1988

Technical Support for Soviet C3/CM WARGAMING at the Naval Postgraduate School

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http://hdl.handle.net/10945/50783

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The work described herein was conducted by ROLANDS & ASSOCIATES Corporation for the Naval Postgraduate School, Monterey, California, under Purchase Order Number N62271-89-M-0519, dated 12/06/88. The NPS Basic Research Group comprised Professors J. Sternberg, C. R. Jones, and R. Thackery. Lois Brunner provides technical support to the Group. This work was performed in support of the BRG evaluation of options for simulation (wargaming) support for their research.

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I. Introduction

The Naval Postgraduate School (NPS) is conducting research to evaluate the potential impact of Soviet Countermeasures (CM) to U. S. Command, Control, Communications and Intelligence (C^3I) capabilities on the U.S. Pacific Command's (PACOM) mission. The PACOM area of responsibility is extremely large, and implementation of its mission requires that CINCPAC successfully orchestrate the actions of a diverse set of forces over this vast distance. In order to achieve the mission, it is imperative that the PACOM strategy include the establishment and retention of an excellent, reliable and complete C^3I network to link and integrate the information available to all its forces.

The Soviets have reached the same conclusion, and have demonstrated an extensive capability to interfere with the PACOM C^3I network through jamming, deception and other forms of counter-measures. The Soviet C^3ICM capabilities are impressive and are enhanced even further due to the vulnerability of the US communications systems, the small number of nodes in the system structure, and the limited redundancy of the communications network.

The purpose of the NPS research is to help determine and understand which communication links and information sources are most important to tactical commanders within PACOM. If the research is successful, CINCPAC will be able to use the results to help decide which information sources should be more thoroughly protected against the Soviet C^3ICM capabilities. In other words, the research is designed to investigate which communication and information links are most important, and where PACOM's limited communication capability should be concentrated to insure that the most effective information system is maintained.

This type of research is difficult because it deals with the essence of the human decision making process. Decisions are not made simply on the basis of current situational information. Instead, they are made on the basis of a combination of available data, the commander's perception of the situation (which may or may not be based on current information), the warfare engagement capabilities available to the commander, and the personality and experience level of the decision maker. Because there are so many variables within the decision making process that can not be controlled, analytic research methods have a limited usefulness. The only alternative available to the NPS researchers is to conduct their study within a wargaming environment.

NPS contracted with ROLANDS & ASSOCIATES Corporation (R&A) to evaluate the current tools available to support the research and recommend a realistic warfare environment within which the Soviet C^3ICM research can be conducted. NPS has accumulated over the last ten years an extensive wargaming capability. The majority of these wargames have been installed at the school to demonstrate to graduate students how wargames may be used as analysis tools. As such, many of the games have been used to demonstrate analytic techniques instead of analysis.

R&A was tasked to evaluate the current NPS wargaming capability in light of the research goals. One goal of the NPS Basic Research Group (BRG) is to use as much of the school's existing wargaming capacity as possible, and maintain a flexibility to present a variety of decision situations under varying information levels. This report presents an analysis of the resources currently available to support the proposed research.

It also describes the tactical situation that the BRG needs to realistically recreate. This description forms the basis for the wargame system requirements. A description of R&A's concept of operations for the research experiments is presented. After the concept of operations is explained, the paper describes the tools that are available and outlines those requirements that can or can not be fulfilled within the currently available NPS wargaming capabilities. A conceptual design that describes the proposed Soviet C^3ICM Research and Analysis Model (SCRAM) is explained.

II. Scope of Research

In order to limit the scope of the problem, the research team has decided to concentrate and narrow the investigation to the information used by the commander of a multi-carrier battle fleet (CVBF) while moving from a known safe haven to an operations zone within strike range of enemy land based air forces. The mission of the CVBF is to arrive at the operations zone as soon as possible, with as much surface and air war fighting capability as possible. There is an inherent tradeoff between arrival time and mission capability that must be weighed and evaluated by the CVBF commander. Arriving at the operations zone early with a greatly reduced war fighting capability is as undesirable as arriving late with a full mission capability.

There are two general types of information available to the battle fleet commander within this general scenario:

1. Non-organic.

This information is from sources not under the direct control of the battle fleet commander. He has the capability to request the information, but has no ability to assign resources to gather the information. Since it is obtained from non-organic sources, the availability, timeliness, reliability and completeness of the data are not within the control of the battle fleet commander. The advantages of the non-organic information is that it comes from strategic and national sources that have a range capability greater than the tactical commander could obtain using any sources owned and under his control. It has the further advantage of being accomplished independent of the CVBF. Thus information gathered from non-organic sources tend not to compromise the current position of the battle fleet. The disadvantages of this information source is that the commander is removed from the data collection process and thus unable to evaluate the reliability of the data obtained.

2. Organic.

This information is from sources that the commander has under his direct control. The commander makes the decision where and when to employ the data collection resources, and thus has the ability to easily evaluate the quality of the information. The tradeoff for this quality control is that the range capability of these sources is not as great as the non-organic sources. Furthermore, employing the organic sources can lead to early enemy detection, delayed en-route movement, and a decreased air sortie generation rate once at the operations zone.

One of the primary decisions facing the CVBF commander is how to maximize use of the information sources that are available. There are other decisions that must be made by the tactical commander within this limited scenario. Each decision requires that the commander consider the tradeoff between more information and final mission objective. These decisions are summarized as follows:

1. When does the enemy detect and localize the CVBF?

This is a function of where the enemy has stationed its reconnaissance capability, the range of that capability and the average search coverage for that capability. Information on the range and search coverage is easily obtained, but the location and type of the enemy reconnaissance capability is not.

2. When can the enemy effect a strike on the CVBF?

This is a function of the commander's perception of when detection and localization occurred. It is also a function of the location, type and range capability of the enemy's strike forces.

3. What is the probability that the enemy will effect a strike?

This is primarily a function of other problems facing the enemy and other more lucrative targets that are within range of the enemy strike forces.

4. From which directions can the enemy effect a strike?

This is primarily a function of the location, type and range capability of the enemy's strike force.

5. Which sectors should be protected using outer air battle resources?

The more air forces the commander employs, the safer the battle fleet is, but there is a price to pay for that safety. Sector defense effectiveness decreases over time, and after prolonged periods can become impossible to maintain. If done too soon, the ability to accomplish the mission once the battle fleet reaches its objective may also be degraded.

6. How far out should sectors be extended?

The farther outward a sector is extended, the safer the battle fleet is from enemy air strike. This is due primarily to the increase in available reaction and interception time of deck launched interceptors. Since the enemy may be detected earlier, the CVBF air defense resources are allowed more time to engage outer air battle. Extended sectors require more resources to obtain the same density of coverage and require longer mission times. This increases the rate of degradation in sortie effectiveness. Extended sector operations also require more tanker resources to be airborne to support the extended sortie flight profiles.

These types of information, their availability and the Commander's perception of the information situation are major factors in determining the outcome of the engagement. It is the responsibility of the research team to identify the relevant factors and determine how to provide better support to the Fleet Commanders.

III. Wargame System Requirements

Given the brief description of the scenario and the type of decision environment that is desired, the following list of requirements was established for a wargaming system that would be used to create a scenario decision environment.

1. The system must be interactive.

The concept of the research experiment is to evaluate a commander's decision process under varying information conditions. The wargaming system will provide the realistic decision environment in which to accomplish this task. As such, the environment must change based on the decision maker's decisions. This means that the system must accept the players decisions and alter the course of events based on that input.

2. The model must be relatively fast.

The decision period that is being represented is in terms of days, not hours. To properly investigate the affect and effect of varying levels of information, the experiment must provide a realistic transit scenario from a safe haven to an operating area. Since hours and not days will be available to conduct the experiment, game ratios of at least six to one are required, and capabilities greater than ten to one are probably necessary.

3. Discrete activities need to be evaluated.

Multi-carrier operations, ship movement, air operations, fuel consumption, sortie generation rates, effects of jamming, and outer air battle resolution need to be modeled. The experiment will be conducted with a multi-carrier battle fleet, and thus the model must be able to represent several carriers and their associated escorts.

The ship speed of advance is a major measure of effectiveness (MOE) for the experiment. The more flights that are operated by the CVBF commander en-route to the operations zone, the longer the transit will take. The model needs to represent at some level, the relationship between flight operations and degraded ability to maintain a maximum speed of advance.

Another major MOE is the ability to conduct flight operations once the CVBF reaches its operations zone. The model must represent sortie generation rate, maintenance capability, crew availability, and surge capacity to insure that the commander is not allowed to fly an increased surveillance CAP mission tasking order without paying the price for the decision. To a lesser extent, but still important, the model needs must account for resource availability on such consumable items as aircraft fuel and weapons. For these reasons, general air operations, fuel consumption and sortie generation rate all need to be modeled at varying levels of detail by the wargaming system.

4. The outer air battle must be represented, but not in detail.

The effects of standard outer air battle tactics need to be portrayed. The implementation of these tactics on an aircraft by aircraft basis is not necessary and is in fact undesirable.

When the CVBF commander makes an allocation of surveillance and protection resource decision, the model needs to return an appropriate level of information and provide the fleet with the proper level of protection. The model does not need to track each aircraft in support of the decision. The decision environment created for the Soviet C^3ICM research experiments will initially be tested using students at NPS. They are not CVBF commanders, and can easily be drawn down to a lower and undesirable decision level, if too much detailed information is available. The decision environment should be conducive to helping maintain fleet perspective for the decision maker and not an individual pilot perspective. Thus the outer air battle effects must be represented, but the air battle itself should not be modeled in detail.

5. The information available must be easily assimilated by the players.

There are four types of information that are available to the experiment participants. Each type of information must be presented in a manner that is easy to interpret and use. The four types are the non-organic information, the organically collected information, the information concerning the current situation and information concerning own force and enemy force capabilities. In the real world, non-organic information is provided usually in the form of message traffic. The organic information is usually in the form of verbal debriefs, while the current situation is obtained from direct observation. The own force and enemy force data are usually not directly acquired, but simply known from prior experience. Whatever format is used to present these information types, it must be organized in a manner that can be quickly assimilated by the game participants. The game speed is expected to be fairly fast, so there will not be much time available for the players to interpret the available information. As much as possible the information should be presented using the same formats that are within the actual decision environment.

6. The controller needs to be able to pre-script a scenario.

The portrayal of non-organic information is extremely important to the conduct of the experiment. Many of the decisions that the commander of the CVBF will be making are based on his perception of the reliability of the available non-organic information. This means that the information provided to the player must be very specifically developed and close attention paid to the wording of each message. This can not be done on an ad hoc basis. The construction of the messages and their exact information content are all part of the experimental design. Scenarios must be carefully pre-scripted to provide the controls necessary to develop valid conclusions.

7. The controller needs to be able to intervene as the scenario is being conducted.

This intervention may be in the form of a controller function or in the form of an enemy player responding to a decision of the CVBF commander. Thus the model needs to be two sided so the enemy can react. For example, if the battle fleet commander decides to employ his organic intelligence gathering resources, he may be detected earlier than the pre-scripted scenario indicated. The controller needs to be able to change the pre-scripting and allow for the early enemy detection and the potential for an early enemy strike formation.

8. History files need to be maintained.

The model needs to maintain game history for post-experiment analysis. The design should permit non-obtrusive data collection as the experiment is being conducted, and facilitate game restart after a period of non-activity. The model must allow the output to be easily changed and accessed as future technical enhancements and research requirements are identified.

IV. Concept of Operations

No single wargame system exists at NPS that meets all of the requirements described in Section III. Conducting a CVBF transit requires numerous people of varied backgrounds in the real world. Although an entire CVBF staff will not be required to conduct the Soviet C^3ICM experiments, more than one person will be required. Four types of information that are available to the battle fleet commander were described in Section II. These information types are:

1. Non-organic
2. Organic
3. Current situation
4. Personal knowledge

Each of these information sources needs to be represented in the experiment. We believe that they need to be portrayed individually. Information types 2 and 3 are closely related and are a direct function of the battle fleet commander's decisions. As will be explained shortly, our concept of operation combines these two information functions into a single function, but provides for two methods of obtaining this functional data.

We envision that a CVBF staff will be represented in the experiment by a commander and at least three staff members. Each of the three staff members will be responsible for a different information type and will be provided a terminal on which to obtain this information and perform their function. These functions are summarized as follows:

1. Non-organic information terminal.

This terminal will be used to obtain the information available to the CVBF from strategic and national resources. Communication between the CVBF and all higher command echelons that need to be represented will be done through this terminal. Since much of this information is passed via message traffic in the real world, this terminal will be primarily message based.

2. Organic and current situation information terminal.

This terminal will provide the battle staff player with the information gathered from organic intelligence resources and information concerning the current game situation. We envision this terminal interacting directly with the combat model or wargame that is creating the realistic warfare environment. As stated in the requirements, the model should be two sided, and thus capable of providing the information on the current disposition of enemy forces. Since the assignment of organic collection resources is a CVBF commander decision, the cause and effect relationship of that decision and the resulting information must be collected and saved. If this is not done, there will be no way to properly measure its importance to the commander in comparison to the non-organic sources.

There is no way of predicting how an experiment's commander will allocate his intelligence gathering capability; therefore, the organically collected data can not be pre-scripted. Furthermore, we feel that any design that requires the controller to determine what information is available from the organic resource assignment will result in inconsistent feedback results. If inconsistent organic intelligence feedback is experienced, the final conclusions may be suspect. We propose that the organic intelligence messages be automatically generated as part of the combat model that is used to run the experiment.

It is mandatory that a graphical display be available to present the current disposition of the battle fleet in relationship to known enemy locations and the assigned operations zone. This display should be updated automatically and contain the commander's perceived situation in a well defined, easily understood format.

3. Personal knowledge information terminal.

This terminal consists of a series of decision aids designed to help the commander evaluate alternatives. In the real world a battle fleet commander has a concept, for example, of his force sortie generation capability and how that affects his longer term ability to maintain flight operations. He also has a Tactical Action Officer (TAO) available to provide quick response to questions such as the strike distance of an enemy bomber force. A TAO is an extremely intelligent information management system that provides the commander with a voice input, natural language processor and almost immediate voice feedback. The TAOs go to school and memorize facts, so they can provide the commander these data as needed.

In the initial stages of the experiment, the personnel available to participate as commander are not going to have the level of operational experience that a battle fleet commander can be expected to have. Coupling this with the fact that the game will be executed at faster than real time, mandates the necessity to provide a series of decision aids to the experiment participants.

The personal knowledge information terminal will provide access to a number of decision aids designed to provide answers to these problems. The aids need to be developed to closely match the results obtained from the combat model. For example, if the decision aid tells the commander that flying 12 sorties within a 90 minute period will reduce his effective speed of advance to 7 knots, and this will result in an overall delay in arrival at the operations area of 25 hours, the final results of implementing the strategy should be fairly close to the predicted value.

This conceptual design proposes a computer hardware suite comprising three user stations. Each station includes three alphanumeric terminals and one graphics display. One user station is intended for each opposing side in SCRAM and one for the control element. This arrangement will provide the environment necessary to meet the requirements that have been defined. The proposed software system will operate equally well with one, two or three user stations.

V. Available Models

The models and algorithms available in the NPS WARLAB to meet the requirements defined herein are limited. None listed meet all of the requirements. This section describes the available resources and models, the requirements that the models do meet, and those requirements for which the models fall short.

The non-organic information terminal model requirement can be met through the use of COMNET. The Communication Network (COMNET) software program was developed by R&A for a series of wargames based experiments that were conducted in the NPS Wargaming and Research Laboratory (WARLAB). COMNET provides the capability to send messages from one communications network node to another in a star configuration. There are a maximum of seven nodes. Each node is connected to a central program that holds and processes the messages. The central program maintains a system clock and insures that messages are delivered to the proper terminal at a specified time. A controller node has the ability to stop messages over any link, individually alter the garble rate of messages over a specific link, alter the delay of a message over any link, and change the game time to real time ratio.

Each player using COMNET, including the controller, can create and send messages. Message creation can be accomplished using a free-format screen editor or pre-formatted messages that require the user to enter only the pertinent and changeable information. The controller or any player can create messages as needed while the program is running. The VAX/VMS editor, EDT, is available from within the program, which allows users familiar with EDT a quick method of creating messages.

EDT also allows a user to retrieve ASCII files from the system. This capability may be used to retrieve pre-formatted messages and enter them into the system when and as desired.

Every message that is sent through the system is saved. The controller has the ability to add notes and small messages to the history file at will. For example, when the controller decides to remove a link from operation, a controller message to that affect can be created and automatically added to the history file. Therefore it is possible to keep an automatic record of the changes and the time of the changes to the non-organic information provided to the player.

The major advantage of COMNET is that it is a small, well documented program, that can be easily changed and upgraded.

There are three major disadvantages to using COMNET as it currently exists:

1. Message traffic is not held in priority order. This results in a routine situation report being assigned the same priority as a flash message concerning enemy activity.

2. COMNET is designed to have one controller and several players. The program assumes that the individual that prepares the message is the person that sends the message. This is not true for the experiments being discussed. The controller will actually be representing numerous external organizations that have data of interest for the player. Not all of these controller based organizations use the same communication links or methods of transmitting data to the CVBF commander. The controller needs several different communication links with the experiment's battle staff.

3. Although COMNET has the capability to delay message and has an internal game clock represented, it is an independent program. Thus its game clock is independent of any other model game clocks. If the timing algorithm of the current situation model is accurate, and the game is maintaining the desired game speed, COMNET and the situation model should (there is no guarantee) remain synchronized. If this is not true, it is possible that the two programs will not be time coordinated. The controller has the ability to readjust the COMNET clock, but it would take close monitoring on the part of the controller to insure that time synchronization is maintained.

The obvious candidate for the organic and current situation terminal driver is the Research Analysis (RESA) model. RESA is an open ocean, blue water, two-sided, interactive naval wargame. It can represent multi-carrier operations, air missions, and air, surface, and sub-surface platforms. It has the capability to initiate game saves and restarts from previously saved scenarios. Series of orders can be pre-defined and entered at will. Thus it is quite feasible to create a series of Red contingency plans, and decide which plan to implement based on the blue commander's decisions.

RESA keeps track of the kinematics of all movement, determines when detections take place, and assesses the outcome of all combat. The position of all forces is displayed on a medium resolution color situation display. The display uses standard Naval Tactical Data System (NTDS) symbolology, and is attached to a color graphics printer that can be used to maintain a record of the situation as the experiment progresses.

The model's major disadvantage is that it is detailed and complex. The documentation is poor and sketchy. The source code is available in the WARLAB, but reviewing and changing the code may be a major undertaking and a risky proposition. To the best of our knowledge there is a configuration management plan in affect but it does not preclude making changes to the model.

The model is not fast. It has a maximum speed of 6 to 1, and that speed may not be achievable if running multi-carrier operations. The major problem with RESA is its level of detail. There is too much. We are extremely worried that the detail level required will draw the decision maker down to the level of a pilot and not maintain an environment conducive to battle fleet decisions.

RESA has a capability to simulate communications jamming, but the work and data required to accomplish this are extensive. The players must be concerned about insuring aircraft with the proper communications suites and jamming equipment are airborne. This requires a great deal of detail and will seriously detract from the decisions that are the subject of this research.

There are several decision aiding programs available on PCs throughout the NPS campus. The Hewlett Packard (HP) computer in the WARLAB has several decision aids that have some possibility of being useful to this research. A major problem with all of the currently available decision aiding tools is the inability to correlate their results to the consequences presented by the combat model. If such correlation does not exist, the decision aid information presented to the battle force commander will be detrimental to the experiment.

A major precept of Decision Support System (DSS) methodology suggests that a DSS be uniquely created for the individual decision environment. It appears the development of a unique DSS to support this research is appropriate.

VI. Implementation Options

There are several implementation options available to develop the decision environment of the C³I research experiments. The final goal of the project should be to create an integrated system that creates a realistic decision environment tempered against the constraints of model fidelity, model cost and implementation time.

The following discussion describes the implementation options for each of the individual support elements described in previous sections. The final option for each component is to integrate the operation of that component into a single coordinated system. Thus even though the components are described separately, the decision on what option or options to use needs to be made from the point of view of the total system architecture.

For the non-organic information terminal, COMNET can be adapted to meet the needs of the Soviet C³ICM experiments. There are three distinct improvement level options that can be described for COMNET. Each option is listed in order of relative difficulty that is, as expected, positively correlated to time and cost.

1. Use COMNET as it exists.

This option assumes that no code changes are made to the COMNET program. If this option is selected there is no solution to the message priority problem. The other two COMNET problems previously described would be solved in the following manner.

The controller would be placed on a MicroVAX workstation terminal that has the capability to display multiple process windows simultaneously. Each controller process window would represent a different intelligence resource or communication link to the CVBF commander. Thus the controller would be operating several COMNET processes simultaneously, but would not need to move among several physical terminals. When sending a non-organic information message to the player, the controller would use the workstation mouse to select the correct communication link process and send the desired message.

The controller would watch the game clock of the experiment and send messages to the player at the appropriate times. A few pre-experiment tests would need to be conducted to determine whether the link delay capability in COMNET matched the timing mechanism of the combat model option that is being used. If it does, the controller simply needs to set the proper delay time parameters for the link, and enter the message at the correct message release time. The delay associated with the link or the collection source would be done by COMNET. If the delay mechanism does not correlate properly in the tests, the controller will have to set the link delay to zero, and manually calculate the proper information delay time. The controller would then be responsible for sending the message over the link at the proper game time.

2. Modify COMNET.

COMNET can be changed to solve any combination of the three problems described. For example, to prioritize messages, each message would be given a priority. This priority would be assigned by the creator and sender of the message. The receiving node's message queue would be sorted by message priority. The COMNET menu display would list not only the total number of messages that were waiting to be read, but it would also list the number of waiting messages by priority. Five priorities would be established: ROUTINE, PRIORITY, IMMEDIATE, FLASH, and FLASH OVERRIDE. Depending on how fancy the priority scheme is implemented, the player could be interrupted when reading a message if a higher priority message arrives. This interrupt feature could also be established by the commander as one of his available decisions.

To solve the link problem, the controller could be given the option of selecting the link over which a message should be sent. Currently a communication link between two COMNET nodes is established as part of the COMNET initialization procedure. This could be changed to allow the user (controller or player) to decide which of the available links should be used for each message. Thus the user would select to whom the message is being sent, and at that time select which link to use. By adding this capability, the controller would only need one COMNET process operating and the appropriate link would be selected for each message.

To partially solve the delay problem, and to improve the ability to develop prescripted information scenarios, it is possible to change the COMNET code to allow predefined messages to have a send time, receive time, and communication link assigned. The COMNET logic would be changed to read in the pre-defined message scenario and hold the messages until the appropriate time. The controller would not need to worry about finding the correct message and sending it at the correct time. The controller would still need to monitor the game time and the COMNET game time to insure proper correlation. If the two times do not match, the controller would only be responsible for updating the COMNET time. This capability already exists within COMNET.

3. Integrate COMNET with the combat model.

This option would be done only if the pre-scripting improvements described under option two are implemented. This option is more difficult and requires that COMNET and the selected combat model be integrated. Option three results in the creation of a simple communication link between the combat model and COMNET. In VAX/VMS terminology, a mailbox between the two processes would be created. Every game cycle (in RESA this is every minute), the game time would be sent from the combat model to COMNET through the established mailbox. COMNET would read the game time and update its game clock. The section of code that synchronizes game time to real time would not be required in this implementation of COMNET. All of the timing mechanisms would be updated on the game time of the combat model.

The first COMNET option is awkward, but workable. The second COMNET option is much nicer and is not difficult. The third option is the most elegant from several aspects, given that a new model is created. This option provides automatic timing and correlation. It also minimizes the researchers' workload during the experiment, in post experiment analysis and data evaluation. Option three would facilitate future model development much better than either Options one or two.

RESA can not be easily adapted to meet the organic and current situation terminal needs of the Soviet C^3ICM experiments. There are two distinct steps or options available to obtain a current situation capability for the experiments. Each option listed herein is in order of relative difficulty and is positively correlated to time and cost.

1. Use RESA expert players.

This option is to try to use RESA in its current configuration as the combat model driver for the experiments. This would require that expert players, not experiment participants, staff the current situation terminal and run RESA. We do not believe that student participants can be taught enough about RESA and the operation of the game to successfully staff this terminal. Personnel assigned to the WARLAB or highly qualified contractor personnel would need to develop several sets of pre-defined contingency plan order sets for the experiments. These order sets would need to be extensively tested to insure that they accomplished the desire goal, and could be altered to meet the commander's orders.

The major problem with RESA is its level of detail. This detail can become overwhelming and cause inconsistencies throughout the experiment. For example, when the CVBF commander orders a feasible sector of coverage, the expert players must be able to quickly and properly get that coverage working. Aircraft inadvertently going home for fuel, tankers not arriving on time, etc., are undesirable situations and can not happen if the experiment is to be successful. The order sets must be robust enough to accomplish the range of decisions available to the commanders.

2. Develop a new combat model that satisfies the research requirements.

Another approach to solving this problem is to develop a simple model that portrays the battle situation at an extremely aggregated level. Instead of providing the user with an infinite realm of situation possibilities, allow the user to enter decisions from a small well defined, but diverse decision set. For example, with RESA, the player can decide where to place a surveillance CAP station. The mission can be told to take station at any location. RESA needs to determine that the order is valid, if fuel is available, and provides a great deal of logic and computation to accomplish the task of specifically flying the mission to the assigned location. This complexity of logic is not required in an aggregated, decision-limited model.

The new model option is complex, but can also be developed incrementally. The underlying premise of this option is that the graphics and kinemetric capabilities of RESA would be used to form the baseline for the new combat model. This new model would not initially track individual ships but would track a carrier and its assigned escorts as an object. Thus, a three carrier battle force would be concerned with the movement and placement of three independent objects.

The new model would allow the user to select from a limited number of alternatives. We would establish a set of decision possibilities for the decision maker. For example the model could pre-define that sending a surveillance CAP out 300 miles versus 150 miles will require tankers, to launch on a predetermined schedule. The experiments's CVBF staff would not need to manipulate the forces in detail, but they would simply select a long range surveillance, a medium range surveillance sector, or a short range surveillance sector.

The following capabilities would need to be added to the extracted RESA baseline.

a. <u>User interface</u>. Two users, the controller and the CVBF current situation staff officer, would be able to interface with the model. The interface would be a menu selection capability in which the Blue player would initially have the following options:

1) Move a carrier task force to a specific latitude and longitude.

2) Select a speed for the carrier task force.

3) Establish a CHAINSAW sector, centered on a specific axis and deployed to a specified distance.

4) Activate or deactivate radar.

5) Select an available EMCON plan.

6) Place aircraft on deck launched alert.

7) Assign a specific number of aircraft to intercept a known enemy mission group.

8) Formation selection.

b. Detection. A simple detection model would need to be developed. This model would be a time to detection model that would be a function of the CHAINSAW sectors occupied, the deploy distance of the sector, the jamming aircraft capability of the enemy mission, the status of active radars and the EMCON plan being used.

c. Enemy localization. A time to localization model would need to be developed. The time the enemy localizes the position of the carriers would be a function of the same characteristics described for the detection model.

d. Speed of advance model. This model would calculate the speed of advance capability of the carrier. This number would be based on the current sea condition, the wind direction and strength, the number and depth of the CHAINSAW sectors being flown, and the launching and recovery of deck launched interceptors. The launch and recovery sequence would not be modeled, and the carrier turning into the wind would not explicitly be modeled. The affects of these procedures will be included in the overall speed of advance of the task force.

e. Strike results. Once an incoming enemy mission is detected, and deck launched interceptors assigned, the only additional information that the commander will receive is the results of the enemy strike. The results will be calculated based on the distance at which the enemy aircraft were first detected, the distance at which the enemy aircraft were when the information of raid size was received by the commander, the number and type of interceptors that were sent, the number and type of escort and screen ships available to the carriers, the number and type of enemy aircraft sent and remaining friendly and enemy aircraft. This model is envisioned as starting off fairly simple, and growing in complexity as needed by further refinements in the experiment fidelity.

The first option, using RESA as it currently exists, is fast and requires minimum start up cost. We feel it is much more risky. R&A is extremely concerned that RESA has too many nuances, errors or peculiarities to be able to get the model to do exactly what the commander wants. The problem of maximum RESA game speed can not be solved, and needs to be strongly considered. The second option, development of a new model, will require a higher initial investment than option one.

In view of our understanding that unique experimental requirements can be identified and that experimental results must be validated, it appears that this option is the most risk averse. That is, option two has a higher probability of providing the research support that is needed than does option one. Option two would facilitate future model enrichment given the research is successful and continues. This option will be more portable than the other options. This could be an important attribute if, for example, the Joint Directors of Laboratories (JDL) members that have similar hardware systems, could support the use of this option if they found the model useful.

The options available for the decision aid terminal are independent of the option selected for the combat model. The time and effort required to implement decision aids are extremely dependent on the combat model option selected.

1. Create manual decision tables.

This option is to create tables and graphs that outline the cause and effect relationships between the commander's decisions and the experiment's results and objectives.

If expert players are used with RESA, this option becomes fairly difficult because the model would need to be run under a variety of circumstances and the data collected to provide the players with a set of information that is correlated with the combat model.

If a new model were developed, the tables themselves could be developed as part of the combat model data set and could then be used to determine the outcome of a given set of circumstances. In other words, the tables would be created and then the combat model would be created. Under this option, correlation would be insured.

2. Automate the decision tables on the same system as the combat model.

This option includes creating several decision aids that could be accessed automatically to obtain the required information. As the experiment progresses, these automated tools could be improved and refined. The following is a list of possible tools that could be developed.

a. Enemy attack radius. The user would be able to specify which type of aircraft were located at which enemy land bases. The decision tool would draw a circle on the graphics display indicating the area that was susceptible to enemy air strikes. It could also display the possible angles of attack for the carriers.

b. Speed of advance calculations. The user would enter the current sea state, wind, and the number of sorties that are being flown, and the model would calculate the speed of advance for the carrier group, and the estimated time of arrival at the group's destination. The decision tool would allow the player to enter a time of arrival at the objective, and the tools would provide information on various mixes of sorties that could be flown. For example, to reach that destination the commander may fly 4 sectors 24 hours a day, or 1 sector at night and 6 sectors during the day, etc. The table generated by the tools would provide a series of alternatives from which the commander could choose.

c. Sortie generation capability. The user would enter the current sortie generation plan. The decision aid would provide information on the availability of aircraft, crew, etc., by the time the group reaches the objective area. The aid could also allow the player to enter the required sortie rate at the objective area, and then provide a table of various current flight alternatives. For example to maintain a 50 sortie rate per day in the objective area 3 days from now, the commander may fly 75 sorties today, and 20 sorties the next two days, or fly only 30 sorties per day for the next three days.

As with the manual option, this option will take longer to develop if the expert player option is selected for the combat model. In fact these types of decision aids may be impossible to develop under the expert player option because RESA may not have the desired cause and effect relationships. These decision aids would be much easier to develop if a new model were developed for the experiments.

3. Use existing decision aids from the HP Integrated Tactical Decision Aid (ITDA) Software.

This option can not be coupled with using expert players to run RESA. The results of these existing decision models do not match the results provided by RESA, and would therefore be of no use to the decision makers.

This option would require that the combat model developed match the algorithms used by the ITDA system. This has the advantage of being tactically accepted by tactical commanders because the ITDA software has been reviewed by fleet staffs and used in an operational environment. The results may not be accurate, but they are acceptable; otherwise they would not have been released for operational use.

The disadvantage of this option is that the development of the combat model will take longer. The algorithms for the decision aids would need to be evaluated, and the combat model designed around these capabilities. Another disadvantage is the decision aids would not be on the same machine as the combat model. Future enhancements that would include integrating the selection of a decision alternative presented by the decision aid with the combat model would be fairly hard.

VII. Conceptual Design

Model Data

There will be no hard coded data within the SCRAM source code. All required data will reside in the scenario database, and will be read into the model as part of the initialization procedure.

The following data are required to support the modeling constructs described later in this design.

1. Passive Detection Multiplier - This data element is used to determine the range at which a force can passively detect an active emitter. (PDM)

2. Time Between Engagements - This data element is used to limit the number of engagements in which an enemy aircraft can engage. (TBE)

3. Number of BLUE Weapons - The number of BLUE weapon types that exist in the scenario. (NBW)

4. Number BLUE Aircraft Types - The number of BLUE aircraft types that exist in the scenario. (NBA)

5. Number BLUE Shipboard Emitter's - The number of BLUE emitter's that can be placed onboard BLUE ships in the scenario. (NBE)

6. Number BLUE Ships - The number of BLUE ships that exist in the scenario. (NBS)

7. Number of Enemy Weapons - The number of enemy weapon types that exist in the scenario. (NEW)

8. Number of Enemy Aircraft Types - The number of enemy aircraft types that exist in the scenario. (NEA)

9. Number of Enemy Bases - The number of enemy bases that are represented. (NEB)

10. Number of Pre-set EMCON Plans - The number of different EMCON plans that exist for the player at the beginning of the game. Note that the player can

create different EMCON plans as the game continues. (NEM)

11. BLUE Weapon Data Set - The following data are entered for each BLUE weapon that exists in the scenario.

a. Name - The text name and identifier of the weapon type. (BWN)

b. PK Array - This array holds the probability of kill for the BLUE weapon against its target. This array is dimensioned by the number of enemy aircraft types. Array(1) holds the PK of this weapon against enemy aircraft of type 1. (BWPK)

12. BLUE Aircraft Data Set - The following data are entered for each BLUE aircraft type that exists in the scenario.

a. Name - The text name and identifier of the aircraft type. (BAN)

b. Speed - The speed of the aircraft in KT. (BAS)

c. Flight Time - The time the aircraft can fly in minutes. (BAT)

d. Weapon Array - This array holds the number of weapons carried by the aircraft. The array is dimensioned by the number of BLUE weapons. Array(1) holds the number of weapon type 1 that are carried onboard the aircraft. (BAW)

e. Radar Power - The power of the aircraft's organic radar. (BAP)

f. Radar Range - The detection range of the aircraft's organic radar in NM. (BARR)

g. Communication Equipment Power - The power of the aircraft's communication equipment. (BAC)

h. Support Aircraft Required - This is a real number that represents the number of support aircraft that must be launched for each of these aircraft each flight time period. A number such as .5 means that for eery two of these aircraft launched, one support aircraft must be launched each flight time period. (BASA)

i. Maximum Flight Hours Per Day - This is the number of hours this aircraft can fly within a 24 hour period. (BAF)

j. Flight Hours Recovery Rate - This is the number of additional hours of flight the aircraft can fly per hour of idle time. (BAAF)

13. BLUE Emitter Data Set - The following data are entered for each BLUE emitter that exists in the scenario.

a. Name - The text name and identifier for the emitter. (BEN)

b. Type - The type of emitter. It may be a surface search radar, air search radar, jammer, or active communication equipment. (BET)

c. Power - The power of the BLUE emitter. (BEP)

d. Range - The effective range of the emitter in NM.

14. BLUE Ship Data Set - The following data are entered for each BLUE ship that exists in the scenario.

a. Name - The text name and identifier of the ship. (BSN)

b. Speed - The maximum attainable speed of the ship in KT. (BSS)

c. Aircraft Array - This array holds the number of aircraft onboard the ship. The array is dimensioned by the number of BLUE aircraft. Array(1) holds the number of BLUE aircraft of type 1 that are onboard the ship. (BSA)

d. Emitter Array - This array holds an indicator whether an emitter is onboard the ship. The array is dimensioned by the number of BLUE emitters. Array(1) holds a 1 if the emitter is onboard the ship, and a zero if it is not. (BSE)

e. Flight Ops Emitter - This is the identifier for the emitter that is required to conduct flight operations. (BSOE)

f. Launch Time - This is the time it takes the ship to launch one aircraft. (BSL)

g. Recovery Time - This is the time it takes the ship to recover one aircraft. (BSR)

h. Probability of Missile Kill Array - This array holds the probability that this ship can kill the indicated type of enemy air-to-surface missile. The array is dimensioned by the number of enemy weapons. Array(1) holds the probability that this ship can kill an incoming enemy missile of type 1. (BSMK)

15. Enemy Weapon Data Set - The following data are entered for each enemy weapon that exists in the scenario.

a. Name - The text name and identifier of the weapon type. (EWN)

b. Type - An indicator whether this is an air-to-air or an air-to-surface weapon. (EWT)

c. Probability of Launch - This is the probability that the weapon successfully launches. It is only used for air-to-surface weapons. (EWL)

d. PK Array - This array holds the probability of kill for the enemy weapon against its target. If it is an air-to-air weapon, this array is dimensioned by the number of BLUE aircraft. If it is an air-to-surface weapon, this array is dimensioned by the number of BLUE ships. Array(1) represents the PK against either BLUE aircraft type 1 or BLUE ship 1. (EWPK)

16. Enemy Aircraft Data Set - The following data are entered for each enemy aircraft that exists in the scenario.

a. Name - The text name and identifier of the aircraft type. (EAN)

b. Speed - The speed of the aircraft in KT. (EAS)

c. Weapon Array - This array holds the number of weapons carried by the aircraft. The array is dimensioned by the number of enemy weapons. Array(1) holds the number of weapon type 1 that are carried onboard the aircraft. (EAW)

d. Radar Range - The range of the aircraft's organic search radar in NM. If the mission of the aircraft is escort, then the search radar represents an air search radar. If the mission of the aircraft is attack, then it represents the surface search radar capability. (EAR)

e. Emitter Activation Range - The distance from the destination point that the enemy aircraft activates its emitters. For jamming mission aircraft the emitter activates is the jammer, for other mission types it is their active radar. (EAE)

f. Jamming Power - The power of the aircraft's organic jammer. (EAP)

17. Enemy Bases Data Set - The following data are entered for each enemy base that exists in the scenario.

a. Name - The text name and identifier for the base.

b. Location - The latitude and longitude of the base. Bases can not be moved. (EBL)

c. Aircraft Array - This array holds the number of enemy aircraft located at the base. The array is dimensioned by the number of enemy aircraft. Array(1) holds the number of enemy aircraft type 1 etc. (EBA)

d. Organic Surface Detection Range - This is the range in NM at which the base has the organic capability to detect BLUE surface vessels or aircraft. (EBD)

e. Mean Time To Detection - This is the mean time in minutes that it takes a base to detect a force once it is within range of the base's organic detection capability. (EBTD)

f. Mean Time From Detection to Localization - This is the mean time in minutes that it takes the base's organic capability to localize the force given that it has been detected. (EBTL)

g. Mean Time to Localize a Passive Detection - This is the mean time in minutes that it takes the base to localize a BLUE force that is actively emitting from which a passive detection was obtained. (EBPL)

18. EMCON Plan Data Set - The following data are entered for each EMCON plan that exists in the scenario.

a. Name - The text name and identifier for the EMCON plan. (EMN)

b. Activation Array - A two dimensional array, number of ships by number of emitters. The array holds an indicator whether the emitter is activated onboard the specified ship. Array(1,3) holds an indicator whether ship 1 has emitter type 3 activated under this EMCON plan. (EMA)

Enemy Detection of BLUE Force

Detection is defined as the instant in time that the enemy knows that the BLUE Force exists. The enemy does not know the exact location of the BLUE force, but it does know that it exists.

Detection can occur at the following times.

1. When an enemy surface force enters the Organic Surface Detection Range (EBD) of an enemy base it is subject to detection. The time of actual detection is an exponential random variate. The exponential distribution will be assigned a mean of EBTD of the base that got the detection.

2. When an active BLUE emitter gets within Passive Detection Range (PDR) of an enemy base. This range is calculated differently for the BLUE entity that can get detected. Either a BLUE ship or a BLUE aircraft can be detected.

BLUE Ship:

PDR of a base = EBD of the base +
(BER of the active ship emitter * PDM)

BLUE Aircraft:

PDR of a base = EBD of the base +
(BARR of the aircraft * PDM) +
Sector Range of the Aircraft

Localization is defined as the instant in time that the enemy knows an exact enough location of the BLUE forces to initiate an airstrike if desired and within range.

Localization will occur relative to the time of detection. The time between detection and localization will be calculated as follows:

1. If detection occurred using Detection Rule 1 above, the time between detection and localization is an exponential random variate. The exponential distribution will be assigned a mean of EBTL of the base that got the detection.

2. If detection occurred using Detection Rule 2 above, the time between detection and localization is an exponential random variate. The exponential distribution will be assigned a mean of EBPL of the base that accomplished the detection.

BLUE Detection of Enemy Aircraft

BLUE aircraft and BLUE ships can detect incoming enemy aircraft. Again detection is defined as the instant in time that the BLUE side realizes that there are enemy aircraft in the vicinity. It does not consist identification of the enemy aircraft or localization of their exact position.

Detection can occur at the following times.

1. When enemy aircraft enter the active detection range of a shipboard air search radar that is active according to the current EMCON plan.

2. When enemy aircraft enter the area covered by the BLUE aircraft organic radar range (BARR) of an early warning aircraft station.

3. When enemy aircraft enter the area covered by a sector. This area is a pie shaped area centered at the formation center and extending out a distance equal to the range of the sector specified by the player plus the BLUE aircraft organic radar range. (BARR)

4. When an enemy aircraft gets within range of any BLUE force equal to its radar range (EAR) times the passive detection multiplier (PDM) after the enemy aircraft has activated its radar according to the activation distance specified. (EAA)

5. When an enemy jamming mission aircraft activates its jammer.

Interception starts immediately if there are sector aircraft flying, or as soon as the player orders deck launched interceptors to conduct the intercept. When interception occurs, the enemy aircraft are localized, and the BLUE aircraft knows the total makeup of the enemy air mission. The time to interception depends on how long it takes the BLUE for to get a radar close enough to the enemy mission to accomplish an active detection. The maximum allowable separation distance (SD) for interception is calculated as follows and is unique for each BLUE platform (i.e. aircraft or ship).

If there is an enemy jammer activated, the SD of a BLUE radar will be calculated as:

SD = SQRT (Radar Power / (EAP * 4 * PI))

The Radar Power is either BAP or BEP depending on whether the radar is onboard an aircraft or onboard a surface vessel.

If there is no enemy jammer activated, the SD is simply the range of the active radar. If a radar is not active because of an existing EMCON plan, the SD is set to infinity. Note that aircraft are not subject to existing EMCON plans, only surface vessels follow an EMCON plan.

The next step is to determine how long it will take to get a BLUE force within its SD of the enemy mission, and thus accomplish the interception or identification.

There are four different BLUE forces that can be used. The time to get to within SD distance of the enemy mission for each force is calculated differently.

1. If the BLUE force is a surface vessel, identification occurs at the instant in time the enemy mission flies within the SD range of the surface vessel.

2. If the BLUE force is an existing early warning aircraft, identification occurs at the instant in time the enemy mission flies within the SD range of the orbit location of the early warning aircraft.

3. If the BLUE force is a deck launched interceptor, the time of identification is equal to the (formula available later). The player must specifically launch a deck launched interceptor.

4. If the BLUE force is a sector CAP aircraft, the location of the CAP aircraft is assumed to be at the maximum range of the sector along the center radial of the sector. Given this location, the calculation for the time to identification is the same as described for the deck launched interceptor. The sector aircraft that is closest to the enemy aircraft is automatically sent on the interception.

Identification does not necessarily mean that the BLUE player is informed immediately about composition of the enemy mission. There is a report delay time that is calculated. The report delay time is different depending on how the identification was accomplished.

1. If identification was accomplished using rules 1 or 2 above, the report delay time is zero. The player is notified at the time of the identification.

2. If identification was accomplished using rule 3 or 4 above, the intercepting

aircraft must get within communication distance (CD) of either a BLUE surface vessel that has a communication emitter activated, or an orbiting early warning aircraft. The CD is calculated with reference to the receiving platform. CD is calculated as follows:

CD = SQRT((Power Comm * Jammer-Comm Range) / EAP))

The Power of the receiving communications equipment is BEP for a surface platform and BAC for an airborne communications platform. The intercepting aircraft selected heads directly for the closest available communication platform. The CD of the platform changes as time passes because of the movement of the enemy jammer. This calculation is checked each game cycle to determine whether a report capability exists.

Speed of Advance

A formation will advance at the ordered speed if all ships within the formation can maintain the designated speed. If all ships can not maintain the designated speed, the speed of advance is set to the speed of the slowest ship in the formation.

Speed of advance is also affected by the number of aircraft that need to be launched. The speed of advance of the formation is recalculated whenever one of the following events occur.

1. The formation reaches a way point and is ordered to change speed.

2. The formation is ordered to maintain another defense sector.

3. The formation is ordered to maintain another early warning station.

4. The formation is ordered to launch a deck launched interceptor.

At these instances in time, the speed of advance in KTS is calculated using the following formula. The Adjusted Speed (AS) for each ship in the formation is calculated. The AS for the entire formation is the smallest ship AS.

The AS for a ship is calculated as follows:

1. Calculate the time required to launch and recover all aircraft from this ship. This is done as follows:

a. Calculate the number of aircraft required to launch per hour (AL). This is done by summing the aircraft required (AR) value over all sectors, early warning stations and interceptors that are maintained by this ship.

AL = Sum of AR for all sectors and stations.

AR = (NA + (NA * BASA)) / BAT

Where NA is the number of aircraft in the sector, early warning mission or interceptor mission.

b. The model currently assumes that the number of launches per hour is equal to the number of recoveries per hour. Given this assumption the aircraft operation time (OT) is calculated using the following formula:

OT = AL * (BSL + BSR)

2. Although not technically true, the speed capability of a ship during flight operations is assumed to be zero. The assumption is considered reasonable because there are times when the ship would need to turn, and in fact travel in a direction opposite from the desired direction. These situations are simply ignored, and the assumption is that no distance advancement is possible during the launch and recovery of aircraft.

The percentage movement time (PMT) per hour is equal to:

PMT = 1.0 - (OT / 60.0)

3. AS = PMT * BSS

If the AS for the formation is greater than the currently ordered speed (OS), the formation speed is set to the ordered speed. If the AS is less than the OS, the formation speed of advance is set to AS. Currently there are no plans to adjust the speed of advance of the formation due to enemy attacks.

<u>Sortie Rate</u>

As part of the initialization procedure, each ship is given an array of the number of flight hours available (FHA) to the ship by aircraft type. This array is a single dimensioned array. It is dimensioned by NBA. NBA(1) contains the total number of flight hours initially available for the ship from aircraft type 1. The values in the FHA array are calculated as follows:

FHA(I) = BAF for the Ith aircraft * BSA(I)

When an aircraft tries to launch, two checks are made. First, the aircraft must be available and onboard the ship. These data are obtained from the BSA array. Second, there must be enough flight hours in the FHA array for the aircraft type to support the full flight time (BAT) of the aircraft. If either check is not passed, the flight will not be allowed to launch.

A ship's FHA array is readjusted whenever an aircraft launches or an aircraft recovers from the ship. A variable associated with the ship holds the time of the last (TL) FHA adjustment. First the time since the last adjustment (TA) is calculated as Current Time (CT) - TL. The following calculation is then done for all aircraft types onboard the ship.

FHA(I) = FHA(I) + (TA * BAAF * BSA(I))

FHA is never allowed to exceed the original value of FHA that was entered as part of the initialization database.

The formation's sortie rate per day is the sum of the sorties per day for all aircraft types over all ships in the formation. A sortie rate (SR) for a specific ship and aircraft combination is calculated as follows:

SR = FHA(I) / BAT for aircraft I.

Strike Results

Both air-to-air combat and air-to-surface combat must be modeled. Air-to-air combat is calculated against all attacks and feints. Air-to-surface strike results are only calculated against the attack missions.

Air-to-air combat takes place at the following times:

1. As soon as interception and identification occurs, if the player has specified a war situation. There are no weapon range checks currently planned.

2. When an interceptor is specifically sent to attack the mission.

Air-to-air combat is resolved in the following manner. Enemy escorts are first priority, then enemy jammer, then enemy attack missions. Although this is not the fighter's priority, the assumption is that the enemy escorts are doing their job and keeping the interceptors away from the attack aircraft.

For each BLUE aircraft, the aircraft selects one enemy aircraft at which to fire. The BLUE aircraft fires 1 weapon at a time until the enemy aircraft is killed or it runs out of weapons. If the enemy aircraft is killed, the BLUE aircraft will not be allowed to fire again until the enemy has had its chance to fire.

After all BLUE aircraft fire, each of the enemy aircraft with air-to-air weapons that have not fired within the TBE time are allowed to select one BLUE aircraft at which to fire. Each capable enemy aircraft fires one weapon at a time until either it runs out of weapons or kills the BLUE aircraft.

This BLUE fire, enemy fire sequence is continued until all aircraft weapons have been expended. At this time, the TBE of the enemy aircraft that fired is set to the current time.

If any BLUE aircraft are remaining, they head toward their home ship. If all enemy aircraft have been killed, all intercepting aircraft are sent back to their home base, and all sector aircraft return to their sector.

Air-to-Surface combat takes place when an enemy attack mission reaches its designated launch point. At this time all air-to-surface missiles are launched. Each weapon randomly selects a ship in the formation. A uniform random variate is drawn to determine whether it launches successfully. This determination is made by comparing the random variate with EWL. Another uniform random variate is drawn to determine whether the ship's missile defenses and decoys stopped the missile. This determination is made by comparing it to the value held in the BSMK array for the type of incoming missile. If the missile successfully arrives at the ship, a third and final uniform random variate is drawn to determine whether the missile impact resulted in a ship kill. This determination is made by comparing the random variate with the value held in the array EWPK. The definition of kill is not intended to mean the ship sank, but is used to indicate that the ship can no longer function as part of the formation.

VIII. Conclusions

NPS is conducting research to evaluate the potential impact of Soviet countermeasures to U. S. C^3I capabilities on the U.S. Pacific Command's (PACOM) mission. The purpose of the research is to develop methodologies to directly relate the Soviet employment of C^3ICM to the ability of U.S. forces to carry out PACOM strategy. These methodologies should help understand which communication links and information sources are the most important to our tactical commanders within PACOM. Given the research is successful, CINCPAC will be able to use the results to decide the level at which information sources should be protected against the Soviet C^3ICM capabilities.

This type of research is most difficult because it deals with many disparate elements that must be effectively interrelated to attain research objectives. For example, the affects of Soviet C^3ICM depend on the interaction between timely C^3ICM information on threats to the naval forces, availability of communications links, warfare engagement capabilities, and command decisions. It also deals with the essence of the human decision making process.

These interactions cannot be satisfactorily treated by analytic techniques alone. They require examination in a carefully controlled environment and the use of non-obtrusive methods to avoid contamination of the data. Fortunately, they are amenable to representation within combat simulations. Unfortunately, there is no single wargame (combat simulation) available at NPS that meets the needs of this research.

There are several implementation options available to develop the decision environment of the C^3I research experiments. The goal is to create an integrated system that provides a realistic decision environment tempered against the constraints of model fidelity, model cost, implementation time, and the availability of the principal investigators.

The final analysis leads to recommending the design and development of a new combat model. The conceptual design includes player stations consisting of three alphanumeric terminals and one graphics display to provide the information and wargaming environment for the research. Our recommendation includes the following:

- o A new model using RESA graphics representations and RESA movement kinemetrics as appropriate. ref. p. 18.

- o An integrated COMNET that will always be synchronized with the combat model. ref. p. 16.

o Automated decision tables. ref. p. 20.

Figure 2, SCRAM Development Estimate, lists the primary functions for implementation of SCRAM.

HOURS: FUNCTIONS:	ANALYST HIGH	ANALYST LOW	PROGRAMMER HIGH	PROGRAMMER LOW
COMNET	50	35	120	84
NEW MODEL:				
o USER INTERFACE	60	42	112	78
o DETECTION	36	25	60	42
o LOCALIZATION	36	25	80	56
o ADVANCE SPEED	56	39	104	73
o STRIKE RESULTS	48	34	118	83
o MOVEMENT	32	22	88	62
o RESA ANALYSIS	44	31	80	56
o RESA EXTRACTION	54	38	160	112
o GRAPHICS	90	63	90	63
DSS DESIGN	20	14	20	14
DSS IMPLEMENTATION	20	14	40	28
TOTALS:	546	382	1,072	750

Figure 2. SCRAM Development Estimate

An estimate of hours by functional expertise and area is provided for planning purposes.

The Soviet C^3ICM Research and Analysis Model (SCRAM) will be a new model that will have an embedded COMNET capability unique to its (SCRAM's) requirements. It will also have the structure and initial decision analysis tables immediately available to the user but on a separate display. This implementation meets all of the research goals while permitting the users a complete understanding and control of the model structure from its inception. It will also provide the NPS Basic Research Group (BRG) an opportunity to nurture the model's growth based on future research requirements.

The development of the SCRAM will provide the NPS BRG a capability to explore and evaluate various ramifications of the Task Force Commander's information environment. Designed to satisfy stringent research requirements, this model will form the basis to permit a detailed evaluation of hypotheses, be analytically defendable, accurate (yet easy to use), and modular. The baseline structure will be modular and data driven to facilitate future growth, flexibility and modification.

The range in elapsed time to completion shown in Figure 2 represents a development to implementation time of from three to four months. Given a start date of 1 June 1989 the pessimistic estimate is 1 October 1989. The optimistic date is 1 September.

While there are no precise metrics that can be used for estimating the development of this type of software, we know that the time and resources required to implement the Soviet C^3ICM Research and Analysis Model depend on a number of diverse factors. This includes the preciseness and completeness of functional requirements, the availability of computer time, quality of available documentation, number and type of changes that occur during implementation and the quality of the developers.

It will be R&A's responsibility to manage these factors and notify the NPS BRG of activities which have, or could have, a negative impact on the schedule. The BRG has responsibility for providing computing resources, data, documentation and test requirements. A preliminary cost estimate is provided at Appendix A.

APPENDIX A

ESTIMATED COSTS

USE and DISCLOSURE of DATA

The data contained in this Appendix are proprietary to ROLANDS & ASSOCIATES Corporation and are provided in this detail by request of the Naval Postgraduate School Basic Research Group contract monitor for evaluation purposes. These data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than as needed to evaluate this effort. If a contract is awarded as a result of, or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the contract. This restriction does not limit the Government's right to use information contained in the data if it is obtainable from another source without restriction. The data subject to this restriction are contained in this Appendix.

Ronald J. Roland, Ph.D.
President

Estimated Costs

The following estimates are based on the substance of this report and our modeling experience. They are proprietary and are not for distribution outside the BRG except for development of budgetary matters expressly related to this effort. These estimates are based on a range of three to four months of full time efforts of one senior analyst and one programmer. No travel, documentation or document reproduction costs are included.

	ANALYST		PROGRAMMER	
	HIGH	LOW	HIGH	LOW
COMNET	$3,808.50	$2,665.95	$3,654.00	$2,557.80
NEW MODEL:				
O USER INTERFACE	$4,570.20	$3,199.14	$3,410.40	$2,387.28
O DETECTION	$2,742.12	$1,919.48	$1,827.00	$1,278.90
O LOCALIZATION	$2,742.12	$1,919.48	$2,436.00	$1,705.20
O ADVANCE SPEED	$4,265.52	$2,985.86	$3,166.80	$2,216.76
O STRIKE RESULTS	$3,656.16	$2,559.31	$3,593.10	$2,515.17
O MOVEMENT	$2,437.44	$1,706.21	$2,679.60	$1,875.72
O RESA ANALYSIS	$3,351.48	$2,346.04	$2,436.00	$1,705.20
O RESA EXTRACTION	$4,113.18	$2,879.23	$4,872.00	$3,410.40
O GRAPHICS	$6,855.30	$4,798.71	$2,740.50	$1,918.35
DSS DESIGN	$1,523.40	$1,066.38	$609.00	$426.30
DSS IMPLEMENTATION	$1,523.40	$1,066.38	$1,218.00	$852.60
SUBTOTALS:	$41,588.82	$29,112.17	$32,642.40	$22,849.68

The total estimated costs range from a minimum of $51,961.85 to $74,231.22.

Soviet C3ICM Research and Analysis Model (SCRAM) Controller's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Orange Force Data:	Model Calculation	Controller Override
Detection of Battle Force:	28-MAY-1989 23:45	
Localization of Battle Force:	29-MAY-1989 06:15	30-MAY-1989 04:00
Planned Ground Force Moves:	4	
Planned Feints:	2	
Planned Attacks:	1	

Blue Force Data:

Pre-planned Intelligence Reports: 6

Soviet C3ICM Research and Analysis Model (SCRAM) Controller's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Planned Ground Force Moves: 4

Number	Force	From	To	Time	Type	Event
1	5 Badgers	Petro	Vlad	29-MAY-1989 19:00	Absolute	
2	15 Backf-E	Petro	Vlad	5:15	Relative	Detection
3	12 Floggers	Petro	Vlad	5:15	Relative	Detection
4	1 Moss	Petro	Vlad	0:00	Relative	Localization

Soviet C3ICM Research and Analysis Model (SCRAM) Controller's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Planned Feints: 2

Number	From	Lat (Bear)	Long (Dist)	Type	Time	Type	Event
1	Vlad	60:00N	170:00W	Absolute	4:30	Relative	Detection
2	Vlad	100	75	Relative	29-MAY-1989 23:15	Absolute	

Soviet C3ICM Research and Analysis Model (SCRAM) Controller's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Planned Feint Number 1:

From:	Vlad		
To:	60:00N 170:00W	Absolute	
Time:	4:30	Relative	Detection
Attack 1:	10 Badgers		
Attack 2:			
Escort:	5 Flogger		
Jammer:	1 Moss		
Early Warning:			

Soviet C3ICM Research and Analysis Model (SCRAM) Controller's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Planned Feint Number 2:

From:	Vlad	
To:	100 75	Relative
Time:	29-MAY-1989 23:15	Absolute
Attack 1:	1 Badgers	
Attack 2:	1 Backf-E	
Escort:	5 Flogger	
Jammer:	1 Moss	
Early Warning:	1 Moss	

Soviet C3ICM Research and Analysis Model (SCRAM) Controller's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Planned Attacks: 1

Number	From	Lat (Bear)	Long (Dist)	Type	Time	Type	Event
1	Vlad	100	75	Relative	2:00	Absolute	Detection

Soviet C3ICM Research and Analysis Model (SCRAM) Controller's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Planned Attack Number 1:

From:	Vlad			
To:	200 75		Relative	
Time:		2:00	Relative	Localization
Attack 1:	10 Badgers			
Attack 2:	10 Backf-E			
Escort:	15 Flogger			
Jammer:	1 Moss			
Early Warning:	1 Moss			

Soviet C3ICM Research and Analysis Model (SCRAM) Controller's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Pre-planned Intelligence Reports: 6

Number	File Name	Time		Type	Event	Number
1	MOVE1.DAT		2:00	Relative	Move	1
2	MOVE2.DAT		1:00	Relative	Move	3
3	LAUNCH1.DAT		0:45	Relative	Feint	2
4	LAUNCH1.ERR	29-MAY-1989	23:30	Absolute		
5	MOVE3.DAT		5:00	Relative	Move	3
6	VLAD.RPT		(1:45)	Relative	Attack	1

25-MAY-1989 14:15	
Sectors ON	
Threat ON	
Formation OFF	
Enemy Bases OFF	
Move Plan ON	
Radar Cover ON	

Soviet C3ICM Research and Analysis Model (SCRAM) Player's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

	Current	Objective
Battle Force Location:	50:00N 140:00W	62:00N 173:00W
Time on Location:	30-MAY-1989 0:45	29-MAY-1989 23:30
Sortied Rate:	66 per day	54 per day
Speed of Advance:	7 KTS	14 KTS
Intermediate Movement Plan:	5	
Number Defense Sectors Flying:	2	
Number Early Warning Aircraft Flying:	1	
EMCON Plan:	ALPHA-1	2
Formation:	PLAN-1S	2

Soviet C3ICM Research and Analysis Model (SCRAM) Player's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Intermediate Movement Plan: 5

Number	Location	Speed
1	55:00N 150:00W	15
2	50:00N 150:00W	10
3	52:00N 160:00W	10
4	55:00N 170:00W	10
5	62:00N 173:00W	24

Soviet C3ICM Research and Analysis Model (SCRAM) Player's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Number Defense Sectors Flying: 2

Number	Aircraft	Ship	Bearing	Width	Range
1	F-14	KITTY	250	30	100
2	FA-18	NIMITZ	280	30	150

Soviet C3ICM Research and Analysis Model (SCRAM) Player's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Number Early Warning Aircraft Flying: 1

Number	Aircraft	Ship	Bearing	Range
1	E-2C	NIMITZ	265	50

Soviet C3ICM Research and Analysis Model (SCRAM) Player's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

EMCON Plan: ALPHA-1 2

Number	Name
1	ALPHA-1
2	BRAVO-1A

Soviet C3ICM Research and Analysis Model (SCRAM) Player's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

EMCON Plan: ALPHA-1

Ship	SPS-10	SPS-55	Link1	Link13	Link23	Link9	Comm12
NIMITZ							ON
PRINCE	ON	ON	ON	ON	ON	ON	ON
N-2							
N-3							
N-4	ON	ON					
N-5							
KITTY							ON
K-1							
K-2							
K-3							
K-4							

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Soviet C3ICM Research and Analysis Model (SCRAM) Player's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Formation: PLAN-1S 2

Number	Name
1	PLAN-1
2	PLAN-1S

Soviet C3ICM Research and Analysis Model (SCRAM) Player's Terminal

Scenario: NorthPac
Game Time: 25-MAY-1989 14:15
Game Ratio: 12:1

Formation: PLAN-1S

Ship	Guide	Bearing	Distance
NIMITZ	Center	10	5
PRINCE	NIMITZ	250	120
N-2	NIMITZ	10	2
N-3	NIMITZ	300	2
N-4	NIMITZ	260	2
N-5	NIMITZ	240	1
KITTY	NIMITZ	180	50
K-1	KITTY	25	2
K-2	KITTY	300	2
K-3	KITTY	270	2
K-4	KITTY	300	5

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