsman</td>
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<td>3.3.1.3 - Receive Steady On Course Report</td>
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<td>3.5 – Determine Range To Station Closing Rate</td>
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<td>3.3.1.3.1 - Acknowledge Report</td>
<td>3.5.1 – Determine Range To Station</td>
<td>2.8 Maintain Ordered Course (Loops until new order received)</td>
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<td>3.4 – Determine Lateral Separation</td>
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<td>2.8.1 - Steer To Maintain Ordered Course</td>
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<td>3.4.1 - Make Necessary Corrections (Assume No Corrections Required)</td>
<td>3.6 - Monitor Conning Officer</td>
<td>2.2 - Maintain Communications (Periodic Task)</td>
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<td>3.6.1 - During Maneuver Correct Conning Officer As Necessary</td>
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<td>3.5 – Determine Range To Station Closing Rate</td>
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<td>3.5.1 – Determine Range To Station</td>
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<td>3.5.2 - Make Necessary Corrections (Assume No Corrections Required)</td>
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<th>Helmsman</th>
<th>Lee Helmsman</th>
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<tbody>
<tr>
<td>00:27</td>
<td>3.6 - Determine When To Match Speeds</td>
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<tr>
<td></td>
<td>3.6.1 - Change Speed Of Ship</td>
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<td></td>
<td>3.6.1.1 - Issue Engine Order</td>
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<td>3.6.1.1.2 - Give Verbal Order To Lee Helm</td>
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<td>3.6.1.2 Receive Repeat-back From Lee Helm</td>
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<td>3.6.1.3 - Determine If Order Was Executed</td>
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<td>3.6.1.4 - Receive Report That Order Was Executed</td>
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<td>3.6.1.4.1 - Acknowledge Report (Lee Helm)</td>
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<td>3.7 - Maneuver Close To Station Alongside</td>
<td>3.8 - Maneuver Close To Station Alongside</td>
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<td>3.7.1 - Monitor Ship's Heading On Gyrocompass</td>
<td>3.8.1 - Monitor Ship's Heading On Gyrocompass</td>
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<td>3.7.3 - Monitor Fore And Aft Motion</td>
<td>3.8.3 - Monitor Fore And Aft Motion</td>
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<td></td>
<td>3.7.4 - Make Necessary Corrections (Assume On Station, No Corrections Required)</td>
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Table 2: Parallel Task Table for UNREP Watch Team (Continued)
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<tr>
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<th>Lee Helmsman</th>
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<tbody>
<tr>
<td>00:35</td>
<td>3.8 – Get Phone And Distance Line Across</td>
<td>3.9 – Get Phone And Distance Line Across</td>
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<td>3.9 – Maintain Station Alongside (LOOP until Breakaway)</td>
<td>3.10 – Maintain Station Alongside (LOOP until Breakaway)</td>
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<td>3.9.1 – Monitor Lateral Separation</td>
<td>3.10.1 – Monitor Lateral Separation</td>
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<td>3.9.2 – Monitor Fore And Aft Motion</td>
<td>3.10.2 – Monitor Fore And Aft Motion</td>
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<td>Tension lines</td>
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<td>3.9.3 – Make Necessary Corrections (Assume Too Far &amp; Falling Back)</td>
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<tr>
<td></td>
<td>3.9.3.1 - Turn Ship</td>
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<td>3.9.3.1.1 - Issue Rudder Order</td>
<td>3.10.3 - Monitor Progress Of Stores And Fuel Transfer</td>
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<td>3.10.4 - Monitor Conning Officer During Maneuver</td>
<td>2.9 – Turn Ship As Ordered</td>
<td>2.9.1 - Receive Order From Conning Officer</td>
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<td>3.9.3.2.1 – Issue Engine Order</td>
<td>2.5 – Maintain Awareness Of third Party Ships (Periodic Task)</td>
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<td>3.9.3.2.1.1 – Increase Speed</td>
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<td>3.9.3.2.1.1.1 – Determine Desired Speed</td>
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<tr>
<td>3.9.3.2.1.2 - Give Verbal Order To Lee Helm</td>
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<td>3.4.1 - Change Speed As Ordered 3.4.2 - Receive Engine Order</td>
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<tr>
<td>3.9.3.2.2 - Receive Repeat-back (Lee Helm)</td>
<td>3.10.5 - Determine Where Own Ship Will Go After UNREP</td>
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<td>3.4.3 - Repeat Order Back To Conning Officer</td>
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<td>3.4.4 - Change Throttle To Match RPM of Ordered Speed</td>
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<td>3.9.3.2.2.1 - Acknowledge Report (Lee Helm)</td>
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<td>3.4.4.1 - Receive Acknowledgement</td>
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<td>2.9.1.2 - Report That The Wheel Is Over To The Conning Officer</td>
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<tr>
<td>3.9.2.2.1 - Acknowledge Report (Helm)</td>
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<td>3.9.3.3 - Determine If Order Was Executed (Lee Helm)</td>
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<tr>
<td>3.9.2.3 - Monitor Ship's Turn</td>
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<td>3.9.2.4 - Monitor Helmsman</td>
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<tr>
<td>3.9.3.3.1 - Receive Report That Order Was Executed (Lee Helm)</td>
<td>3.10.6 - Monitor Bridge Watch Team</td>
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<td>3.4.4.2 - Report Pitch/RPM Change To Conning Officer</td>
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<tr>
<td>3.9.2.5 - Receive Steady On Course Report (Helm)</td>
<td>2.9.1.3 - Report Steady On Course To Conning Officer</td>
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<td>00:40 3.9.2.6 - Acknowledge Report (Helm) (Loop To Maintain Station)</td>
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<td>2.9.1.3.1 - Receive Acknowledgement</td>
<td>3.5 - Maintain Ordered Speed (Loops until new order received) 2.2 – Maintain Communications (Periodic Task)</td>
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<tbody>
<tr>
<td>02:30</td>
<td>4.0 - Complete Breakaway Phase</td>
<td>4.0 - Complete Breakaway Phase</td>
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<td>2.3 - Maintain Awareness Of Third Party Ships (Periodic Task)</td>
<td>2.5 - Maintain Awareness Of third Party Ships (Periodic Task)</td>
<td>2.10.1 - Steer To Maintain Ordered Course</td>
<td>2.2 - Maintain Communications (Periodic Task)</td>
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<td></td>
<td>4.1 - Maintain Station Alongside (LOOP)</td>
<td>4.1 - Maintain Station Alongside (LOOP)</td>
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<td>4.1.1 - Monitor Lateral Separation</td>
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<td>4.2 - De-tension Lines</td>
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<td>4.3 - Determine All Lines Clear</td>
<td>4.2 - Determine All Lines Clear</td>
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<td>2.2 - Maintain Communications (Periodic Task)</td>
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<td>4.4 - Receive Breakaway Order From CO</td>
<td>4.3 - Receive Breakaway Order From CO</td>
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<td>4.4 - Breakaway</td>
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<td>2.2 - Maintain Communications (Periodic Task)</td>
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<td>4.5.1.1 - Issue Engine Order</td>
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<td>4.5.1.3.1 - Acknowledge Report (Lee Helm)</td>
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<td>4.5.2 - Turn Ship</td>
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<td>4.5.2.1 – Visually Verify Direction Of Turn Clear</td>
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<td>4.5.2.2.2 – Give Verbal Order To Helm</td>
<td>4.4.1 - Monitor Conning Officer During Maneuver 4.4.1.1 - Correct Conning Officer As Necessary</td>
<td>2.11 – Turn Ship As Ordered 2.11.1 - Receive Order From Conning Officer</td>
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<td>4.5.2.3 – Receive Repeat-back From Helm</td>
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<td>2.2.1.1 - Repeat Order Back To Conning Officer 2.11.2 - Turn The Wheel</td>
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</tr>
<tr>
<td>4.5.2.3.1 - Acknowledge Report (Helm)</td>
<td></td>
<td></td>
<td>2.11.2 - Receive Acknowledgement</td>
<td></td>
</tr>
<tr>
<td>4.6.1 - Monitor Ship’s Turn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5.1.4 – Determine If Order Was Executed (Engine)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5.2.4 - Determine If Order Was Executed (Turn)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.6.2 – Monitor Helmsman</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5.1.5 - Receive Report That Order Was Executed (Lee Helm)</td>
<td></td>
<td></td>
<td>4.1.3 - Report Pitch/RPM Change To Conning Officer</td>
<td></td>
</tr>
<tr>
<td>4.5.1.5.1 – Acknowledge Report (Lee Helm)</td>
<td></td>
<td></td>
<td>4.1.3.1 - Receive Acknowledgement</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Parallel Task Table for UNREP Watch Team (Continued)
## Parallel Task Table

<table>
<thead>
<tr>
<th>Time</th>
<th>Conning Officer</th>
<th>Officer Of The Deck</th>
<th>Helmsman</th>
<th>Lee Helmsman</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5.2.5 - Receive Report That Order Was Executed (Helm)</td>
<td></td>
<td>2.11.1.2 - Report That The Wheel Is Over To The Conning Officer</td>
<td>4.2 - Maintain Ordered Speed (Loops until new order received)</td>
<td></td>
</tr>
<tr>
<td>4.5.2.5.1 - Acknowledge Report (Helm)</td>
<td></td>
<td>2.11.1.2.1 - Receive Acknowledgement</td>
<td>2.2 - Maintain Communications (Periodic Task)</td>
<td></td>
</tr>
<tr>
<td>4.5.3 – Make Necessary Corrections (Assume No Corrections Required)</td>
<td>4.4.2 - Monitor Conning Officer During Maneuver</td>
<td>4.4.2.1 - Correct Conning Officer As Necessary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.7 – Determine Stern Is Clear</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8 – Turn Ship</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.1 – Visually Verify Direction Of Turn Clear</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.2 – Issue Rudder Order</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.2.1 – Starboard Turn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.2.1.1 – Determine How Far To Turn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.2.1.2 – Determine Degree Of Rudder To Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.2.2 – Give Verbal Order To Helm</td>
<td>2.5 – Maintain Awareness Of third Party Ships (Periodic Task)</td>
<td>2.12 – Turn Ship As Ordered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.2.2.1 - Acknowledge Report (Helm)</td>
<td>2.12.3 - Receive Acknowledgement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.2.2.1.1 - Receive Repeat-back From Helm</td>
<td>2.12.1.1 - Repeat Order Back To Conning Officer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.2.3 – Determine If Order Was Executed (Turn)</td>
<td>2.12.2 - Turn The Wheel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8.2.4 – Receive Report That Order Was Executed (Helm)</td>
<td></td>
<td>2.12.1.2 - Report That The Wheel Is Over To The Conning Officer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Parallel Task Table for UNREP Watch Team (Continued)
Table 2: Parallel Task Table for UNREP Watch Team (Continued)

F. VALIDATION OF THE TASK ANALYSIS

With the task analysis completed, the remaining goal of the thesis was to have the task analysis validated by experienced ship-handlers. This goal was accomplished by having five SWOs of various experience levels individually review the task analysis for accuracy and completeness. Each participant signed an agreement to participate in the validation anonymously. Participants were asked to read a one page brief on the notations used to describe the tasks, followed by a list of goals that would be accomplished during the review. These goals were as follows:

- Identify any discrepancies in the Conning Officer GOMS-like sequential UNREP task analysis.
• Identify any missing goals, tasks and/or methods a Conning Officer is required to perform during an UNREP.

• Identify any missing visual or audible cues that a Conning Officer may use to recognize or monitor progress during an UNREP.

Participants were also given a copy of the same assumptions for the UNREP scenario as were listed previously in this chapter on page 49. Each review was scenario based and was conducted in a format similar to a SWO board. The researcher verbally built a scenario while reading through the task analysis notation and participants followed along with their own copy of the analysis. This method was determined to be the most expedient way to review the large volume of information. At any time during the scenario that a reviewer thought a task was missing or out of place, they stopped the researcher and expressed their concern. The researcher recorded the discrepancy and then continued building the scenario. The review process took approximately an hour per session.

The following is a brief profile of the naval personnel who reviewed the task analysis. All were qualified Surface Warfare Officers. One was a post Commanding Officer, two were post Executive Officers, one post Department Head and one post Division Officer. There were two Commanders, one Lieutenant Commander and two Lieutenants. The two Commanders are currently Curriculum Officers at the Naval Postgraduate School, while the others are non-computer science graduate students.

The validation reviews proved to be very useful and resulted in several revisions to the task analysis. The most significant correction was the addition of the goal:
Inform Helmsman Before Lines Are Tensioned. This was a very important addition since failing to accomplish this goal could result in a collision. Other corrections were relatively minor in comparison. All corrections were made and the task analysis is an accurate and complete representation of the tasks performed by a bridge watch team in general and specifically the Conning Officer during an UNREP.
VI. CONCLUSIONS

A. SUMMARY OF WORK

Training ship-handlers is a long, costly and difficult task. The simulators available today are costly and available to only a relatively few ship drivers. The Surface Warfare Officers School (SWOS) has recognized the tremendous capabilities of VE technology and is pushing the envelope in an effort to train Surface Warriors better, faster and cheaper. Researchers at the Naval Air Warfare Center Training Systems Division (NAWC TSD) have developed a test-bed called the Conning Officers Virtual Environment (COVE). COVE currently provides only a limited Underway Replenishment (UNREP) scenario. The purpose of this thesis was to provide a cognitive task analysis to ensure that the UNREP scenario developed for the actual simulator delivered to SWOS is based on the tasks that a Conning Officer must be able to perform during a real world UNREP. As the COVE project advances to the next level of development, the need to keep experienced ship-handlers in the development loop is essential. The research for this thesis was done and reviewed by experienced ship-handlers.

At the request of researchers at the NAWC TSD, a cognitive task analysis of a Conning Officer during an UNREP was constructed. After a thorough literature review and preliminary task analysis, the UNREP task was determined to consist of sequential as well as parallel tasks. This implies that not only does the Conning Officer perform
sequential and parallel tasks, but he also performs tasks in parallel to tasks that other
bridge watch standers perform. In some cases, there are even tasks that are executed in
sequence with other watch stader tasks.

Various notations and methodologies were considered before the CMN GOMS
notation was chosen. CMN GOMS is a serial notation and was easily modified to capture
the tasks that make up UNREP. The first step was to determine what tasks a Conning
Officer must accomplish to drive a ship during an UNREP. Once this was done, the tasks
were named and sorted into levels of analysis, i.e. Unit-Level, Functional-Level and
Detailed-Level. Tasks performed in parallel with tasks executed by other watch standers
were also documented. Next, the tasks each watch stader performed were placed in a
CMN GOMS-like notation, the difference being that true CMN GOMS notation is
sequential. As it is used here, it is intended to allow tasks to repeat periodically, as well as
to allow task sequences to loop for long periods of time. These modifications were
necessary for two reasons; first, there are many ways to do a UNREP, and second,
UNREP is a very long task, often lasting for over three hours. Thus, during a particular
phase of an UNREP, the same sequence of tasks may loop several times while other tasks
may occur periodically during periods when the Conning Officer's task load is low.

After all tasks were placed into the CMN GOMS-like notation, a table that
illustrates a typical UNREP was constructed, with watch standers' sequential tasks in
columns and parallel tasks in rows. This allows the reader to read down the Conning
Officer column and understand a typical sequence of tasks a Conning Officer must
perform. To get a snapshot of the possible parallel tasks taking place, the reader can read across a row.

Finally, in an effort to do quality assurance and to validate the task analysis, the analysis was presented to five Surface Warfare Officers of various ranks and experience. They were instructed to review the task analysis paying particular attention to identifying missing cues and tasks as well as the sequence in which the tasks occur. The information gathered during the validation interviews was used to update the CMN GOMS-like analysis and parallel task table. This validation process ensured that multiple experienced ship-handlers had reviewed the task analysis and that the analysis would be as complete and accurate as possible.

The result of the research was a validated sequential and parallel task analysis of the primary members of a bridge watch team during an UNREP. However, the analysis focused on the tasks executed by the Conning Officer during an UNREP. The other watch stander tasks were included to show the interaction between the Conning Officer and other watch standers that must be modeled to some degree in the VE scenario.

B. THESIS QUESTIONS

The following questions were addressed in this thesis:

- What specific tasks are required of a Conning Officer during UNREP?

The use of the CMN GOMS task analysis notation to document the tasks required of a Conning Officer proved to be very successful. The CMN GOMS
notation highlighted the most significant tasks while still capturing the subtasks, methods and cues required to accomplish the tasks. This question was addressed in greater detail in chapter 5.

- **What are the cues used for ship handling during an UNREP?**

  The CMN GOMS notation can be expanded to capture various granularities of detail related to a given task. In this analysis, the method used to accomplish a given task details the cues necessary to accomplish the task. This question was addressed in detail in chapter 5.

- **What is a suitable level of analysis and associated methodology required to conduct a task analysis of a ship-handling task?**

  The CMN GOMS notation provides a suitable level of detail for conducting a cognitive task analysis of a single watch stander for virtual environment scenario development. However, most shipboard tasks take a significant amount of time and are accomplished by teamwork. This aspect is not easily captured with CPM GOMS notation or any other notation found during the literature review for this thesis.
C. RECOMMENDATIONS FOR FUTURE WORK

1. Future Scenarios

The following is a list of future scenarios that would provide beneficial training experiences for Conning Officers:

- Rules of the Road tutorial
- Maneuvering in restricted waters (shallow underwater obstacles)
- Maneuvering in shallow vs. deep water (different ship-handling characteristics)
- Maneuvering through a heavy traffic environment (an armada of fishing vessels)
- Flight quarters maneuvering
- Minefield maneuvering
- Harbor navigation (good daytime visibility, low visibility, nighttime)
- Plane guard (stationed 1000 yards behind an Aircraft Carrier)
- Division tactics (formation steaming with one or more additional ships)
- Anchoring
- Station keeping (maneuvering in a various screen formations)
- Man overboard maneuvers (all different patterns)
- Night time contact light configuration (opening, closing, crossing)
- Approaching a pier (with or without tugs)
- Casualty control (loss of a shaft, loss of steering)
Collision avoidance and recovery

Each scenario should be able to implement one or more of the following variables: location (Blue water/Brown water), time of day (light/dark), wind (direction/speed), current (direction/speed), ship's speed and engine configuration, visibility (fog/rain), sea state, trailing a towed array, depth of water and the number of contacts around own ship. Since most critical ship-handling situations take time to develop, the key to avoiding problems at sea is to recognize a possible problem early, take appropriate action early, and monitor the result to ensure the action taken corrected the problem. For example, if the Conning Officer recognizes that a contact on the horizon will pass own ship at an unacceptable range, the Conning Officer can make a slight course change early to avoid this situation. However, if the Conning Officer waits until the contact is ten thousand yards away, a significant course and speed change will be required to avoid the contact. This illustrates that scenarios must be scripted to develop over time and provide the user with the same cues that are used to make decisions at sea. Another variable that exists is the personnel, since some personnel may play major rolls in one scenario and have a relatively insignificant roll in another. For instance, in most restricted waters such as a harbor, a pilot will come onboard and in some cases the pilot may not be up to standards or a language barrier may exist. Since the ship's CO is ultimately responsible for the ship, when this situation occurs the CO, Navigator and Conning Officer will have to work harder to insure the safety of the ship.
Implementing the variables discussed above will allow the instructor to customize each scenario run for a specific level student. Although it appears that COVE is currently being targeted at the intermediate ship-handlers at SWOS Department Head School, it is believed that this tool will have a significant impact in training Division Officer Course students as well. Inexperienced ship-handlers could be given relatively simple Rules of the Road scenarios, while intermediate ship drivers could practice casualty control scenarios and the advanced ship drivers could do emergency collision avoidance and recovery scenarios. Currently a means to practice collision avoidance and recovery does not exist. This simulator should allow collisions to occur, so that personnel can learn from their mistakes and determine which emergency maneuvers work best in a given situation, as well as develop know emergency techniques. Emergency scenarios could be replayed so that case studies can be used to evaluate the officers actions to determine what works or doesn't work. This capability alone would be a major advancement in training capability.

2. Virtual CO

The Virtual CO would be a mechanism that acts like a real CO, i.e. an intelligent tutor. It would coach the Conning Officer during training exercises and it would establish and monitor ship-handling performance measures during scenarios. The Conning Officer would drive a ship in a VE scenario and the Virtual CO program would monitor the Conning Officer's performance. If the Conning Officer were to exceed some performance
criteria the Virtual CO would indicate to the Conning Officer what had been done wrong and how to correct the situation.

3. Naval Postgraduate School (NPS) Experiments

During discussions between NPS researchers and researcher from NAWC TSD, it was recognized that NPS offers a unique environment for ship-handling simulator development and testing. Two primary advantages were noted: (1) Most Surface Warfare Officers at NPS will attend SWOS Department Head School immediately following graduation, (2) NPS has domain area experts (SWOs) who have the opportunity to dedicate a year or more to research relevant to the development of a ship-handling simulator. These are largely untapped resources.

D. HOW TO USE THE TASK ANALYSIS

This task analysis should be used as a guide for COVE scenario developers and programmers. It provides an outline of the tasks that must be modeled or accounted for in the final COVE UNREP scenario. Additionally, the thesis lists many variables that should be able to be modified by the user/instructor through a graphical user interface to vary the level of difficulty of each scenario run. The use of this task analysis to develop simulator scenarios does not guarantee training transfer. However, it is an important step in the right direction. Experienced ship-handlers will find a scenario that closely represents the real world more engaging, and thus perceive that it is a beneficial training experience.
APPENDIX

A. TASK ANALYSIS OF A CONNING OFFICER DURING UNREP

1. Unit Task Level Analysis

   goal: Execute_UNREP
   . goal: Complete_Brief_Phase
   . goal: Complete_Approach_Phase
   . goal: Complete_Alongside_Phase
   . goal: Complete_Breakaway_Phase

2. Functional Level Analysis

   goal: Execute_UNREP
   . goal: Complete_Brief_Phase
   . . goal: Know_UNREP_Plan
   . . goal: Complete_Approach_Phase
   . . . goal: Know_UNREP_Plan
   . . . goal: Maintain_Communications
   . . . goal: Maintain_Awareness_Of_Third_Party_Ships
   . . . goal: Maintain_Station
   . . . goal: Receive_Report_Own_Ship_Ready_To_Go_Alongside
   . . . goal: Make_Approach
   . . goal: Complete_Alongside_Phase
   . . . goal: Determine_When_Bow_Crosses_Stern
   . . . goal: Watch_For_Bow_To_Be_Pushed_Away_From_Replenishment_Ship
   . . . goal: Monitor_Venturi_Effect_Alongside_Replenishment_Ship
   . . . goal: Determine_Lateral_Separation
   . . . goal: Determine_Range_To_Station_Closing_Rate
   . . . goal: Determine_When_To_Match_Speeds
   . . . goal: Maneuver_Close_To_Station_Alongside
   . . . goal: Get_Phone_And_Distance_Line_Across
   . . . goal: Maintain_Station_Alongside

   . goal: Complete_Breakaway_Phase
   . . goal: Maintain_Station_Alongside
   . . goal: Determine_All_Lines_Clear
   . . goal: Receive_Breakaway_Order_From_CO
3. Detailed Level Analysis

goal: Execute_UNREP
  . goal: Complete_Brief_Phase
  . goal: Know_UNREP_Plan
  . . [select: Go_To_OPS_Brief
  . . . Go_To_CIC_Before_Watch
  . . . Receive_UNREP_Brief_On_Bridge]
  . goal: Know_Plant_Configuration
  . . [select: Go_To_OPS_Brief
  . . . Go_To_CCS_Before_Watch
  . . . Receive_UNREP_Brief_on_Bridge]

  . goal: Complete_Approach_Phase
  . . goal: Know_UNREP_Plan
  . . . goal: Determine.Side_To_Approach_On
  . . . [select: Observe_ROMEO_Flag_On_Replenishment_Ship
  . . . Recall_From_Brief
  . . . Radio_Communication_With_Replenishment_Ship]
  . . goal: Know_Plant_Configuration
  . . . [select: Call_CCS_From_Bridge
  . . . Ask_Lee_Helm_To_Get_Configuration_From_CCS]
  . goal: Go_To_Bridge_Wing
  . . goal: Determine_Which_Bridge_Wing
  . . . Chose_Side_That_Will_Be_To_Replenishment_Ship
  . . goal: Maintain_Communications ...periodic task
  . . . [select: Use_Amplified_Communications_System
  . . . Yell_Through_Hatch ...if amp fail/not available
  . . . Visual_Expressions ...for comms. with CO, OOD
  . . . Verbal_Communications
  . . . Use_Relay_Person] ...if amp fail/not available
  . . . Verify_Order_Received
  . goal: Maintain_Awareness_Of_Third_Party_Ships ...periodic task
  . . [select: Visually_Scan_Horizon
  . . . Listen_For_Contact_Reports
  . . . Ask_OOD_About_Contacts]
  . . . goal: Maintain_Station ...loops until Make_Approach executed
  . . . goal: Shoot_Bearing_To_Replenishment_Ship ...frequently until alongside
  . . . [select: Use_Alidade_On_Bridge_Wing

. . goal: Breakaway
. . goal: Go_To_Next_Station_Or_Duties_Assigned
Use_Radar_Bearing_To_Replenishment_Ship
Replenishment_Ship's_Masts_Lineup
Masthead_Lights_Of_Replenishment_Ship_Lineup ...at night
Own_Ship_In_Wake_Of_UNREP_Ship] ...at night/low vis
goal: Get_Range_To_Replenishment_Ship ...frequently until alongside
[select: Get_Range_From_Stadimeter
Call_For_Radar_Range ...anytime and at night/low visibility
Visual_Estimate] ...in between updates
goal: Determine_If_On_Station
goal: Determine_If_Range_To_Replenishment_Ship_Correct
Compare_Range_With_Ordered_Range
goal: Determine_If_Bearing_To_Replenishment_Ship_Correct
Compare_Bearing_With_Ordered_Bearing
Verify_On_Station
goal: Make_Necessary_Corrections ...loop back to Maintain_Station
[select goal: Turn_Ship ...see page 56
goal: Change_Speed_Of_Ship] ...see page 55
goal: Receive_Report_Own_Ship_Ready_To_Go_Alongside
Receive_Verbal_Report_From_OOD
goal: Acknowledge_Receiving_Report
Verbally_Repeat_Order_Received
goal: Order_ROMEO_Raised_On_The_Side_To_Go_Alongside
Order_Signalman_To_The_Dip_ROMEO ...OOD may do this
goal: Make_Approach
goal: Observe_ROMEO_Close-up_On_Replenishment_Ship
[select: Observe_ROMEO_Move_Up_On_Replenishment_Ship
Observe_Flashing_Light_Signal ...at night/low visibility
Receive_Radio_Transmission] ...at night/low visibility
goal: Receive_Approach_Order_From_CO
[select: Receive_Verbal_Order_From_CO_To_Commence_Approach
Receive_Verbal_Order_Via_XO_To_Commence_Approach
Receive_Verbal_Order_Via_OOD_To_Commence_Approach]
goal: Acknowledge_Receiving_Order
Verbally_Acknowledge_Order_Received
goal: Order_ROMEO_Raised_On_The_Side_To_Go_Alongside
Order_Signalman_To_Close-up_ROMEO ...OOD may do this
goal: Change_Speed_Of_Ship ...commence approach
goal: Issue_Engine_Order ...to lee helmsman
[select goal: Increase_Speed
goal: Determine_Desired_Speed
[select: Use_Predetermined_Speed_From_UNREP_Brief
Use_Speed_CO_Orders
Use Safe Speed For Current Weather Conditions

group: goal
  : Give Verbal Order To Lee Helm

  : Decrease Speed
    : Determine Desired Speed
      : [select: Use Predetermined Speed From UNREP Brief
        : Use Speed CO Orders
        : Use Safe Speed For Current Weather Conditions
      ]

  : Give Verbal Order To Lee Helm

  : Listen For Repeat-back From Lee Helm
    : [select goal: Acknowledge Repeat-back ...if received
      : Repeat Order ...if not received

  : Determine If Order Was Executed
    : [select: Listen For Change In Engine Sound
      : Observe Range To Replenishment Ship Close
      : Observe Target Angle Of Replenishment Ship Change
      : Observe Feeling Speed Increase
      : Observe RPM Indicator
      : Observe Increase On Speed Indicator

  : Receive Report That Order Was Executed
    : Listen For Report From Lee Helm
      : [select goal: Acknowledge Report ...if received
        : Request Status Of Order Execution] ...if not received

  : Turn Ship ...to change lateral separation
    : [select: Walk To Bridge Wing Of The Direction Of Turn To Look
      : Request Another Watch Team Member Visually Check]

  : Issue Rudder Order ...to helmsman
    : [select goal: Starboard Turn
      : Determine How Far To Turn
        : [select: Use Prior Experience To Estimate Distance
          : Use Radian Rule To Monitor Turn
          : Follow CO's Orders]

      : Determine Degree Of Rudder To Use
        : [select: Use The Rule Of Thirty To Determine Amount
          : Use Prior Experience To Estimate Amount
          : Follow CO's Orders]

      : Give Verbal Order To Helm

  : Port Turn
    : [select: Use Prior Experience To Estimate Distance
      : Use Radian Rule To Monitor Turn
Follow CO's Orders]  
  . goal: Determine Degree Of Rudder To Use  
  . [select: Use The Rule Of Thirty To Determine Amount  
  . Use Prior Experience To Estimate Amount  
  . Follow CO's Orders]  
  . goal: Give Verbal Order To Helm]  
  . goal: Receive Repeat-back From Helm  
  . Listen For Report From Helm  
  . [select goal: Acknowledge Repeat-back ...if received  
  . goal: Repeat Order] ...if not received  
  . goal: Determine If Order Was Executed  
  . [select: Observe Rudder Angle Indicator  
  Observe Wake Of Replenishment Ship  
  Observe Feeling Ship Heel  
  Observe Target Angle Of Replenishment Ship Change  
  Observe Horizon  
  Observe Wake Of Own Ship  
  Observe Gyrocompass Heading Change  
  Observe Feeling That Ship Is Turning]  
  . goal: Receive Report That Order Was Executed  
  . Listen For Report From Helmsman  
  . [select goal: Acknowledge Report ...if received  
  . goal: Request Status Of Order Execution] ...if not received  
  . goal: Monitor Ship's Turn  
  . [select: Observe Rudder Angle Indicator  
  Observe Feeling Ship Heel  
  Observe Wake Of Replenishment Ship  
  Observe Wake Of Own Ship  
  Observe Horizon  
  Observe Gyrocompass Heading Change  
  Observe Feeling That Ship Is Turning  
  Observe Rate Of Turn Increase/ Decrease]  
  . goal: Monitor Helmsman  
  . [select: Observe Turn Progress On Gyrocompass  
  Observe Rudder Angle Indicator]  
  . goal: Make Necessary Corrections  
  . [select goal: Turn Ship]  
  . goal: Change Speed Of Ship]  
  . goal: Receive Steady On Course Report  
  . Listen For Steady On Course Report  
  . [select goal: Acknowledge Report ...if received  
  . goal: Request Status Of Order Execution] ...if not received
goal: Get_Range_To_Replenishment_Ship
   [select: Get_Range_From_Stadimeter
      Call_For_Radar_Range]
   goal: Determine_Range_Closing/Opening_Rate ...relative speed
      [select: Call_For_Current_Speed
         Observe_Speed_Indicator
         Estimate_Closing_Rate]
   goal: Shoot_Bearing_To_Replenishment_Ship
      [select: Use_Alidade_On_Bridge_Wing
         Call_For_Radar_Bearing] ...at night/low visibility
   goal: Determine_If_Lateral_Separation_Closing/Opening/Maintaining
      [select: Use_Radian_Rule_Method
         Use_Table_Of_Radian_Rule_Values_Method
         Observe_Distance_Between_Wakes
         Use_Seaman's_Eye_Method ...requires experience
         Use_Combination_Of_The_Above]
   goal: Determine_If_Lateral_Separation_Too_Close/Far
      [select: Use_Radian_Rule_Method
         Use_Table_Of_Radian_Rule_Values_Method
         Observe_Distance_Between_Wakes
         Use_Seaman's_Eye_Method ...requires experience
         Use_Combination_Of_The_Above]
   goal: Make_Necessary_Corrections
      [select goal: Turn_Ship
         goal: Change_Speed_Of_Ship]
   goal: Determine_If_Lateral_Separation_Is_Safe_To_Go_Alongside
      Visually_Estimate_Lateral_Separation
   goal: Make_Necessary_Corrections ...if not safe
      [select goal: Turn_Ship
         goal: Change_Speed_Of_Ship]
   goal: Monitor_Bow_As_It_Approaches_Replenishment_Ship's_Stern
   Watch_For_Pressure_To_Push_Bow_Away_From_Stern

goal: Complete_Alongside_Phase
   goal: Determine_When_Bow_Crosses_Stern
   Visually_Estimate
   goal: Watch_For_Bow_To_Be_Pushed_Away_From_Replenishment_Ship
      Observe_Bow_Motion ...high pressure area between bow and stern
   goal: Monitor_Venturi_Effect_Alongside_Replenishment_Ship ...< 80 feet
   goal: Monitor_Lateral_Separation_Distance
      [select: Observe_Wake_Action_Between_Ships
         Visually_Estimate_Opening/Closing_Trend
Visually Estimate Lateral Separation

- goal: Make Necessary Corrections if too far or close
  - [select goal: Turn Ship
    - goal: Change Speed Of Ship
  - goal: Determine Lateral Separation >90 feet
  - [select: Observe Wake Action Between Ships
    - Visually Estimate Lateral Separation Distance
    - goal: Make Necessary Correction if too far or close
    - [select goal: Turn Ship
      - goal: Change Speed Of Ship
    - goal: Determine Range To Station_Closing Rate
    - goal: Determine Range To Station
      - [select: Visually Estimate Distance
        - Observe Rate Which Features On Replenishment Ship Pass
        - goal: Make Necessary Correction if too fast or slow
        - [select goal: Turn Ship
          - goal: Change Speed Of Ship
          - goal: Determine When To Match Speeds
            - Compare Speed Between Ships_Estimate When To Match Speed
          - goal: Change Speed Of Ship
          - goal: Maneuver Close To Station_Alongside
            - goal: Monitor Ships Heading On Gyrocompass repeats frequently
            - Observe Bridge Wing Gyrocompass
            - goal: Monitor Lateral Separation
              - [select: Observe Wake Between Ships
                - Visually Estimate Opening/Closing Trend
                - goal: Monitor Fore_Aft Motion
                  - [select: Use Replenishment Ship's Riggings As Range
                    - Use Replenishment Ship's Bulkhead As Range
                  - goal: Make Necessary Correction to move towards station
                  - [select goal: Turn Ship
                    - goal: Change Speed Of Ship
                    - goal: Get Phone And Distance Line Across when near station
                      - Give Order To Send Phone And Distance Line Across
                    - goal: Maintain Station Alongside loop until All Lines Clear
                      - goal: Monitor Lateral Separation
                        - [select: Observe Flags On Phone And Distance Line Open/Close
                          - Visually Estimate Opening/Closing Trend
                          - Observe Chemical Lights On Phone And Distance Line
                          - goal: Monitor Fore_Aft Motion
                          - [select: Use Replenishment Ship's Riggings As Range
                            - Use Replenishment Ship's Bulkheads As Range
Observe_Angle_Of_Phone_And_Distance_Line  
Goal: Make_Necessary_Correction  
...to stay on station  
  [Select: Goal: Turn_Ship]  
  Goal: Change_Speed_Of_Ship]  
  Goal: Inform_Helmsman_Before_Lines_Are_Tensioned  
  Receive_Report_That_Lines_Are_Being_Tensioned  
  Goal: Inform_Helmsman_To_That_Lines_Are_Being_Tensioned  
  [Select: Goal: Receive_Repeat-back]  
  Goal: Repeat_Order]  
  ...if received  
  ...if not received  
Goal: Complete_Breakaway_Phase  
Goal: Maintain_Station_Alongside  
...same loop as above  
Goal: Monitor_Lateral_Separation  
[Select: Goal: Observe_Wake_Between_Ships]  
  Visually_Estimate_Opening/Closing_Trend]  
Goal: Monitor_Fore_And_Aft_Motion  
[Select: Use_Replenishment_Ship's_Riggings_As_Range]  
  Use_Replenishment_Ship's_Bulkhead_As_Range]  
Goal: Make_Necessary_Correction  
...to move towards station  
[Select: Goal: Turn_Ship]  
  Goal: Change_Speed_Of_Ship]  
Goal: Inform_Helmsman_Before_Lines_Are_De-tensioned  
Receive_Report_That_Lines_Are_Being_De-tensioned  
Goal: Inform_Helmsman_To_That_Lines_Are_Being_De-tensioned  
[Select: Goal: Receive_Repeat-back]  
  Goal: Repeat_Order]  
  ...if received  
  ...if not received  
Goal: Determine_All_Lines_Clear  
[Select: Visually_Verify_All_Lines_Clear]  
  Receive_Report_All_Lines_Clear]  
Goal: Receive_Breakaway_Order_From_CO  
  Receive_Verbal_Order_From_CO  
Goal: Acknowledge_Receiving_Order  
  Verbally_Repeat_Order_Received  
Goal: Breakaway  
...start breakaway  
Goal: Change_Speed_Of_Ship  
...increase speed to pull away  
Goal: Turn_Ship  
...done in small increments until stern is clear  
Goal: Monitor_Ship’s_Turn  
...until stern clear  
Goal: Observe_Ship’s_Stern_Does_Not_Move_Towards_Replenishment_Ship  
Goal: Make_Necessary_Correction  
[Select: Goal: Turn_Ship]  
  Goal: Change_Speed_Of_Ship]  
  ...see repeated methods  
Goal: Determine_Stern_Is_Clear  

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B. TASK ANALYSIS OF AN OFFICER OF THE DECK DURING UNREP

1. Unit Task Level Analysis

   goal: Execute_UNREP
   . goal: Complete_Brief_Phase
   . goal: Complete_Approach_Phase
   . goal: Complete_Alongside_Phase
   . goal: Complete_Breakaway_Phase

2. Functional Level Analysis

   goal: Execute_UNREP
   . goal: Complete_Brief_Phase
   . . goal: Know_UNREP_Plan
       . goal: Complete_Approach_Phase
       . . goal: Know_UNREP_Plan
       . . goal: Supervise_Bridge_Watch_Team
       . . goal: Maintain_Communications
       . . goal: Ensure_Safety_Of_Own_Ship
       . . goal: Maintain_Awareness_Of_Third_Party_Ships
       . . goal: Ensure_Own_Ship_Ready_To_Go_Alongside
       . . goal: Ensure_Conning_Officer_Maintains_Station
       . . goal: Supervise_Conning_Officer_During_Approach
       . . goal: Complete_Alongside_Phase
       . . . goal: Supervise_Conning_Officer_While_Alongside
       . . . goal: Determine_When_Bow_Crosses_Stern
       . . . goal: Watch_For_Bow_To_Be_Pushed_Away_From_Replenishment_Ship
       . . . goal: Monitor_Venturi_Effect_Alongside_Replenishment_Ship
       . . . goal: Determine_Lateral_Separation
       . . . goal: Determine_Range_To_Station_Closing_Rate
       . . . goal: Determine_When_To_Match_Speed
       . . . goal: Maneuver_Close_To_Station_Alongside
       . . . goal: Get_Phone_And_Distance_Line_Across
       . . . goal: Maintain_Station_Alongside ...loop until UNREP complete
   . goal: Supervise_Bridge_Watch_Team
   . . goal: Maintain_Awareness_Of_Third_Party_Shipping
goal: Maintain_Communications

goal: Complete_Breakaway_Phase
  goal: Supervise_Conning_Office_While_Alongside
  goal: Supervise_Bridge_Watch_Team
  goal: Maintain_Awareness_Of_Third_Party_Shipping
  goal: Know_Where_To_Go_Next
  goal: Maintain_Communications

3. Detailed Level Analysis

goal: Execute_UNREP
  goal: Complete_Brief_Phase
  goal: Know_UNREP_Plan
  [select: Go_To_OPS_Brief
    Go_To_CIC_Before_Watch
    Receive_UNREP_Brief_on_Bridge
    Talk_To_Operations_Officer_About_Changes
    Talk_To_CO_About_Plan]
  goal: Know_Plant_Configuration
  [select: Go_To_OPS_Brief
    Go_To_CCS_Before_Watch
    Receive_UNREP_Brief_on_Bridge
    Talk_To_Chief_Engineer_About_Plant_Status]

  goal: Complete_Approach_Phase
  goal: Know_UNREP_Plan
  [select: Receive_UNREP_Brief_On_Bridge
    Talk_To_Operations_Officer_About_Changes
    Talk_To_CO_About_Plan]
  goal: Know_Plant_Configuration
  [select: Call_CCS_From_Bridge
    Ask_Lee_Helm_To_Get_Configuration_From_CCS
    Talk_To_Chief_Engineer_About_Plant_Status]
  goal: Determine_Side_To_Approach_On
  [select: Observe_ROMEO_Flag_On_Replenishment_Ship
    Radio_Communication_With_Replenishment_Ship]
  goal: Supervise_Bridge_Watch_Team
  goal: Ensure_Bridge_Manned_Ready ...before starting approach
  Observe_Each_Station_Manned
  goal: Correct_Discrepancies ...if not manned
  Contact_Responsible_Department
goal: Ensure All Communications Equipment Operational
  Order All Watch Standers To Do Phone Check
  goal: Correct Discrepancies ...if not operational
  Contact Responsible Department
  goal: Ensure Signalman Has Correct Flags Displayed
  Observe Flags From Bridge Wing
  goal: Correct Discrepancies ...if not correct
  Contact Signalman
  goal: Ensure Quartermaster Has Correct Flags Displayed
  Observe Masthead Lights From Bridge Wing
  goal: Correct Discrepancies ...if not correct
  Contact Quartermaster
  goal: Ensure All Bridge Equipment Setup And Operational
  Check Radar Display
  Check Radios
  Check Miscellaneous Equipment
  goal: Correct Discrepancies ...if not operational
  Contact Problem
  goal: Ensure Bridge Watch Standers Remain Alert
  Monitor Behavior Of Watch Standers
  Control Noise Level On Bridge
  goal: Correct Discrepancies ...if not alert
  Contact Problem
  goal: Maintain Communications ...with CO, Conn, Helm and Lee helm
  [select goal: Communicate With Watch Team
    [select: Yell Through Hatch
      Visual Expression
      Verbal Communications]
    goal: Communicate With Other Ships
    [select: Use Bridge To Bridge Radio
      Use Secure Radio
      Use Flag Signals
      Use Flashing Light Signals]
    Verify Message Received]
  goal: Ensure Own Ship Ready To Go Alongside
  Monitor UNREP Checklist
  goal: Ensure All Personnel On Station
  Receive Manned Ready Reports From UNREP Stations
  Receive Manned Ready Reports From All Department Heads
  goal: Contact Department Head Of Delinquent Department
  Call Department Head
  goal: Set Restricted Maneuvering
Observe Flashing Light Signal ...at night/low visibility
Receive Radio Transmission] ...at night/low visibility

goal: Receive Approach Order From CO

[select: Receive Verbal Order From CO To Commence Approach
Receive Verbal Order Via XO To Commence Approach]

goal: Acknowledge Receiving Order
Verbally Repeat Order Received

goal: Order Conning Officer To Commence Approach
Verbally Order Conning Officer

goal: Monitor Ship’s Turn ...may use multiple methods

[select: Observe Rudder Angle Indicator
Observe Feeling Ship Heel
Observe Wake Of Own Ship
Observe Horizon
Observe Gyrocompass Heading Change
Observe Feeling That Ship Is Turning
Observe Rate Of Turn Increase/Decrease]

goal: Monitor Helm

Observe Turn Progress On Gyrocompass
Observe Rudder Angle Indicator

goal: Monitor Conning Officer During Maneuver

goal: Correct Conning Officer As Necessary

goal: Determine Range To Replenishment Ship

[select: Get Range From Stadimeter
Call For Radar Range]

goal: Determine Range Closing/Opening Rate

[select: Call For Current Speed
Observe Speed Indicator
Estimate Closing Rate]

goal: Determine Lateral Separation Closing/Opening

goal: Shoot Bearing To Replenishment Ship

[select: Use Alidade On Bridge Wing
Call For Radar Bearing] ...at night/low vis

goal: Determine If Lateral Separation Too Close/Far

[select: Use Radian Rule Method
Use Table Of Radian Rule Values Method
Observe Distance Between Wakes
Use Seaman’s Eye Method ...requires experience
Use Combination Of The Above]

goal: Monitor Conning Officer During Maneuver

goal: Correct Conning Officer As Necessary

goal: Monitor Bow As It Approaches Replenishment Ship's Stern
Watch_For_Pressure_To_Push_Bow_Away_From_Stern

goal: Determine_If_Lateral_Separation_Is_Safe_To_Go_Alongside

Visually_Estimate_Lateral_Separation

goal: Monitor_Corning_Officer_During_Maneuver

Determine_If_Order_From_Corning_Officer_Correct_For_Situation

goal: Correct_Corning_Officer_As_Necessary

[select goal: Coach_Corning_Officer

  . Make_Helpful_Course_Speed_Recommendations
  . goal: Order_Corning_Officer_To_Correct_Problem
  . Give_Corning_Officer_Engine_Orders
  . Give_Corning_Officer_Rudder_Orders]

goal: Complete_Alongside_Phase

goal: Supervise_Corning_Officer_While_Alongside ...CO does this

goal: Monitor_Corning_Officer_During_Maneuver

Determine_If_Order_From_Corning_Officer_Correct_For_Situation

goal: Correct_Corning_Officer_As_Necessary

[select goal: Coach_Corning_Officer

  . Make_Helpful_Course_Speed_Recommendations
  . goal: Order_Corning_Officer_To_Correct_Problem
  . Give_Corning_Officer_Engine_Orders
  . Give_Corning_Officer_Rudder_Orders]

goal: Supervise_Bridge_Watch_Team

goal: Ensure_All_Personnel_Are_Alert

Observe_Bridge_Watch_Standers

goal: Ensure_All_Equipment_Failures_Are_Immediately_Corrected

Immediately.Contact.Responsible_Department

goal: Ensure_Quartermaster_Maintains_Correct_Track

[select: Observe_Ship's_Track_On_Chart

  . Discuss_Ship's_Track_With_Quartermaster]

goal: Maintain_Quiet_Bridge

Monitor_Conversation_And_Noise_Level_On_Bridge

goal: Determine_When_Bow_Crosses_Stern

Visually_Estimate

goal: Watch_For_Bow_To_Be_Pushed_Away_From_Replenishment_Ship

Observe_Bow_Motion

goal: Monitor_Venturi_Effect_Alongside_Replenishment_Ship ...< 80 feet

Observe_Wake_Action_Between_Ships

goal: Monitor_Lateral_Separation_Distance

Visually_Estimate_Opening/Closing_Trend ...depth perception

Visually_Estimate_Lateral_Separation ...depth perception

goal: Monitor_Corning_Officer_During_Maneuver
goal: Correct_Conning_Officer_As_Necessary
goal: Determine_Lateral_Separation ... >80 feet
  [select: Observe_Wake_Action_Between_Ships
  Visually_Estimate_Lateral_Separation_Distance]
goal: Monitor_Conning_Officer_During_Maneuver
goal: Correct_Conning_Officer_As_Necessary
goal: Determine_Range_To_Station_Closing_Rate
goal: Determine_Range_To_Station
  [select: Visually_Estimate_Distance
  Observe_Rate_At_Which_Items_On_Replenishment_Ship_Pass]
goal: Monitor_Conning_Officer_During_Maneuver
goal: Correct_Conning_Officer_As_Necessary
goal: Determine_When_To_Match_Speed
  Compare_Relative_Speed_Of_Ships_Estimate_When_To_Match_Speed
  goal: Change_Speed_Of_Ship
goal: Maneuver_Close_To_Station_Alongside
goal: Monitor_Ships_Heading_On_Gyrocompass
  Observe_Bridge_Wing_Gyrocompass
goal: Monitor_Lateral_Separation
  Observe_Wake_Between_Ships
  Visually_Estimate_Opening/Closing_Trend
goal: Monitor_Fore_And_Aft_Motion
  [select: Use_Replenishment_Ship's_Riggings_As_Range
  Use_Replenishment_Ship's_Bulkhead_As_Range]
goal: Monitor_Conning_Officer_During_Maneuver
  goal: Correct_Conning_Officer_As_Necessary
goal: Get_Phone_And_Distance_Line_Across ... when on station
  Give_Order_To_Send_Phone_And_Distance_Line_Across
  goal: Maintain_Station_Alongside ... loop until UNREP complete
  goal: Monitor_Lateral_Separation
  [select: Observe_Flags_On_Phone_And_Distance_Line
  Visually_Estimate_Opening/Closing_Trend
  Observe_Chemical_Lights_On_Phone_And_Distance_Line]
goal: Monitor_Fore_And_Aft_Motion
  [select: Use_Replenishment_Ship's_Riggings_As_Range
  Use_Replenishment_Ship's_Bulkheads_As_Range
  Observe_Angle_Of_Phone_And_Distance_Line]
goal: Monitor_Conning_Officer_During_Maneuver
goal: Correct_Conning_Officer_As_Necessary
goal: Determine_Where_Own_Ship_Will_Go_After_UNREP
  Discuss_Plans_With_Operations_Officer
  Discuss_Plans_With_Combat_Information_Center_Watch_Officer
Discuss Plans With CO

. goal: Monitor Progress Of Stores And Fuel Transfer
. Receive Progress Reports From UNREP Stations
. goal: Report Progress To CO
. Make Verbal Report To CO

. goal: Complete Breakaway Phase
. goal: Maintain Station Alongside
. goal: Determine All Lines Clear
. [select: Visually Verify All Lines Clear
. Receive Report All Lines Clear]
. goal: Receive Breakaway Order From CO
. Receive Verbal Order From CO
. goal: Acknowledge Receiving Order
. Verbally Repeat Order Received
. goal: Breakaway
. goal: Ensure Conning Officer Commences Breakaway Maneuver
. Observe Conning Officers Actions
. goal: Monitor Turn
. Observe Ship's Stern Doesn't Move Towards Replenishment Ship
. goal: Monitor Conning Officer During Maneuver
. Determine If Order From Conning Officer Correct For Situation
. goal: Correct Conning Officer As Necessary
. [select goal: Coach Conning Officer
. . . . . . . . . . . . . . Make Helpful Recommendations
. . . . . . . . . . . . . . goal: Order Conning Officer To Correct Problem
. . . . . . . . . . . . . . . . . Give Conning Officer Engine Orders
. . . . . . . . . . . . . . . . . Give Conning Officer Rudder Orders]
. goal: Determine Stern Is Clear
. Observe Stern Clear Of Replenishment Ship's Bow
. goal: Go To Next Station Or Duties Assigned

C. TASK ANALYSIS OF A HELMSMAN DURING UNREP

1. Unit Task Level Analysis

goal: Execute UNREP
. goal: Complete Approach Phase
. goal: Complete Alongside Phase
. goal: Complete Breakaway Phase
2. **Functional Level Analysis**

goal: Execute UNREP
  . goal: Complete Approach Phase
    . goal: Maintain Ordered Course
    . goal: Turn Ship As Ordered
  . goal: Complete Alongside Phase
    . goal: Maintain Ordered Course
    . goal: Turn Ship As Ordered
  . goal: Complete Breakaway Phase
    . goal: Maintain Ordered Course
    . goal: Turn Ship As Ordered

3. **Detailed Level Analysis**

goal: Execute UNREP
  . goal: Complete Approach Phase
    . goal: Maintain Ordered Course ...normal condition loop
      . . . Observe Changes In Gyrocompass Heading
      . . . goal: Steer To Maintain Ordered Course
      . . . Turn Wheel As Required To Maintain Course ...within limits
    . goal: Turn Ship As Ordered
    . . . goal: Receive Order From Conning Officer
    . . . . Listen For Order
    . . . . goal: Repeat Order Back To Conning Officer
    . . . . goal: Receive Acknowledgement
    . . . . goal: Turn Wheel
    . . . Turn Wheel In Ordered Direction The Ordered Amount
    . . . . goal: Report That The Wheel Is Over To The Conning Officer
    . . . . goal: Receive Acknowledgement
    . . . . goal: Monitor Turn
    . . . [select: Observe Changes In Gyrocompass Heading
      . . . . Observe Rate Of Ships Turn
      . . . . Observe Rudder Angle Indicator
      . . . . Observe Feel Of Ship Turn
      . . . . Observe Horizon]
    . . . . goal: Stop Ships Turn On Ordered Course
    . . . . Estimate When To Reduce Degree Of Rudder
    . . . . goal: Reduce Rudder To Slow Swing Of Ship
    . . . . Turn Wheel As Required
    . . . . goal: Stop The Swing Of The Ship

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.... Estimate Degree Of Counter Rudder To Stop Swing Of Ship
.... goal: Counter Steer To Stop Swing Of Ship
.... Turn Wheel As Required In Opposite Direction Of Turn
.... goal: Steady Ship On Ordered Course
.... Make Small Steering Corrections Until Ship Is Steady On Course
.... goal: Report Ship Steady On Ordered Course To Conning Officer
.... goal: Inform Conning Officer Of Steering Problems
.... goal: Detect Steering System Casualty
.... [select: Observe Steering Alarms
.... Notice No/Slow Response To Turn Of Wheel
.... Receive Steering Casualty Message From Aft Steering
.... Notice Loss Of Gyrocompass]
.... goal: Detect Steering Problems Related To Sea Condition
.... Notice Need To Use More Rudder Than Normally Required
.... goal: Get Permission From Conning Officer To Use More Rudder
.... goal: Maintain Communications ...with Conning Officer
.... [select: Use Amplified Communications System
.... Use Someone To Relay] ...if amp fail/not available
.... Verify Communications Received

D. TASK ANALYSIS OF A LEE HELMSMAN DURING UNREP

1. Unit Task Level Analysis

goal: Execute UNREP
   . goal: Complete Approach Phase
   . goal: Complete Alongside Phase
   . goal: Complete Breakaway Phase

2. Functional Level Analysis

goal: Execute UNREP
   . goal: Complete Approach Phase
   . . goal: Maintain Ordered Speed
   . . goal: Change Speed As Ordered

   . goal: Complete Alongside Phase
   . . goal: Maintain Ordered Speed
   . . goal: Change Speed As Ordered

   . goal: Complete Breakaway Phase
   . . goal: Maintain Ordered Speed
goal: Change_Speed_As_Ordered

3. Detailed Level Analysis

goal: Execute_UNREP
  . goal: Complete_Approach_Phase
    . goal: Maintain_Ordered_Speed ...normal condition loop
      . [select: Observe_Throttle ...ensure it is not moved
        . Observe_RPM_Indicator
        . Observe_Pitch_Indicator
        . Observe_Speed_Indicator]
    . goal: Change_Speed_As_Ordered
      . goal: Receive_Engine_Order
        . Listen_For_Order_From_Conning_Officer
        . goal: Repeat_Order_Back_To_Conning_Officer
        . goal: Change_Throttle_To_Ordered_Speed
          . [select: Change_Throttle_To_Match_RPM_Of_Ordered_Speed
            Change_Throttle_To_Match_Pitch_Of_Ordered_Speed]
        . goal: Report_Pitch/RPM_Change_Complete_To_Conning_Officer
        . goal: Inform_Conning_Officer_Of_Engineering_Problems
          . goal: Detect_Unusual_Changes_In_RPM
            . Observe_RPM_Indicator
            . Report_Problem_To_Conning_Officer
          . goal: Detect_Unusual_Changes_In_Pitch
            . Observe_Pitch_Indicator
            . Report_Problem_To_Conning_Officer
          . goal: Detect_No/Slow_Response_To_Throttle_Changes
            . Report_Problem_To_Conning_Officer
          . goal: Maintain_Communications ...with CCS, Aft Steering,
            . [select: Use_Amplified_Communications_System
              Use_Someone_To_Relay]
        . Verify_Order_Received

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LIST OF REFERENCES


1. Defense Technical Information Center ........................................... 2
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