I. III. ANALYSIS TOOLS

A. INTRODUCTION

Conducting the Top Down and Bottom Up analysis as described in the previous chapter required an extensive analysis effort. This analysis examined a variety of different areas, each of which required unique approaches and methods to resolve. Certain analysis tools were appropriate to specific portions of this analysis. A brief description of the tools and methods used in the ExWar study and the rationale for their selection and use are presented below.

B. FUNCTIONAL FLOW BLOCK DIAGRAM

A functional analysis of Expeditionary Warfare and its associated missions provided the cornerstone of the Top Down Analysis. Functional analysis permits consideration of a problem independent of specific technical solutions and provides a basis for developing innovative alternative solutions through the reallocation or redistribution of functions within the system. Before functions can be reallocated or redistributed, however, a functional decomposition of the overall system is required. The primary tool for accomplishing this functional decomposition is the Functional Flow Block Diagram (FFBD). FFBDs help structure system requirements by cataloging required tasks, provide insight into system organization, and make it easy to identify major functional interfaces. An FFBD consists of multiple levels of functional boxes, with each level corresponding to a uniformly increasing level of functional detail. High level functions are decomposed into lower level functions. The boxes containing these functions are connected by arrows showing the overall process flow. Logical functions are used to convey how processes flow along or around a series of paths. According to Blanchard and Fabrycky (1998), FFBDs help to ensure

1. All facets of system design and development, production, operation, and support are considered.

2. All elements of the system are fully recognized and defined.
3. A means is provided for relating system packaging concepts and support requirements to specific system functions.
4. The proper sequences of activity and design relationships are established with critical design interfaces.

The functional decomposition of ExWar is enclosed as Appendix 3-1. For more information about Functional Flow Block Diagram techniques, see Blanchard and Fabryky (1998), Buede (2000), and Sage and Armstrong (2000).

C. INTEGRATED DEFINITION LANGUAGE

Integrated Definition Language (IDEF) is a structured analysis method that is a more detailed methodology for defining system tasks. IDEF is designed to build functional models of systems. Systems are depicted as a series of arrows and boxes. The inputs and outputs of each functional block connect to previous and subsequent blocks by flow arrows and logic gates as in FFBDs. Additional arrows run into each block to depict the controls and mechanisms affecting the function, as shown below.

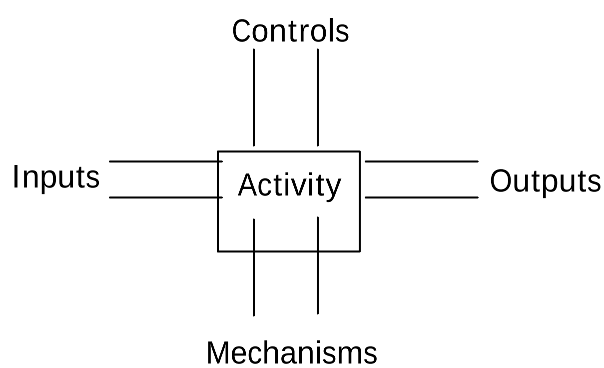

Figure IV-1: IDEF Modeling Conventions (Source: Sage and Armstrong, 2000)

Ordinary FFBDs do not include this important information concerning controls and mechanisms. Attaching IDEF control and mechanism notation to the FFBD provides additional system definition and insight into interfaces and common processes throughout the system. IDEF notation is attached to the FFBD, enclosed in Appendix 8-1. For a comprehensive description of IDEF syntax and methodology, see Buede (2000).

D. OBJECT DIAGRAMS

Where FFBDs depict dynamic relationships, object diagrams present a static view. The diagrams present a clear view of each item's relationship to other system components. Object diagrams allow the identification and consolidation of similar functions, missions, or components. A top level object diagram was created early in the analysis to assist in problem definition. These diagrams are enclosed in Appendix 8-1. For an indepth discussion of object oriented methods and their role in the requirements analysis process, see Kulak and Guiney (2000).

E. DESIGN OF EXPERIMENTS

Processes consist of people, materials, and machines operating in certain conditions in a given environment to produce a desired product or end state. These variables are referred to as factors. When designing processes, it is desirable to know which of these factors affect the desired end state and to determine the optimum values for these factors. Experiments consist of purposeful and controlled changes in the factors while measuring the corresponding changes in the output or end state, allowing both a better understanding of the process and how the controlled variables affect the overall system response. Design of experiments refers to the process of rigorously planning the experiment so valid data can be collected and then analyzed to produce valid conclusions. When the experiment contains random noise, variations, or experimental errors, statistical methodology is required to reach valid conclusions. Experiments on large scale systems often involve many factors, resulting in complex, computationally intensive, multiple factorial designs.

In order to reduce the statistical overhead of traditional design of experiments while retaining the benefits of rigorous analysis, industry has increasingly turned to Taguchi Methods in parameter design. Taking advantage of orthogonal arrays, Taguchi

Methods provide a quick and accurate solution for experiments consisting of only a few, well structured designs by using pre-structured analysis techniques. These characteristics made Taguchi methods ideal for inclusion as a way to structure the Expeditionary Warfare modeling effort.

For an in depth discussion of Taguchi Methods, design of experiments, and their role in process analysis, see Montgomery (1997) and Schmidt and Launsby (1992).

F. OPERATIONS ANALYSIS TOOLS

Basic operations analysis tools were used to perform many pre-analysis tasks and generate results for analysis not requiring computer modeling and simulation. These techniques included linear programming, decision analysis, sensitivity analysis, search theory, network analysis, and queuing theory.

Linear programming uses an objective function and a series of constraints to minimize or maximize some quantity. Linear programs determined the optimal mix of MV-22 and heavy lift aircraft in future expeditionary task forces.

Decision analysis is a method for determining optimum strategies when evaluating multiple decision alternatives under uncertain current or future conditions. Decision analysis was used to perform the mine countermeasures analysis.

Sensitivity analysis involves evaluating how changes in the inputs or processes affect the outputs. Sensitivity analysis was employed throughout the ExWar study.

Search theory uses probabilistic methods to plan and evaluate the effectiveness of searching an area using a given pattern to locate a certain object or class of objects. Search theory was used to perform the mine countermeasures and force protection analyses.

Network analysis converts systems into a series of nodes and connecting arcs to find optimal solutions to a range of problems including finding the shortest route and determining the maximal flow through the network. Network analysis was used as part of the analysis of material flows through the task force to the Marines ashore.

Queuing theory uses mathematical formulas and relationships in order to determine the operating characteristics of a queue or waiting line. Queuing theory was used to examine material and personnel flow through ExWar platforms to the objective ashore.

For an in depth discussion of these tools and methods, see Anderson, Sweeney, and Williams (1997) and Wagner, Mylander, and Sanders (1999).

G. EXTEND™

Simulation is a powerful tool for analyzing, designing, and operating complex systems. A model is a logical abstract description of how a system performs. Simulations involve designing a model of a system and carrying out experiments on it as it progresses through time (Imagine That! 2000). An ExWar model was required in order to experiment with the effects of materials flow through an expeditionary task force. Modeling a system as large and intricate as an expeditionary operation required a powerful and highly flexible simulation tool.

Imagine That!'s EXTEND™ is a software program that supports developing dynamic simulation models of complex processes. An EXTEND™ model is composed of components, or blocks, and their interconnections. "At its core, Extend is a dynamic, iconic simulation environment with a built-in development system for extensibility. It enables you to simulate discrete event, continuous, and combined discrete event/continuous processes and systems, plus allows you to build your own modules." (Imagine That!, 2000).

With its ability to simulate large, complex processes involving a wide variety of platforms and materials, EXTEND™ models were the foundation of the Bottom Up analysis effort. Construction of a large scale, detailed EXTEND™ model enabled the study of emergent behavior and the investigation of non-linear effects on the ExWar system. This model could be reconfigured relatively quickly to examine the effectiveness of various architectures and concepts of operation.

H. ARENA™

While EXTEND™ was used to build a large scale system model, there were also smaller scale problems and pre-analyses that required a simple, fast, and accurate modeling tool. Rockwell Automation's ARENA™ simulation was used to complete these analyses. ARENA™ uses a combination of process simulation and optimization technologies to model dynamic systems to demonstrate, predict, and measure system performance under different sets of rules and scenarios. The test runs occur in a controlled (simulated) environment, which allowed easy experimentation with various conditions and decision criteria. Construction of the models is relatively rapid, through ARENA™'s use of ready made, drag and drop process module. Because of their ease of construction, relative simplicity, and easy of manipulation, ARENA™ models were used to generate data and test concepts on a smaller scale prior to subsequent introduction into the much larger EXTEND™ model. For more information on ARENA™, see Kelton et al (2001).

I. MINITAB

The use of Design of Experiments in conjunction with the EXTEND expeditionary warfare models generated a large quantity of statistical data for reduction and analysis. MINITAB software was used to perform this data processing.

MINITAB Release 13 is a statistical software package providing comprehensive statistics capabilities, including exploratory data analysis, basic statistics, regression, analysis of variance, sample size and power calculations, multivariate analysis, nonparametrics, time series, cross-tabulations, and simulations. MINITAB Release 13 also contains a feature called StatGuide—Statistical guidance for many of MINITAB's text-based and graphical analyses— from basic statistics to design of experiments. MINITAB is adept at analyzing design of experiments, with capabilities to generate and analyze full and fractional designs, Plackett-Burman designs, Taguchi designs, response surface designs, and mixture models. MINITAB also employs an easy to use graphical interface.

MINITAB allowed rapid generation of processed DOE data as well as providing the capability to quickly reevaluate existing results and incorporating the latest data into the existing results database. For more detailed information on MINITAB, see Ryan and Joiner (1994).

J. EINSTein

Enhanced ISAAC Neural Simulation Toolkit (EINSTein) is an artificial-life laboratory for exploring self-organized emergence in land combat. The simulation, originally designed to model small unit ground combat, was written by Andrew Ilachinski and modified by Greg Cox of the Center for Naval Analysis (CNA) for use in maritime warfare. The simulation is a beta-version, agent-base simulation where each ship is given "attributes" that describes its mission, capabilities, and aggressiveness. The ships are then placed in a scenario driven environment and starting location. When the simulation is run, the ships are free to move, act, engage, and disengage opposing forces according to these attributes. EINSTein was used in supporting operations analysis studies to examine force protection concepts against various surface threats.

K. MATLAB™

MathWorks MATLAB™ is a computing software package suitable for calculations involved a number of different mathematical, engineering, and statistical applications. The MATLAB environment provides for both mathematical computing, and visualization of results through a wide variety of graphing and data presentation formats. Built-in interfaces allow access and data importation from stored files and external databases and programs. In addition, MATLAB™ is capable of integrating external routines written in C, C++, Fortran, and Java with MATLAB™ applications.

MATLAB™ was used for numerous and varied engineering calculations for aircraft and ship design, as well as to conduct the genetic algorithm analysis of expeditionary warfare architectures.

L. VISIO™

Microsoft Visio® is a drawing and diagramming tool that allowed the team to visualize, document, and share ideas with flowcharts and block diagrams. Visio supports FFBD and IDEF notation and was used to create the functional flow contained in Appendix 3-1.

M. EXCEL™

Microsoft Excel™ is a spreadsheet and data analysis program. Microsoft Excel was used to perform many smaller scale pre analysis calculations, and answer most operational analysis questions requiring search or decision theory.