Evolution of Models at the Warrior Preparation Center

Problems and Solutions for Higher-Echelon Exercises

Patrick D. Allen

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United States Army

RAND

PREFACE

This Report documents the results of a two-year RAND project that provided direct support to the Warrior Preparation Center (WPC), a U.S. military training support facility located in Germany. The project investigated the methodology of several models used to support U.S. forces in Europe. This document should be of interest to individuals interested in military training, training simulations, training facilities, and exercise design.

The research described here was accomplished and reported in 1991 at the request of Brig Gen David L. Vesely of the Air Force Intelligence Command, who was at that time commander of the WPC. Since then, many changes have occurred at the WPC and with its modeling suite, so that the Report's description of the WPC issues is more historical in nature. Despite this, RAND is issuing the Report now because the kinds of issues raised will continue to emerge in other organizations. It should also be noted that the independent analysis reported here was always controversial within the WPC and will continue to be. More generally, opinions about how to deal with both issues of detail and higher-level depictions of battle vary drastically in the community.

This project was jointly funded to varying degrees over time by both the Army and the Air Force. During the first year, funding was provided under the Manpower and Training Program of the Army Research Division's Arroyo Center. During the second year, funding was provided both under the Force Employment and Development Program of the Arroyo Center and under the Force Employment Program of Project AIR FORCE. Project AIR FORCE and the Arroyo Center are two of RAND's federally funded research and development centers.

SUMMARY

PURPOSE

This Report describes the evolution of the suite of models at the Warrior Preparation Center (WPC) and RAND's participation in the evaluations leading to the decisions regarding the future WPC model suite. The author spent over two years (1989–1991) on site at the WPC interviewing exercise participants, supporting analysis of WPC exercises, reviewing the existing WPC model suite, and examining alternative models. He was asked by the WPC commander at that time, then Col David Vesely, to perform a critical review of the existing WPC suite of models, and to head the Models Investigation Project.[1]

The review and the investigation led to a set of recommendations regarding the future WPC suite of models. Some of these recommendations have already been implemented at the WPC. This Report documents the findings of these investigations and describes, to the best of our knowledge, the WPC's progress as of June 1992 in implementing those recommendations. This information will be of interest to any organization attempting to design or support higher-echelon exercises in particular and computer-assisted exercises in general.

BACKGROUND AND RESULTS

The WPC is a training support facility manned and funded by U.S. Air Force Europe and U.S. Army Europe. The WPC's current mission is to provide the opportunity for senior commanders and their staffs to train in the operational art of war through the use of interactive computer simulation and distributed wargaming techniques.

[1]The research described here was accomplished and reported in 1991 at the request of Brig Gen David L. Vesely of the Air Force Intelligence Command, who was at that time commander of the WPC. Since then, many changes have occurred at the WPC and with its modeling suite, so that the Report's description of the WPC issues is more historical in nature. Despite this, RAND is issuing the Report now because the kinds of issues raised will continue to emerge in other organizations. It should also be noted that the independent analysis reported here was always controversial within the WPC and will continue to be. More generally, opinions about how to deal with both issues of detail and higher-level depictions of battle vary drastically in the community.

RAND's cooperation with the WPC extends back to the formation of the WPC in 1983, with increased cooperation over the last four years that led to the author's 1989 to 1991 tour at the WPC on a direct-assistance project. During this tour at the WPC, RAND's efforts were defined by mutual agreement with the WPC and focused on three related areas:

1. A critical examination of the methodological issues in the current WPC suite of models, emphasizing current performance and areas requiring improvement
2. Analysis support to the WPC's Analysis Group, including interviews of WPC customers and surveys of exercise participants[2]
3. An investigation of existing models that might serve as alternatives to the existing WPC suite of models.

In 1988, the WPC faced a sudden change in its customer base that created new problems for the way the WPC traditionally accomplished its mission. Underlying assumptions and exercise designs that were well-suited for the earlier customer base needed to be critically evaluated in the light of these new requirements. Once the underlying assumptions were identified and evaluated by the author for current applicability, the search for alternative models and exercise designs could begin in earnest.

The author initiated and led the Models Investigation Project that reported directly to the WPC's commander and vice-commander at that time. WPC personnel from each functional area were assigned to the project team. As team leader, the author prepared a report of the project's findings that led to two significant recommendations and results.

The first key recommendation was that the WPC should have two sets of models—one for army group and above exercises, and one for army group and below exercises.[3] This recommendation has been

[2]WPC customers are the users of the WPC training support facility. These customers have included almost all of the major and primary U.S. and NATO commands in Europe.

[3]Either model suite could be used for army group exercises, depending upon the composition of the training audience and the training objectives. If the training audience includes the army group staff and many staff elements from subordinate echelons, then a continuous air picture may be required, and therefore the more detailed suite should be used. If, instead, the training audience includes only the army group staff in the training audience, and any subordinate echelons are represented as response cells, then a continuous air picture is not required, and the less detailed model(s) may be used.

partially accepted by the WPC. After assuring the Senior Officer Steering Committee (SOSC) that the Joint Theater-Level Simulation (JTLS) would offer future benefit to the WPC, the WPC obtained consent from the SOSC for the WPC to pursue the use of JTLS for the upcoming higher-echelon Allied Command Europe (ACE) 92 exercise.[4]

The second key recommendation was that for lower-echelon exercises, the Corps Battle Simulation (CBS) should be substituted for the existing WPC ground warfare simulation (GRWSIM), given three modifications.[5] Since the completion of the direct assistance project, these three modifications have been accomplished and are undergoing testing. The WPC's current position is that CBS will be available as an alternative to GRWSIM, but that GRWSIM will continue to be available for any customers who may prefer to use it.

The inclusion of both JTLS and CBS at the WPC would bring the WPC into the larger community of joint training that uses the same service-approved and centrally controlled training models. By placing less emphasis on extensive in-house model development, the WPC will be able to avoid five of the seven overhead model-development tasks that incur large manpower and cost requirements.[6] Fully accepting these recommendations will allow the WPC to provide improved training support at reduced manpower and cost requirements in the long run. In the short run, the transition to the alternative models will entail increased support requirements, especially if the WPC attempts to fully maintain the GRWSIM model recommended for replacement.

The rest of the summary provides additional material on the change in the WPC customer base and training environment, the institutional assumptions that contributed to a need for change, the reevaluation of these old assumptions, and a description of the proposed future WPC model suite.

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[4]Because of recent dramatic world events, the design of ACE 92 has since been significantly changed. It appears that ACE 92 will now be a seminar game, performed without the support of a combat simulation.

[5]CBS was previously called the Joint Exercise Support Simulation (JESS). The specific modifications are listed in Section 6.

[6]The seven overhead tasks are model design, coding, testing, configuration control, documentation, database development and database configuration control. The first five tasks can be avoided by placing less emphasis on in-house model development.

CHANGES IN THE WPC CUSTOMER BASE AND TRAINING ENVIRONMENT

To understand the present capabilities and limitations of the WPC, it is necessary to examine briefly the evolutionary path the WPC has taken. The WPC mission is to provide the opportunity for senior commanders and their staffs to train in the operational art of war using interactive computer simulation and distributed wargaming techniques.

The composition of the WPC's customer base recently expanded from predominantly corps and army group or allied tactics air force–level headquarters to ACE-level and regional headquarters (e.g., AFNORTH, AFCENT, AFSOUTH) with the advent of the ACE-wide exercise. The WPC model suite, however, was designed to provide sufficient detail to support corps-level exercises. This level of detail became a tremendous burden for higher-echelon exercises, especially because of the high manpower and cost requirements. For example, the number of training support personnel required to operate every company and aircraft flight for a region-wide or higher-echelon exercise was estimated as somewhere between 300 and 500 additional training support personnel.[7] In the face of projected manpower shortages, this large personnel requirement for training support personnel became infeasible from the perspective of the training headquarters. The issue was not just the need to supply a sufficient number of bodies but the need to supply a sufficient number of personnel with the unique set of skills associated with the key staff functions to be represented during an exercise.

Although the current suite of models could still adequately support corps and army group/ATAF-level exercises, it became apparent that the existing WPC suite of models could not adequately support an ACE-wide exercise and was cumbersome for regional exercises. As a result of the problems encountered during the ACE-wide "ACE 89" exercise, many participants, independent groups (including RAND), and the WPC began searching for alternative models and exercise designs more appropriate for regional and ACE-wide exercises.

[7]For example, a training headquarters wishes to exercise a regional headquarters, such as AFCENT. The WPC provides its own manpower, the hardware, and the software provided by its own personnel authorizations and budget. The training headquarters must provide the 300 to 500 additional training support personnel from its own personnel authorizations, in addition to the personnel of the subordinate headquarters being trained. Furthermore, the communications costs must be provided by the training headquarters, or through special funds provided for projects, such as the Defense Advanced Research Projects Agency's distributed wargaming project.

INSTITUTIONAL ASSUMPTIONS THAT CONTRIBUTED TO A NEED FOR CHANGE

The early experiences at the WPC helped institutionalize the assumptions that drove model development and exercise design at the WPC. The WPC commander and directors delineated the following assumptions to RAND personnel[8] at a meeting early in the summer of 1989:

1. Realism can only be provided by a large amount or high level of detail in the models (e.g., represent and operate every aircraft and every company individually).
2. Higher-echelon exercises require the same level of detail as lower-echelon exercises.
3. Training headquarters require 1:1 time compression.[9]
4. Changing code is the key to responding to customer needs, even during exercises.

Although these assumptions were adequate for the early corps and army group–level training headquarters and the training environment the early WPC faced, *they were not valid for* higher-echelon exercises and the new training environment the WPC faced.

For example, when the WPC was first formed in 1983, there were no existing models that could adequately support the requirements of the early WPC customer base. The AirLand Battle doctrine was not yet published, and few models adequately represented the interaction of air and ground components. Therefore, the decision was made to perform model development and model modification in house. This led to the fourth assumption, that changing the code was the best way to be responsive to customer needs.

Unfortunately, model development carries with it a large number of overhead tasks, including model design, coding, testing, configuration control, documentation, database development, and database configu-

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[8]RAND employee Leland Pleger, a former acting commander of the WPC, visited the WPC as project leader of the RAND Unit Training Strategies project. The author participated in that meeting. The WPC commander at that time was COL Campbell, who was Col Vesely's predecessor.

[9]Time compression is the ratio of model time to real (clock) time. For example, a 3:1 time compression means that three days in the computer simulation can be accomplished in one day of real time. A 1:1 time compression ratio means simulated time equals real time. There is no time compression when the simulation time equals real time, but the time compression *ratio* is 1:1.

ration control. As a result, the WPC required itself to incorporate a large number of personnel with unique skills and incur high annual costs to adequately perform these associated overhead tasks.[10]

Many successful training support facilities (e.g., the National Simulation Center, the Vth Corps simulation center, or the Joint Warfare Center) do not assume the responsibility for substantial in-house model development. Very little code writing occurs at these organizations, and few personnel are associated with code writing or modification. Instead, they use centrally developed, monitored, and controlled models to support exercises, and they provide the flexibility to customer needs strictly through database modifications. These training support facilities appear to be very successful with very limited manpower and budget requirements.

REEVALUATING OLD ASSUMPTIONS

Because of the dwindling manpower and monetary resources projected to be available to the military in Europe in general and to the WPC in particular, RAND initiated a reevaluation of some of their institutional assumptions (listed above). This reevaluation had two significant results when briefed to the WPC commander and vice commander.

The first RAND recommendation was that the WPC should strive to reduce in-house model development and modification and should focus on improving training support activities. This recommendation supported the WPC's decision not to perform any further major model development in house, although significant model maintenance would still be performed. WPC training support activities include, for example, defining WPC model requirements and monitoring external organizations building models for the WPC, but without incurring the enormous overhead requirements of major in-house model development activities. Since the centrally funded organization incurs the overhead costs and manpower requirements, the WPC does not have to incur these costs. As a result, WPC manpower and funds previously allocated to overhead model development tasks could be reallocated to improved training support, including database preparation, defining WPC model requirements, and monitoring external model development. This approach will allow the WPC to adapt to the changing training requirements in the face of projected reductions in

[10]As of mid-1992, there were 150 authorized personnel positions at the WPC and a budget of $10 million, not including add-on funds and additional training support personnel and communications required to support specific exercises.

manpower and budget. Although the transition away from in-house model development cannot be instantaneous, the WPC use of models common to the rest of the training community will greatly facilitate this transition.

PROPOSED WPC FUTURE MODEL SUITE

A second RAND recommendation resulted from the initiation of a new investigation of alternative models and exercise designs without the old institutional assumptions. The author initiated and led the Models Investigation Project, which reported directly to the WPC commander and vice commander. WPC personnel were assigned to the project team from each of the WPC's functional areas. The author prepared the project report that recommended two sets of models (one for army group and above and another for army group and below). The project team also recommended the CBS model as a good alternative for the WPC's GRWSIM model for lower-echelon exercises and the JTLS model for higher-echelon training.

CBS and AWSIM for Army Group and Below Exercises

The CBS model has a number of advantages over the current GRWSIM ground combat model. A few of the most important advantages include an adequate representation of basic combined arms effects (currently absent in GRWSIM), easier database preparation, a more flexible representation of unit location, and the ability to combine and separate units dynamically during model execution. The level of resolution of the two ground models is virtually identical. Both models can track units to company level, and the terrain hex sizes are 3 km in CBS and 3.2 km in GRWSIM. Manpower requirements to operate either model in the same exercise design are equivalent.

The WPC identified three specific changes for model modifications so that CBS could support WPC exercises: First, CBS must be connected to the Air War Simulation (AWSIM) model. Second, CBS must be expanded so that multiple corps may be trained in the same exercise, including the rear and deep operations. Third, CBS must allow its graphical interface to interface with the more recent Graphic Interface Aggregate Controller (GIAC) system, which was developed under WPC sponsorship.

Since the completion of the author's tour at the WPC, all three requirements have been accomplished and are undergoing testing. As of June 1992, the AWSIM-to-CBS interface had been tested and ac-

cepted for use in an upcoming exercise in preparation for REFORGER 92. The CBS "play box" had been expanded to handle multiple corps and deep- and rear-area play. And the GIAC had been connected to the Corps Battle Simulation's generic interface tool. The WPC's current plan is for CBS to be accepted as an alternative to GRWSIM, but GRWSIM will still be retained at this time for use by customers who might prefer GRWSIM over CBS.

Both the JTLS and the CBS model will bring the WPC to a larger community of users that use the same tools. The JTLS model is available to every unified commander, and the CBS model is a service-approved model available to every U.S. corps, the Battle Command Training Program, and to the United Kingdom. CBS has also been selected by the U.S. and allied nations to be the simulation of choice to support two allied exercises in Japan and Korea during 1992 and 1993.

ACKNOWLEDGMENTS

This RAND Report describes some significant changes in the evolution of combat modeling at the WPC. Such changes involve many people in assessing the status of models at the WPC, exploring the basic assumptions underlying the WPC's use of models, investigating alternative models, and setting in motion the changes desired. This effort was cooperative in nature.

Special thanks for excellent cooperation goes to the commander of the WPC for whom this work was performed, Brig Gen David L. Vesely, and the vice commander, COL John Eberle. Their support in asking the difficult questions, reevaluating old assumptions, and looking at new alternatives was invaluable. They pursued the questions and made the tough decisions.

Any errors or omissions in this document are, of course, my responsibility.

CONTENTS

GLOSSARY

AAFCE	Allied Air Forces Central Europe (NATO)
ACE	Allied Command Europe (NATO)
ADSIM	Air Defense Simulation
AFRA	Ground combat model of AGATHA theater-level model
AGATHA	Theater-level combat model from IABG
AIDA	Air combat model of AGATHA theater-level model
ATAF	Allied tactical air force
ATOC	Air Tactical Operations Center
AWSIM	Air War Simulation (WPC's air combat model)
BCTP	Battle Command Training Program
BICM	BCTP Intelligence Collection Model
CAX	Computer-assisted exercise
CBS	Corps Battle Simulation (a combat model)
CENTAG	Central Army Group (NATO)
CINC	Commander-in-chief (usually of a major headquarters)
DWS	Distributed Warfare Simulation
EIFEL	NATO Air Forces communication system (German acronym)
GIAC	Graphic Interface Aggregate Controller (WPC player interface software)
GRWSIM	Ground Warfare Simulation (WPC's ground combat model)
HEX	Hexagon—the basic geographical unit for many models
IABG	Industrial Arbeit Betrieb Gesellschaft (the German research facility that built the AGATHA model)
ICM	Intelligence Collection Model
ITAWS	Improved Theater Air Wargaming System
JESS	Joint Exercise Support System (now called CBS)
JTLS	Joint Theater-Level Simulation
METRIC-V	Theater-level combat model built by BDM
MSC	Major Subordinate Commander (NATO)
MTM	McClintic Theater-Level Model
NATO	North Atlantic Treaty Organization
PSC	Principal Subordinate Commander (NATO)
REFORGER	Return of Forces to Germany exercise
RSAS	RAND Strategy Assessment System
SHAPE	Supreme Headquarters Allied Powers Europe

Simscript	A simulation language
SOC	Sector Operations Center
SOSC	Senior Officer Steering Committee (of WPC)
TACSIM	Tactical Simulation (for intelligence exercises)
TACWAR	Tactical Warfare model
TAM	Theater Analysis Model
TTSM	Theater transition sustainment model (army logistics)
USAFE	United States Air Force, Europe
USAREUR	United States Army, Europe
VTC	Video teleconferencing
WPC	Warrior Preparation Center, Einsiedlerhof, Germany

1. INTRODUCTION

PURPOSE

This document describes the evolution of the suite of models at the Warrior Preparation Center (WPC) and RAND's participation in the evaluations leading to the decisions regarding the future WPC model suite.

BACKGROUND

The WPC is a training support facility manned and funded by U.S. Air Force Europe (USAFE) and U.S. Army Europe (USAREUR). Its current mission is to provide the opportunity for senior commanders and their staffs to train in the operational art of war through the use of interactive computer simulation and distributed wargaming techniques.[1] Although the WPC is a U.S. training facility, many of the exercise participants are Allied headquarters of NATO. One reason for heavy NATO participation is that all higher-echelon exercises in Europe involve NATO headquarters. A second reason is that many U.S. commanders are dual-hatted as NATO commanders. For example, the U.S. commanders of USAFE and USAREUR also serve as the commanders of Allied Air Forces Central Europe (AAFCE)[2] and Central Army Group (CENTAG), respectively. In addition, the Supreme Allied Commander, Europe is also a U.S. four-star general, the commander-in-chief (CINC) of U.S. European Command. Therefore, allied participation at the WPC has been encouraged by U.S. commanders in their roles as NATO commanders.

Even though the U.S. military has used simulations in support of training exercises for years, there is still much experimentation in exercise design and in the use of simulations in support of training exercises (Allen, 1992c). Every method of training, including simulations, produces artificialities that tend to detract from the exercise realism and the achievement of the training objectives. To further complicate the matter, the state of the art in military simulations continues to advance at a rapid pace, driven by advances in new soft-

[1]The WPC has proposed that the phrase "and distributed wargaming techniques" be deleted, since many methods are available to support training.

[2]AAFCE will be renamed Air Central Europe (AIRCENT) in the near future.

ware, languages, hardware (both the computers and graphical interfaces), and communication technology for distributed simulations.

RAND has been at the leading edge of many of these technological advances and has had considerable experience in developing combat models for analysis. However, RAND expertise in simulations for training and military exercise design was more limited. Both the WPC and RAND concluded that loaning a RAND analyst to the WPC would be mutually beneficial.

RAND Involvement at the WPC

RAND's cooperation with the WPC extends back to the WPC's initial formation in 1983, but RAND's involvement increased in 1987, when the Distributed Wargaming Symposium was held at RAND (Bankes, 1992). Shortly thereafter, a RAND analyst was assigned to the WPC for a one-year tour with the Analysis Directorate. Two publications resulted from that tour: one unclassified paper on the Joint Warrior Exercise at the WPC (Rehmus, 1987) and one classified report on military lessons at the WPC.

RAND participation continued with a second analyst (the author) succeeding the first in March 1989. Although originally planned as a one-year tour funded by the Army, the tour was extended at the request of the USAFE Director of Operations for a second year, with funding provided by both the U.S. Air Force and the U.S. Army. During this tour, the work focused on three RAND projects with WPC cooperation:

1. A critical examination of the methodological issues in the current WPC suite of models, emphasizing current performance and areas requiring improvement
2. Analysis support to the WPC's Analysis Group, including interviews of WPC customers and surveys of exercise participants[3]
3. An investigation of existing models that might serve as alternatives to the existing WPC suite of models.

[3]WPC customers are the users of the WPC training support facility. These customers have included almost all of the major and primary U.S. and NATO commands in Europe.

Examination of the Methodology

Examples of methodology issues examined included the fire support methodologies (artillery, surface-to-surface missiles, and air-to-ground fires), WPC database preparation and configuration control issues, and participation in the Air War Simulation (AWSIM) model-calibration conference held at the WPC in 1990.[4] Many of the recommendations were implemented by the WPC during and after the author's tour.

Analysis Support

The WPC Analysis Group designed and conducted surveys of exercise participants and training support personnel with RAND's assistance. In addition, the author interviewed numerous exercise participants, including the exercise directors of most of the major commands that participated in WPC exercises. Those interviews provided essential input in determining the strengths and weaknesses of the existing WPC suite of models and, in some cases, suggested an alternative model to be examined.

Alternative Models Investigation

The author initiated and headed the WPC Models Investigation Project and reported his findings directly to the commander and vice commander of the WPC. His team included personnel from each major functional area at the WPC. This project involved the examination of a list of existing models proposed as alternatives to the existing WPC suite.

Project Results

The three preceding RAND projects produced two significant results. The first was the recommendation that the WPC should have two sets of models—one for army group and above exercises, and one for army group and below. (The decision as to which model set to use at army group level depends upon the composition of the training headquarters and the training objectives. See Section 6 for a more detailed description.) Based on this recommendation, the WPC decided to pursue the use of the Joint Theater-Level Simulation (JTLS) for the upcoming higher-echelon Allied Command Europe (ACE) 92 exer-

[4]This conference included representatives from the air and air defense forces of most NATO nations, so that they could help calibrate the air model parameters.

cise, and obtained Senior Officer Steering Committee (SOSC) approval for this effort.[5]

The second key recommendation was that the Corps Battle Simulation (CBS) be a replacement to the existing WPC Ground Warfare Simulation (GRWSIM), given three specific modifications. These three required modifications have already been made and are being tested for use in REFORGER 92. The WPC has accepted using CBS as an alternative to the GRWSIM model for lower-echelon exercises, but has decided to retain GRWSIM for use by customers that may prefer it.

ORGANIZATION OF THE DOCUMENT

Section 2 briefly describes the history of the WPC, which is essential to understanding the present capabilities and issues of the WPC. Section 3 examines the key institutional assumptions that have driven the evolution of the existing suite of models at the WPC and that precluded the acceptance of alternative models until these assumptions were reexamined. Section 4 describes issues that have derived from the evolution of the WPC in a rapidly changing training environment. Section 5 describes alternative models available for use at the WPC, including models not previously available or not considered acceptable based on the WPC's institutional assumptions. Section 6 describes the project results, including a description of the proposed future WPC model suite.

[5]Because of recent, dramatic world events, the design of ACE 92 has since been significantly changed. It appears that ACE 92 will now be a seminar game, performed without the support of a combat simulation.

2. HISTORY

Understanding the present capabilities and limitations of the WPC requires a brief examination of its evolution. The first subsection describes the WPC mission and the composition of participating training headquarters, or the customer base, over time. The second subsection presents the issue of model availability, or lack thereof, when the WPC was first being formed.

WPC MISSION AND CUSTOMER BASE

The WPC Mission

Originally, the WPC was to provide the opportunity for senior European commanders and their staffs to train in the operational art of war. This mission has been revised several times. During the author's tour, the WPC dropped the term "European" and added the phrase "through interactive computer simulation and distributed wargaming techniques" to the mission statement. Thus, the current mission is to provide the opportunity for senior commanders and their staffs to train in the operational art of war through the use of interactive computer simulation and distributed wargaming techniques.

This change in the mission statement reflects the changing international and training environment, as well as new technology available to support training exercises. The collapse of the traditional Warsaw Pact threat has led to a number of sudden and significant changes. In the international arena, NATO members are reducing military budgets and manpower allocations to reflect the perception of a reduced threat. This action, in turn, has significantly reduced both the funds and manpower available for training exercises. In addition, the tolerance for air and ground field maneuvers (and the associated road congestion, noise pollution, and damage to private and public property) has also significantly decreased.

One result of these changes has been the shift away from large-scale field exercises toward more computer-assisted exercises (Allen, 1992c). Since the WPC has been the focal point for the Distributed Warfare Simulation (DWS) exercises, the requirement for the use of DWS techniques was added to the WPC mission statement.

Another result has been a change in the perceived threat and the need for credible scenarios in which to train NATO forces. Rather

than two large forces opposing each other from a standing start, forces in future conflicts may have to travel long distances to engage each other. For example, the main opposing armored forces may have to travel across Poland and parts of Germany to become engaged, or there may be out-of-area contingencies to consider. Overall force densities may be less, but the scope of the battlefield and the effects of air and naval forces will be even more significant. These scenarios, in turn, drive the requirements for models capable of providing the increased scope in both geography and time.

A third result of these changes is that the objectives of the training audiences have also changed over the years. When the WPC was first formed, the AirLand Battle doctrine did not yet exist. The term "orchestrate the war" was one aspect of the then-current doctrine that later became the "synchronization" part of the AirLand Battle doctrine. As the doctrine became more mature, the training objectives evolved as well, especially after Operation Desert Storm. As the training objectives evolved, the requirements for the models used for training evolved as well. A greater emphasis was placed on all functional areas (including combat arms, combat support, and combat service support) and how each contributed to a synchronized effort.

The deletion of the term "European" from the WPC mission statement reflects a desire by the WPC to broaden its customer base beyond NATO. One topic of discussion is that if the WPC succeeds in this effort and if the DWS program is successful, the WPC may not need to remain in Europe and, in the long run, might relocate to the United States. At the same time, U.S.-European relations can benefit from maintaining an allied training facility in Europe.

In the meantime, the WPC customer base continues to be predominantly NATO. However, even this customer base has evolved significantly over time.

The Evolution of the WPC Customer Base

Early in the history of the WPC (1983 to 1985), there were two primary training headquarters in the customer base: army group and/or allied tactical air force (ATAF) exercises and corps-level exercises. Since the USAREUR commander is dual-hatted as the NATO CENTAG commander, most army group exercises at the WPC involved CENTAG. At first, U.S. corps were the primary corps-level training headquarters. As the CBS[1] became available to all U.S.

[1]CBS was previously called the Joint Exercise Support Simulation (JESS).

corps, they preferred to use their own resources and simulations to support their exercises. As a result, the focus of exercises at the WPC has shifted from the corps level to echelons above corps.

This initial makeup of the WPC customer base understandably resulted in a suite of models focused on supporting corps-level exercises, with the ability to expand to army group and ATAF-level exercises as necessary. In addition, the early WPC customer base contributed to the key assumptions that would later create problems for the WPC, as described later.

A significant change in the WPC customer base occurred in late 1987. The CINC of ACE planned an ACE-wide exercise to be held in the Fall of 1989 (called ACE 89). Furthermore, this exercise was not planned as a one-time event but as the beginning of a series of exercises that would involve all of ACE every third year, with possible annual regional exercises (Allied Forces Northern Europe, Allied Forces Central Europe, and Allied Forces Southern Europe). With this decision, the projected WPC exercise training headquarters had increased to encompass at least four echelons (Supreme Headquarters, Allied Powers Europe; regional commands or major subordinate commands [MSCs]; army group, ATAF, or principal subordinate commands [PSCs]; and corps, Allied Tactical Operations Center [ATOC], and Sector Operations Center [SOC] commands), as well as many subordinate commanders (e.g., division, brigade, and wing commanders and staffs).[2]

The WPC had no requirement to employ the existing suite of models (designed primarily for corps and army group or ATAF-level exercises) for regional or ACE-wide exercises. However, the key assumptions that had been driving WPC exercise designs for the last several years were used to design the first ACE-wide exercise. As a result, the WPC chose simply to expand the scope of the existing suite of models to represent the Central Region, while the Southern Region would be partially dynamically scripted and partially supported by the Joint Analytic Warfare Simulation from the U.S. Armed Forces Staff College, and the Northern Region and the United Kingdom Air Command would be dynamically scripted command post exercises.

It came as no surprise to independent observers and many participants that the ACE 89 exercise did not succeed and that the level of

[2]After ACE-89, it was agreed that the training headquarters for an ACE-wide exercise should be no lower than corps-level. The existing WPC suite of models, however, still requires a sufficient number of personnel to move every company individually to support each corps headquarters in the training audience.

resolution was inappropriate for the level of the primary training headquarters—the MSCs and the PSCs. Many of the training objectives were not met; the ground war as played in GRWSIM was very slow because of the inability to handle orders in real time for every company-sized unit in the theater. Similarly, the air war suffered major degradations whenever a large raid was sent, for similar reasons—trying to assess simultaneously the movement and combat of individual aircraft and air defense sites in a theater of operations in real time. Attempting to represent the Central Region down to company-level ground units and flying every aircraft individually was technologically risky and of questionable value even if technologically feasible.

The technological risk was associated with the fact that it was unclear whether or not the existing computers, communications devices, and software could support such a large exercise in real time, since it had never been attempted before. In addition, the value of high detail in higher-echelon exercises is extremely questionable, since it leads to unrealistic results, as described in Section 3.[3]

The value of this level of detail is questionable for other reasons as well. One reason to question the benefit of such enormous detail was the number of training support personnel required to run the current suite of models. Operating every company and aircraft flight for an ACE-wide exercise was conservatively estimated to require somewhere between 300 and 500 personnel. (Some estimates reached 1000 training support personnel, depending on which personnel were counted as the focus of the training effort and which were counted as training support personnel.) In the face of projected manpower shortages, this large personnel requirement became infeasible from the perspective of the training headquarters. The issue was not just supplying a sufficient number of bodies, but supplying a sufficient number of personnel with the unique set of skills associated with the key staff functions.

A second reason to question the value of a high level of detail pertains to the time-compression ratio used in the exercise.[4] For higher-eche-

[3]Proponents of the existing WPC suite of models claim that every aircraft or company must be explicitly represented and operated, since some types of individual assets are important. It is true that some special assets with unique capabilities need to be represented explicitly, which is why even aggregate combat models tend to treat these few special assets individually. This issue is also discussed in more detail in Section 3.

[4]Time compression is the ratio of model time to real (clock) time. For example, a 3:1 time compression means that three days in the computer simulation can be accomplished in one day of real time. A 1:1 time compression ratio means simulated

lon exercises, it is not uncommon to run the exercise faster than real time. For example, since a theater commander may make significant decisions every few days, an exercise representing a week may be run in a day. However, during ACE 89, it was not possible to represent even a 1:1 time ratio, let alone a compressed time ratio. Most issues at the MSC and PSC level have to do with sustainability, logistics, and force allocation. These issues require longer time horizons than one week, wnich was the length of time planned for the exercise. To address the higher-echelon issues, the WPC models would have to be capable of running at better than 1:1 time compression. To run at higher speeds, however, would be difficult because of the high level of detail represented by the existing suite of models.

Although the current suite of models could adequately support corps and army group/ATAF-level exercises, it became apparent that they could not adequately support an ACE-wide or regional exercise. The new customer base could not be adequately exercised with the current suite of models at the WPC. As a result of the problems encountered during ACE 89, many participants, independent groups, and the WPC began searching for alternative models and exercise designs more appropriate for regional and ACE-wide exercises.

MODELS AVAILABLE WHEN WPC WAS FORMED

Before examining the models investigated in the wake of ACE 89, let us first examine the availability of corps and above training models when the WPC was first formed. While a number of models and approaches were considered, the following description seeks to highlight the major considerations. The WPC needed an air model and a ground model that could be linked together to support training exercises. At that time, almost all combat simulations were analytic simulations rather than training simulations. Since the WPC needed to be up and running in less than a year, the organization felt that it could not wait for the right model to be developed, so they needed to modify what was available at the time for their own use.

This requirement meant that the models used as the basis for the air and ground models had to be relatively simple so that they could be adapted through strictly in-house capabilities.[5] The choice for the air combat model was the Air Defense Simulation (ADSIM), a naval-air model adapted for use in a land theater by representing aircraft

time equals real time. There is no time compression when the simulation time equals real time, but the time compression *ratio* is 1:1.

[5]Since the early WPC could hand-pick the best programmers available from the Army and Air Force, the in-house capabilities for software changes were significant.

carriers as fixed airfields. The choice for the ground combat model was the McClintic Theater Model (MTM). The two models were connected through a relatively simple interface, and the current suite of WPC models was born.[6]

Due to the extensive changes made to both ADSIM and MTM, the name of each model was changed. The WPC's version of ADSIM became the Air Warfare Simulation (AWSIM), while their version of MTM became the Ground Warfare Simulation (GRWSIM). Other models were added to the WPC suite of models over time, either through in-house development from scratch or through adapting existing models. The Follow-on Forces Attack model and the Intelligence Collection Module (ICM) were in-house developments. The Naval Warfare Simulation was a minor variation of the Research, Evaluation, and Systems Analysis model, which was a later incarnation of the ADSIM model with expanded surface and subsurface capabilities. The Joint Electronics Combat Electronic Warfare Simulation was built by the Joint Electronics Warfare Center specifically for use with the AWSIM air model.

Probably the most appropriate analytical model that could be used for training was the IDAHEX ground combat model (from IDA) connected to the Improved Theater Air Wargaming System model. However, the existing IDAHEX databases for Central Europe were theater-wide, and most of the WPC's early training headquarters were corps. As a result, the IDAHEX model was used for a while at the WPC as a "context" simulation, dynamically describing events to the flanks, deep, and rear of a corps-level training headquarters.

When the JTLS model first appeared under the Modern Aids to Planning Program, it was used on a trial basis at the WPC for two exercises. Owing to the immaturity of the early JTLS model (it was still under development, subject to frequent crashes, and lacked an adequate player interface), it was not considered appropriate for WPC exercises. After significant in-house debate and maneuvering, the decision was made to discard the JTLS model and proceed with strictly in-house capabilities.

For the next few years, the WPC continued to focus on in-house development and high levels of detail to support the customer base. When the customer base expanded to include ACE and regional training headquarters, the natural tendency was to follow the same path.

[6]The CBS (then called JESS) was not yet ready for use at this time, but would be ready a year or two later. The WPC then considered MTM (the precursor to GRWSIM) to be an interim solution, and would reconsider CBS when it had matured.

This approach did not work, for the reasons described above. Fortunately, alternative models had been under development by other agencies. Although the WPC was aware alternative models existed, it considered none of them adequate, largely as a result of the traditional institutional assumptions described in Section 3. These assumptions tended to filter out all alternatives so that the only useful set of models for WPC exercises was the one already in use, as described in the next section.

3. KEY ASSUMPTIONS

This section examines some underlying assumptions that have guided the evolution of the existing suite of models, describes how those assumptions have led to some of the WPC's present issues, and the opportunities created when these assumptions were reevaluated.

BACKGROUND

To understand some of the WPC's present issues, one must understand the key underlying assumptions that have guided the evolution of the existing WPC suite of models. The following assumptions were delineated by the WPC commander and directors to RAND personnel at a meeting early in the summer of 1989:

- Realism can only be provided by a large amount or high level of detail in the models (e.g., represent and operate every aircraft and every company individually),
- Higher-echelon exercises require the same level of detail as lower-echelon exercises,
- Training headquarters require 1:1 time compression,
- Changing code is the key instrument in responding to customer needs, even during exercises.

The following subsections examine each of these four assumptions.

ASSUMPTION 1: REALISM REQUIRES A HIGH LEVEL OF DETAIL

This assumption grew as a result of the early experiences of the WPC. Since most of the early training headquarters were at the corps level and below, most of their attention, complaints, and recommendations for changes focused on adding more detail to the models. For example, every indirect fire strike had to be called for by a training support person interacting directly with the computer terminal. The models were modified to increase the detail in the representation of call for fire procedures for air and artillery missions. Detailed mission planning and prioritization of targets was added to the attack helicopter module. Firing doctrines for air defense assets were added for each firing battery. Features related to tactical issues began to

dominate the models, but these details were appropriate for most of the training headquarters being supported.

When higher-echelon exercises were performed, it was assumed that the detailed models would adequately represent aggregate effects visible at the higher echelons. Unfortunately, this is not true. The reason is that the sum of the parts do not add linearly to provide an accurate representation of the aggregate effects. The following three examples illustrate why a model accurate at one echelon will not automatically provide appropriate results at higher echelons.[1]

First Example: Ground Unit Movement Rates

The first example deals with ground unit movement. In GRWSIM, company-sized units move at approximately 25 km/h, which is appropriate for a small mechanized unit. A division contains about 90 company-sized units in GRWSIM. When all of the companies in the division are moved on roads, the average movement rate in the model that the division sustains over a day is about 20 km/h. Real divisions, however, move at a sustained daily rate of only about 7 km/h or less.[2]

The reason that the movement rate of the aggregate unit, when represented by its component units, does not accurately represent a division's movement rate is that the model does not account for the factors that, in reality, significantly slow the units. Time must be spent planning a move. The larger the unit (i.e., the higher the echelon), the more time must be spent planning a move across all echelons before the first vehicle rolls forward.

In addition to planning, a number of coordination and control procedures keep units from interfering with each other, getting lost, or getting mixed together. Some models have a limited representation of

[1]This does not mean that someone could not theoretically invent a highly detailed combat model that would accurately represent aggregate events. It just means that this has not been accomplished to date, and how it would be accomplished even in theory is not yet known. See the Proceedings of the Variable Resolution Modeling Symposium, May 5 and 6, 1992.

[2]The fastest sustained Soviet advance in World War II occurred during the Soviet invasion of Manchuria in 1945. The 6th Guards Tank Army advanced 900 km in 11 days, an average of 82 km per day (Vigor, 1983, p. 112.), although rapid single-day advances could achieve 150 to 160 km per day (Savkin, 1965, pp. 4–5.). During Operation Desert Storm, the U.S. 24th Mechanized Division advanced about 240 km in three days, which is nearly 80 km per day. An advance of 80 km per day is less than 4 km/h. Even the 320-km advance by U.S.-lead elements in the first two days was equivalent to at most 7 km per hour (Adler, 1991). An advance of 20 km/h, as represented in the model, would equal a daily sustained rate of advance of 480 km—far beyond anything recorded even in recent history.

congestion, but many more factors that delay administrative movements are not included in models, such as units getting lost or getting separated in the middle of even a coordinated move. All of these "friction" factors cause large units to move much more slowly than their component units.

In addition to the friction of war, there is also the fog of war. For example, in most models, if a bridge is knocked out in front of a unit, all elements in that unit "know" the bridge is out and immediately take alternate routes. Real units in the field have much less information available, a fact that contributes to the fog of war and consequently slows the unit's movement.

These shortcomings are true of many models. In general, combat models are adequate representations of movement and combat within a narrow range of echelons, since each is calibrated to a single echelon. Representing forces two echelons away from the calibration echelon using the same values risks unrealistic results in most ground combat models.

The alternative to adding even more detail to a model to attempt to account for all of these friction and fog factors is to use a model calibrated for the echelon being trained. Division movement rates are known over a wide range of circumstances, and therefore one can calibrate a model for division movement rates. This would assure the training headquarters that the movement rates are appropriate for their level of exercise, and at reduced manpower support costs, as described in the next section.

(One could even go so far as to insert random delays into a unit's movement rate to train staffs to plan for unexpected delays. Unfortunately, random delays without a good reason are likely to cause participants to declare such a model to be unrealistic.)

Proponents of the existing WPC suite of models argue that there may be flaws in the existing models, but they are "good enough" to support training. It is true that all models have flaws, and the question is whether or not the flaws detract from the training experience. Using a highly detailed model that misrepresents divisional movement rates detracts from the training experience, while a more aggregate, less detailed model that is properly calibrated to divisional movement rates supports the training experience. In addition, since the highly detailed models are both cost and manpower intensive and still include serious flaws, a more aggregate model, even one with the same flaws but with lower manpower and cost requirements, would be preferred.

Second Example: Artillery Fire Mission Rates

The second example of more detail not necessarily providing realistic results occurred in the area of artillery fire missions. There were several problems with the fire support representation in the GRWSIM model. Much of the artillery lethality was caused by the fact that units in GRWSIM are located at hex centers, thereby ensuring any artillery fire into a hex will damage forces located anywhere in that hex. In reality, it is difficult to ensure hitting a target that lies somewhere in an area 3 km on a side.

However, another problem arose in the area of fire support responsiveness, especially in the threat cells. In many earlier exercises, a single artillery commander for an Army would be able to have 15 artillery battalions on call at any time. As a Red reconnaissance unit detected a Blue maneuver unit, all 15 artillery battalions would strike that hex and destroy the Blue unit. Then, because any other threat reconnaissance or maneuver unit along the front would detect a Blue unit, all 15 artillery battalions would fire at that hex as well. In one exercise, this procedure cleared almost all Blue units in front of the advancing threat forces, so little ground combat ever took place. This occurred in spite of the fact that the threat force ratio was 1:1 against prepared defenders in rough or mountainous terrain.[3]

The problem was that the model allowed each side too much information about the other and insufficient restrictions on what they were allowed to do. When all artillery battalions are represented, the opportunity for the players to micromanage each unit soon appears. As a result, a group consisting of many small component units fights with the speed and cohesion of a single small unit.[4]

Third Example: Air Combat Engagement Rates

The AWSIM air model is another example. At the engagement level, the attrition assessment appeared reasonable. However, the overall engagement rates appeared to many participants to be too high.

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[3]It is true that, according to threat doctrine, preparatory fires from massed artillery before a prepared assault could neutralize a defending maneuver battalion. In reality, this can occur only at the start of a prepared assault and not as part of massed fires available at any time to support advancing forces.

[4]As a postscript to this example, the problem of massed artillery fires anywhere across the front was solved at the WPC by using new procedures in the threat cell. These procedures required that a delay be imposed by passing the fire requests through a threat fire support cell not collocated with the maneuver unit cells. The implementation of these procedures appears to have been successful and serves as an example that not all problems need to be solved by model changes.

Those supporting the air model claimed that those participants who did not like the "answer" were just trying to ignore the facts, that the model's algorithms were mathematically sound, and, therefore, that the model should be believed. Those questioning the model's engagement rates pointed out that the rates of engagement were much higher than had ever been observed, that they did not account for the fog and friction of war, and that, although the model was mathematically sound, it was not necessarily an appropriate representation of air combat.

The problem with the air model's overall engagement rate is similar to the problem with artillery described above. It is true that, given the engagement occurs, the attrition represented is reasonable. The problem is that the frequency of engagement is too high, because too much information is given to the players and because there is virtually no representation of the fog and friction of war. The identification of friend or foe, for example, is too quick, easy, and unrealistic.[5] As a result, it is easy to quickly and efficiently allocate resources when there is little uncertainty and a lot of accurate information. Like the two ground model examples, it is relatively easy to micromanage all the component air defense and aircraft elements to act as quickly and as coherently as *a single component* when so much information is available.

The air model assumes all engagements are independent events, when, in reality, they are highly dependent events. Even though the air model is mathematically sound, given the assumption of independence, the assumption itself is inappropriate as a realistic representation of air combat. A Military Operations Research Society conference held several years ago indicated that the engagement rates in our models are much higher than found in field experiments.[6] This continues to be true in most air combat models, not just the one at the WPC.[7]

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[5]It is true that the colors of selected aircraft change from blue to red on the screen to encourage fratricide, but the real identity can be found by simply asking the screen. Overall, if aircraft are Red they are shown in red, and if Blue shown in blue, all across the front all the time.

[6]Based on a presentation by Air Force General Goodson at the 54th Annual Military Operations Research Symposium.

[7]As a postscript to this example, the problem of high engagement rates was partially ameliorated by setting an engagement intensity parameter. The AWSIM air model, like most combat models, has a set of intensity parameters that may be used to reduce the overall level of attrition, which may better represent the aggregate engagement rates. These intensity parameters were set by a senior officer committee during the second part of the air calibration conference held in September 1990.

Conclusions About Assumption 1

Overall, the first assumption does not match reality. A high level of detail will not necessarily accurately represent the aggregate effects of ground and air combat. Proponents of the existing WPC suite of models have claimed that some special assets, such as the Joint Surveillance and Target Attack Radar System (JSTARS) and Airborne Warning and Control System (AWACS) or the Army Tactical Missile System, can have a significant effect on the course of the war, and therefore should be uniquely represented. It is true that assets with special or unique capabilities should be represented explicitly, which is why even aggregate combat models tend to represent JSTARS, AWACS, and ATACMS individually. However, this does not mean that every single fighter aircraft or tank needs to be represented in a theater-wide model. Groups of aircraft or groups of ground vehicles can be aggregated so that their aggregate effects match reality. As shown above, representing these assets individually does not lead to their aggregate effects being realistic; instead, they are very unrealistic.

The following is a good rule of thumb for determining which assets are unique: If the asset in question can affect the movement or combat of the common unit of resolution, then the asset should be represented individually. For example, let us assume that the unit of resolution is brigade-sized maneuver units for the ground combat model. An ATACMS with proper munitions has sufficient firepower to significantly slow and attrite a brigade-sized armored unit. Therefore, ATACMS should be represented uniquely in a model that represents brigade-sized maneuver units. Conversely, a single tank or artillery tube is not likely to significantly slow or attrite an armored brigade. Therefore, tanks and artillery assets should be aggregated into the common resolution for maneuver and artillery units in the model.

ASSUMPTION 2: HIGH AND LOW ECHELONS REQUIRE SAME LEVEL OF DETAIL

Problems in the level of detail increased significantly as the customer base expanded to include higher echelons. The assumption the WPC made as an institution was that if a lot of detail were required for lower-echelon exercises, then at least the same amount of detail would be required for higher-echelon exercises.

Not only is this assumption not true, but the opposite assumption—that less detail is important to appropriately represent higher-echelon results—is the valid conclusion. As shown in the preceding three ex-

amples, a large amount of detail can produce unrealistic results during higher-echelon exercises. The aggregate effects are not well represented by unrealistically micromanaged components. As a result, it is preferable to use a model appropriate for the echelon being exercised. The closer a model is calibrated to the echelon being trained, the better the match between the aggregate rates and the component rates. Since it would be expensive to have a separate model for each echelon, the author recommended that the WPC use an aggregated model for the higher-echelon training headquarters and use a modification of the existing suite of models for lower-echelon exercises.

Selecting a model appropriate to the echelon being trained is not just a function of proper calibration. It is also a function of the issues that are the focus of attention of the training headquarters. At the lower echelons (e.g., corps and below), tactical and combat issues dominate the attention of the training headquarters. At the higher echelons (e.g., echelons above corps), strategic and sustainability issues dominate. The middle echelons (e.g., corps and possibly army group) are often the most difficult to represent, since they straddle both sets of issues.

The sustainability issue is much more critical at the higher echelons. A model that supports higher-echelon exercises will need to be able to track selected key items, such as guided antitank missiles, advanced air-to-air and air-to-ground munitions, or the number of sea-launched cruise missiles. These scarce but important items are the focus of attention at the higher echelons. They are not interested in every widget and spare part but in overall tonnages of relatively common items. To support higher-echelon exercises, the focus must be on the issues that are of interest to the training headquarters. This approach thereby avoids the increased manpower overhead of handling unnecessary detail.

The manpower and communications costs of the existing detailed models in support of higher-echelon exercises were extraordinarily high (from 300 to 500 additional training support personnel and $1 million in communications costs). The issues of priority to the higher-echelon training headquarters were dwarfed by the large amount of detail of the current model suite. The current suite of models was projected to cover only one region, not all of ACE, thereby requiring additional models, manpower, and costs to accomplish the mission.

Proponents of the WPC's existing suite of detailed models argued that the ACE 89 exercise design from SHAPE only required one region be exercised at great detail, while the other regions would be supported

in less detail in separate but simultaneous exercises. However, this was a chicken-and-egg problem. SHAPE wanted to exercise all the regions, but the current WPC suite of models could only support a single region exercise. Therefore, SHAPE specified an exercise design that focused on one region with the other two regions supporting. Had the current WPC suite of models not been so limited, the SHAPE exercise requirement would have been for all of the main regions to be included in the exercise.

This same issue was raised again during the first ACE-92 planning conference. Because of the opportunities raised by considering less-detailed models, SHAPE concluded that all of the regions (MSCs) would be exercised in ACE-92 at the same level of resolution. The decision as to which model to use was not made during that meeting, but SHAPE endorsed the proposal to pursue the less-detailed JTLS model. Since the current suite of WPC models could not fulfill the requirement to model three regions simultaneously, some less detailed model will be used for ACE-92.

The assumption that higher echelons required the same level of detail as lower echelons caused the WPC to design all of the supported exercises around their existing suite of models. Since the air model represented every aircraft in a continuous air picture, the exercise design included the requirement for sufficient personnel to operate every aircraft within a continuous air picture. Similarly, since the ground model represented company-sized units, the exercise design included the requirement for sufficient personnel to operate every company on the battlefield. Once the first two assumptions were questioned, the opportunity arose to examine alternative models and exercise designs, as described in Section 5.

ASSUMPTION 3: TRAINING HEADQUARTERS REQUIRE 1:1 TIME COMPRESSION

The time compression factor is the ratio of model time to real (clock) time. Therefore, a 3:1 time compression means that 3 hours of model assessment are accomplished in 1 hour of clock time.

The assumption that the training headquarters require a 1:1 time ratio was also based on early WPC experience. Several early exercises at the WPC increased the time compression by increments up to a factor of five. The result was that the training headquarters personnel could not keep up with the model events and therefore requested that the time compression be returned to 1:1. After several attempts at varying the time compression ratio, the WPC concluded that all the

training headquarters required a 1:1 time compression for their exercises.[8]

As long as the WPC accepted the first two assumptions (that more detail means better realism and that higher echelons mean at least the same amount of detail), the exercise design focused on continuously monitoring the ground and air picture at aircraft and company level. The resulting large number of training support personnel was faced with many inputs to prepare and outputs to process for the training headquarters. As a result, the requirement to monitor the battlefield continuously at aircraft and company resolution required a 1:1 time compression ratio. If, however, the first two assumptions were reconsidered, the need for a 1:1 time compression ratio could also be reconsidered. If the training support personnel are not required to monitor the battlefield continuously for every aircraft and every company, the opportunity exists to support an exercise with a time compression factor greater than one.

One of the main reasons that the training headquarters could not keep up with the increased time compression is that training models are so manpower intensive. This is a common feature of training models. In analytical models, many aspects, such as the command and control processes, are automated to differing degrees of quality and realism. In training models, however, few decisions are automated. As a result, for any unit to move, fight, or otherwise change its status in a training model, a person must explicitly command that event to occur. Nothing occurs without a player initiating the action, and therefore a large number of players are required to make things happen. The faster one wishes events to occur, the more players are required, up to some limit, usually the number of input terminals.

The training headquarters and response cells required a 1:1 time compression ratio both to keep up with the model events and to prepare their staff reports according to a specified schedule. For example, assume that a corps headquarters is the lowest echelon training headquarters in the exercise. Also assume that the corps headquarters has requested a status report from its subordinate divisions. The response cell representing the division headquarters must examine the status of every company in each division in terms of combat and logistics status. In GRWSIM, there are about 90 company-sized maneuver and support units in each division, and if there are three di-

[8]By contrast, the National Defense University and the annual Global Game at the Naval War College both successfully use time compression factors of 4:1 or more to meet their training objectives.

visions and an armored cavalry regiment in the corps, there may be over 300 company-sized units to examine before a composite report can be prepared for the corps headquarters. In reality, the information on the subordinate units in the division has already been prepared by subordinate staffs. In the model, however, this task must be performed by the response cell staff, and this is very time-consuming. A more aggregate model would allow the response cell to report the status of subordinate units much more quickly and in a format more like standard operating procedures.

At the lower echelons, the staff reports are prepared on a daily basis or even more frequently, depending upon the echelon. At the higher echelons, the staff reports may be prepared on a daily basis, but little tends to change on a daily basis at the NATO-wide, MSC, or even the higher elements of the PSC levels. Depending on the time compression ratio used in an exercise, the rate of staff report preparation could be tailored to the time compression selected. If the exercise were played on a relatively continuous basis, the reports would flow from the model to the response cells with sufficient time to be prepared in standard formats. One could also design the exercise to jump forward to the next "interesting" event and to present the training headquarters with the next situation. In either case, the demand on the training headquarters would be tailored to the training objectives.

The training objectives at the higher echelons usually focus on issues that exceed the length of most exercises, which last a week to ten days. Most higher-echelon issues have a scope measured in weeks or even months, especially in the realms of sustainability, long-term allocations, and strategic asset deployment. Time compression is an essential tool in addressing the needs of higher-echelon training objectives.

Some NATO organizations have employed a 24-hour assessment in an 8-hour day. The WPC has found that if one is exercising two shifts, it is important to keep the time compression a multiple of two, so that each shift will be exercised at the same time each day. Depending upon how much one wishes to stress the staff and the number of shifts to be trained, one could perform 20 to 40 days of war in a 10-day exercise. A 40-day simulated war would actually begin to address many of the key sustainability issues that are the focus of attention at the higher echelons.[9]

[9]Most of the discussion about time compression during WPC exercises focused on the army group level. It was concluded that if the commander and higher staff

Proponents of the existing WPC suite of detailed models argued that the first week of the war was the most critical in Europe because of the limited stocks of munitions and the small number of reserves. Whether or not this was the best exercise design for the time is debatable, but the current situation in NATO is significantly different. Not only has the threat significantly decreased, but it could take most of a week just for the heavy armored forces of each side to engage. Since NATO exercises tend to last between a week and ten days, there is now even a greater need to use time compression in higher-echelon exercises to train past the first battle.

It is clear that the higher-echelon issues revolve around sustainability and long-term force employment issues. It is also clear that these issues are not likely to be significant in just ten days. For example, there is little doubt that NATO now has sufficient stocks and reserves to last the first week of a conflict. The question is whether or not NATO has sufficient stocks and reserves to last two weeks, or a month, or longer. Therefore, RAND recommended that the issue of an appropriate time compression factor be reviewed for higher-echelon exercises. Unfortunately, significant time compression was precluded by the existing suite of models, owing to the need to constantly monitor events and input all orders manually. What would be necessary would be a model that allowed preloading selected commands and that allowed changing the time compression as events unfold. Both of these features were available in the JTLS model, as described in a later section.

ASSUMPTION 4: CHANGING MODEL CODE WAS KEY TO RESPONSIVENESS

Since there were no viable training models at the appropriate echelons available to the WPC when it was first formed, and since a substantial in-house ability for software changes was initially available, the WPC chose the "code change" route to respond to customer needs. Had there been a suitable combat model ready for use at the WPC, then only data changes and procedural work-arounds would have been sufficient to meet the training objectives. Unfortunately, model development and model modification carry burdensome overhead

elements were included in the training audience, time compression was feasible. The lower army group staff elements would provide many of the response cell functions at reduced detail. If the lower army group staff elements were included in the training audience, the subordinate corps, ATOCs, and SOCs would be required in the training audience, which required more detail. An exercise design with the additional detail probably leads to the need for a 1:1 time ratio, depending upon the training objectives.

tasks. Being responsible for model development or modification meant that the WPC was also responsible for model design, model coding, configuration control, model testing, database development, database configuration control, quality assurance, and documentation. It became apparent to the WPC that a lot of money and manpower was being allocated to model development tasks. Of the 100 authorized personnel positions at the WPC in 1989, over a third were involved in the seven overhead tasks required by in-house model development.[10] In comparison, other training facilities, such as the V Corps simulation Center (with at most 12 personnel) or the Joint Warfare Center (with 39 personnel), are much smaller in manpower and budget than the WPC, primarily because they do not assume responsibility for extensive in-house model development. The National Simulation Center, for example, has only a few personnel involved in code writing or modification, since they rely on centrally controlled and funded model development.

Fortunately, there are models now available that would not require the WPC to be responsible for all of the overhead. The design, coding, configuration control, testing, and documentation of the code are handled by an outside agency responsible for model configuration control.[11] When these overhead tasks are handled by an external organization, the WPC monetary and manpower requirements should decrease significantly.

During the author's tour, the WPC decided to significantly reduce in-house model development of large models and focus instead on managing the development of large models (such as the Theater Transition Sustainment Model [TTSM]) and maintaining their existing suite of models. In spite of this decision, however, the WPC continues to maintain the assumption that the best way to respond to customer needs is through substantial code changes, even during an exercise. For example, there were significant code changes during most major WPC exercises, including both the ACE 89 and Cactus Juggler 90, to attempt to fix model problems. Sometimes these fixes worked, and sometimes they didn't (such as in ACE 89).[12]

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[10]As of mid-1992, the WPC had expanded to include 150 personnel positions.

[11]Configuration control for CBS is held by the National Simulation Center, while configuration control for JTLS is held by the Joint Warfare Center.

[12]The other training facilities listed above use code work-arounds during an exercise only as a last resort, since more often than not additional errors are added into the model. A training support facility cannot afford to keep the training headquarters waiting for the code to be debugged.

By contrast, the training support facilities listed above rely almost solely on database changes, which are more reliable and less risky than attempting to use untested or not thoroughly tested code changes, especially during an exercise. There is an advantage to being able to tell the training headquarters that these are the current model capabilities and that the code could not be changed locally.

EFFECTS OF THESE ASSUMPTIONS

Although alternative models were available that did not require so many overhead tasks, the preceding assumptions tended to filter out the benefits of all alternatives so that the only appropriate set of models for WPC exercises appeared to be the existing WPC suite of models. As a result, the WPC assumed that only the existing suite of models could adequately accomplish its mission of training support. Given its institutional assumptions, the WPC considered the existing models and the mission inseparable. Over time, more and more effort and money were spent on fixing problems and improving the existing suite of models rather than stepping back and reevaluating some of the basic assumptions that drove the efforts of the institution.

Once these implicit assumptions were made explicit and the WPC authorized a RAND review of them, these four assumptions were found to be no longer sacred. As a result of these findings and other investigations, alternative models could be objectively examined for use at the WPC, as described in Section 5. The proof that the reexamination was successful is that the WPC agreed to pursue the more aggregate JTLS model and to provide CBS as an alternative to GRWSIM. Both of these events are landmarks in the recent history of the WPC, which had preferred to design all exercises around the benefits and limitations of the existing suite of models.

4. PRESENT ISSUES

The preceding institutional assumptions created problems in terms of limitations of the training benefit. These problems were due to the inappropriate resolution of the models and to the high manpower and monetary costs needed to support a high level of detail in the models. The inappropriateness of too detailed a resolution for supporting higher-echelon exercises was discussed in the preceding section. This section will focus on the high manpower and high cost requirements in a time of dwindling personnel and monetary resources. Only using an appropriate level of resolution in the models will reduce the high manpower and cost requirements and achieve an appropriate level of resolution.

HIGH MANPOWER REQUIREMENTS

The high manpower requirements issue can be divided into two categories: manpower required from the training headquarters for exercise support and manpower required at the WPC to handle the overhead tasks associated with model development and modification. Using the alternative models can reduce manpower requirements, although these requirements may increase somewhat during the transition period, as described below.

Manpower Requirements for Exercise Support

As mentioned above, a common feature of training models is the lack of automated command and control. As a result, all basic actions performed by simulated units, vessels, and aircraft must be initiated by a human player. No movement or combat occurs unless a player initiates the action and continuously monitors the game for changes in the situation. As a result, training models tend to be manpower intensive. The more units, vessels, or aircraft included in the training model, the more people are required to manipulate these assets.

When the WPC had earlier assumed that higher echelons required at least the same level of resolution as the lower echelons, the number of company-sized units, surface-to-air missile batteries, and aircraft represented in the ground and air models increased as well. Along with the number of assets to be represented, the number of players required to make all of these assets move and fight, and to monitor them continuously, also increased. Just making the ground and air

models work in ACE 89 required 300 to 500 training support personnel. These training support or response cell personnel were not considered part of the training audience, since they did not include the commanders or staffs of the corps headquarters or air facilities defined as the training audience in the exercise design. The projections for ACE 92 were even higher, since naval play would also be included. And these exercises were designed to focus on only a single region. There are at least three major regions in ACE, and the other two would require their own models and additional training support personnel.

The problem is more complicated than simply finding a sufficient number of bodies to fill the player terminals. The problem is that the training support personnel must be very familiar with the functions and procedures of the staff or line element they represent. If they do not have these skills, the play of the exercise is severely degraded. For example, during Centurion Shield 90, the Air Force provided almost 100 personnel to fill Air Force staff positions in air support operation centers, SOCs, and ATOCs. Unfortunately, none of them had been trained in the staff tasks and procedures in the positions they were attempting to fill. After actual ATOC personnel from a nearby facility provided a crash overview of their procedures, the augmentees courageously attempted to fill the roles of these staffs, but many procedural errors occurred. As a result, a number of control interventions into the model were implemented to remedy these problems, and the training headquarters had to compensate for response cells with insufficient experience (Allen, 1992a). This was not just a problem of the training audience providing an insufficient number of qualified staff to support the exercise, but that the existing WPC model suite requires such a large number of support personnel to accomplish the exercise because of the high level of detail in the models. When an alternative exercise design is combined with a more aggregate combat model, fewer training support personnel are required to support higher-echelon exercises.

A more aggregated model has fewer assets, vessels, and aircraft groups to manipulate. Therefore, the manpower required just to make the models work decreases significantly. The number of staff positions required to man response cells also decreases. When the model resolves to corps staffs, none of the subordinate staffs or their skills are required. Only a representation of the corps staff is required. In contrast, ACE 89 included corps headquarters in the training audience, which required hundreds of support personnel just to manipulate and report on every friendly and detected enemy company in the region. This detail was used even though the declared

training audiences in ACE 89 were the MSCs and PSCs, at the regional and army group echelons, respectively. A more aggregate model is more appropriate for higher-echelon exercises.

Not only does an aggregate model require fewer training support personnel, but also the response cell staffs can focus on providing information to the training headquarters in standard military formats (e.g., map overlays, situation reports, intelligence reports), rather than monitoring an unfamiliar computer screen. When higher-echelon exercises include representing all echelons down to brigade staffs, each cell must perform the staff functions required to communicate with higher, lower, and lateral commands. However, because of the already high manpower requirements, these personnel were often the same personnel required to manipulate the models and monitor them on a continuous basis. As a result, the only staff functions provided by the lower response cells were to provide specifically requested information. Operational overlays, standard operational reports, and other standard staff functions were not produced because of the model demand for continuous monitoring.

As an alternative, if the response cell personnel are not required to manipulate the model and monitor it continuously, they can focus on the tasks of preparing reports and overlays and responding to requests of higher and lateral commands. In an exercise designed around the JTLS model, player terminals could be manned by personnel from the WPC, another training facility, or a contractor. One advantage of the WPC accepting the JTLS model is that the training audience will have available at least two different higher-echelon exercise designs to choose from to best satisfy their training requirements within their manpower and monetary constraints: JTLS, which tracks 10 to 20 brigade-sized units per corps, or GRWSIM, which tracks 300 company-sized units per corps.

Some elements of the WPC were concerned that the training headquarters might not be satisfied with a less detailed model. They pointed to the projected exercise design, which included corps, ATOCs, and SOCs defined as actual participants, not as training response cells, in regional and ACE-wide exercises. How could the higher-echelon training headquarters be convinced to reduce the number of subordinate headquarters in the training audience?

The real question was why the higher echelons were requesting the inclusion of the corps, ATOCs, and SOCs in the training audience in the first place. During the initial planning conferences, the higher echelons realized that the number of training support personnel required by their organization would be very large. Since these person-

nel would be required to be part of the training support staff, they might as well be defined as part of the training audience. Unfortunately, including them as part of the training audience fed into the WPC assumption that at least the same level of resolution was required for higher-echelon exercises as at lower-echelon exercises. In reality, the higher-echelon headquarters were just as happy to need fewer personnel and to include only those staff elements required for a higher-echelon exercise.[1]

Another advantage of using an aggregated model or models for higher-echelon exercises is that one might be able to exercise all three main ACE regions in the same exercise using a computer-assisted exercise with the same resolution. Elements could move from one region to another during an exercise, rather than having to change to a region that is being assessed by a model with a different resolution or by a dynamically scripted exercise. If one were to attempt to exercise all three main ACE regions at the company level and with a resolution that flew every aircraft, the manpower requirements would be in the thousands. By contrast, the same scope could be represented by a more aggregated model with less detail that would require only about 100 training support personnel.

Manpower Requirements for the WPC Organization

Many of the current manpower requirements the WPC has defined derive from the assumed responsibility for model development and modification. As previously described, the related overhead tasks include model design, coding, code configuration control, model testing, model documentation, database development, and database configuration control.

Because of the rapid pace of model changes, many of these overhead tasks were not consistently accomplished at the WPC, leading to larger problems later. Before the WPC implemented a model-code configuration control board, lack of configuration control caused the wrong versions of the model to be loaded for exercises. The WPC still does not have a comparable configuration control program for its model databases. Lack of database configuration control still leads to

[1]For example, a training headquarters wishes to exercise a regional headquarters, such as AFCENT. The WPC provides its own manpower, the hardware, and the software provided by its own personnel authorizations and budget. The training headquarters must provide the 300 to 500 additional training support personnel from its own personnel authorizations, in addition to the personnel of the subordinate headquarters being trained.

problems with parameters set for one exercise appearing in the database of the next exercise, as occurred during Centurion Shield 90 (Allen, 1992a). Lack of documentation causes most training of new programmers to follow the "guild" method, whereupon the new programmer trains under an experienced programmer. Unfortunately, the rapid demand for code changes has far outpaced the ability of the personnel to focus both on training and on changing codes. As a result, a large lag time occurs between a new employee starting and when he or she is proficient in selected model changes.

A large number of WPC personnel are engaged in performing many of these overhead tasks. In addition, contractors have been hired at increased costs to fulfill many of these overhead functions, such as documenting GRWSIM. Furthermore, as the personnel who modified the initially simple models have left the WPC, the new personnel are faced with a complicated code of more than a million lines with inadequate documentation. The new personnel actually face a more difficult task than the personnel who helped create the WPC.

The WPC has received SOSC approval to attempt to use the JTLS model for a higher-echelon exercise (ACE 92), as well as to allow CBS to be an alternative for the GRWSIM model.[2] These two approvals will allow the WPC to remove five of the seven overhead tasks listed above. Both the JTLS and CBS models have had a consistently well-funded and well-manned set of model designers, coders, testers, configuration controllers, and documentation writers over the years. The WPC will no longer have to provide personnel to perform these overhead tasks for most of their models, since these tasks will be undertaken by a central and separately funded facility.

The WPC will still need personnel with sufficient comprehension of the models to know which parameters to change under which conditions. In addition, the database development and database configuration control overhead will still be required at the WPC. However, these are only two of the seven overhead tasks currently undertaken by the WPC for model development.

As the WPC brings the JTLS and the CBS model into its suite, there will probably be a temporary increase in both manpower and cost. During this transition period, personnel with sufficient knowledge of these two models will either need to be trained in house or brought in from the outside. If the WPC chooses to maintain its existing

[2]Because of recent, dramatic world events, the design of ACE 92 has since been significantly changed. It appears that ACE 92 will now be a seminar game, performed without the support of a combat simulation.

suite of models and bring in the new models, this increase is unavoidable. At least part of this increase could be offset by simply replacing GRWSIM with CBS. All of the personnel associated with the GRWSIM model development overhead tasks could be transferred to CBS. However, since the WPC has chosen to simply allow CBS as an alternative rather than as a replacement to GRWSIM, the personnel costs will remain higher than before the new models were included. RAND recommends that the WPC choose to retire GRWSIM and simply use the service-approved CBS model instead.

HIGH COST REQUIREMENTS

The cost issue also divides into two categories: the required exercise support costs that the exercising headquarters pays and the costs the WPC requires and pays to handle the overhead tasks associated with model development and model modification.

Cost Requirements for Exercise Support

One of the technological advances the WPC uses is the distributed warfare simulation. Although the main hardware and software suite is centrally located at the WPC, portable vans with remote computers are located at response cell locations, such as the wartime locations of the main headquarters participating in the exercise. Inputs to the models from the remote sites are transmitted through secure channels to the mainframes at the WPC. The global database at the WPC is updated using the inputs from all of the remote sites, and this updated global database is transmitted back to each remote site. The players may then access the updated information and input new orders. Updates to the ground model, for example, occur roughly every 20 minutes, depending upon player input load and breaks in the communications links.

One of the primary drivers of the exercise costs the customer pays is the cost of the communications links. The costs of the communications links are a function of the bandwidth necessary to transmit the data in a specified period of time. Unfortunately, communications bandwidths tend to come in fixed increments rather than continuous amounts. The common fixed bandwidths are 9.6 kilobits per second (KB), 64 KB, and approximately 2 megabits (MB). The cost increases roughly proportional to the bandwidth. For example, the total cost for CBS communications for a ten-day three-echelon exercise (brigade through company or division through battalion) using 9.6 KB lines is about $30,000. The communications cost associated with the wide

(2 MB) bandwidth for GRWSIM, AWSIM, and video teleconferencing (VTC) is around $100,000 per day, or about a million dollars for a REFORGER exercise (Allen, 1992c).

The AWSIM air model can distribute updates to two remote terminals using the 64 KB line. The GRWSIM ground model however, requires a bandwidth in excess of the 64 KB line to update the whole database every 20 minutes. Therefore, the next larger line (2 MB) is required to distribute GRWSIM to remote sites at a communication cost of $100,000 per day.

In contrast, the CBS model requires only a 9.6 KB line to distribute to a remote site, which costs about $3,000 per day. The main reason for the difference in bandwidth between the CBS and GRWSIM models is that CBS only passes changes to the database during each update, while GRWSIM transmits the whole database for every update.[3] Recent improvements in the CBS communications software have further reduced the requirement so that more data may be passed along the existing 9.6 KB bandwidth. Therefore, the communications costs for WPC exercises could be significantly reduced if the CBS model replaced the GRWSIM model. Even though the CBS model will be required to be connected with AWSIM, each remote site will not need more than one AWSIM terminal for the air defense assets commanded from that site. One AWSIM terminal and up to three CBS terminals can be distributed to each remote site on a 64 KB line.[4] The approximate cost of using the 64 KB lines versus the 2 MB lines is about $20,000 versus $100,000 per day.

Another technology that has been employed in conjunction with the DWS is VTC. VTC allows up to 21 remote sites to communicate with each other with both visual and audio signals. This allows face-to-face communication between the commanders or selected staff members of each headquarters at specified times during the exercise. In addition, briefings have often been given between remote sites, including maps, overlays, and charts. This technology has been popular with many of the training headquarters. VTC is still in its infancy, and more research needs to be done to make it reliable, efficient, and inexpensive.

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[3]The WPC has attempted to transmit only updates rather than the whole database, but this has not worked successfully to date.

[4]This assumes that the AWSIM model's bandwidth has not significantly increased since 1991. At that time, two AWSIM terminals could be run from a single 64 KB line. Therefore, using only one AWSIM terminal will leave about half of the bandwidth available for CBS terminals.

At the moment, VTC requires a minimum of 64 KB and a maximum of 256 KB bandwidth. Since VTC would absorb all of the 64 KB line to a distributed site, using the VTC in support of a distributed exercise requires a 2 MB line. Since the GRWSIM model also requires a 2 MB line, VTC has been considered a "sunk" cost when the GRWSIM model is distributed. Conversely, when questioning the high cost of distributing the GRWSIM model, the answer has often been that it is considered a sunk cost when VTC is used. The problem is that both VTC and the GRWSIM model cannot be considered sunk costs of each other.

The communications costs of distributed exercises are paid by the customer or through special project funds, such as DARPA's distributed warfare project. These costs are in addition to the WPC's operating budget. The costs can be significantly reduced by replacing the GRWSIM model with the CBS model and by using VTC only on an as-needed basis. For example, VTC was used heavily during ACE 89 and Cactus Juggler 90. However, during Centurion Shield 90, VTC was rarely used and usually then only by WPC personnel communicating with the remote sites. Not every exercise needs VTC.

RAND has strongly recommended that the funding and overall distinction between the distributed wargaming capabilities and the VTC capabilities be clearly separated. At the moment, several parties are interested in the possible wartime use of the DWS. Upon closer examination, however, their interest is strictly in VTC. Similarly, funding for the use of VTC should be separate from the use of the DWS. Although it makes perfect sense that they use the same remote vans to keep the hardware costs down, the customer should have the option of not paying for the unnecessary overhead of VTC when all that is required to support the exercise is the DWS.

Cost Requirements for the WPC Organization

Many WPC cost requirements are driven by its assumed responsibility for model development and modification. The overhead costs associated with model development are high. In addition to building new models and modifying old models, there are developmental costs. For example, improved player interfaces, such as the new Graphic Interface Aggregate Controller (GIAC) for the GRWSIM model, are essential to helping players keep up with model events and input new orders efficiently. Configuration control has required the import of new hardware and software tools. Contractors have been hired to document the GRWSIM model and to improve model testing by simulating the peak loads experienced during exercises.

Because of the assumed responsibility for model development and modification, the WPC has spent millions of dollars on overhead tasks related to model development. During 1991, the costs for GRWSIM model improvements, documentation, and the GIAC player interface exceeded four million dollars. The only place that actually uses the GRWSIM model for exercise support is the WPC. The cost of the GIAC development may be spread over other models at the WPC. Other organizations might also find this tool useful, if they accept the GIAC as an interface for their models, but none are currently pursuing this option.

In contrast, the U.S. Army centrally funds the CBS model under the Army Family of Simulations. Currently, every U.S. corps, as well as training facilities in the United Kingdom, uses CBS. Similarly, the JCS centrally funds the JTLS model. JTLS has been made available to every unified CINC under the Modern Aids to Planning Program.

Proponents of GRWSIM claim that it has been used by more training headquarters than has CBS. The only reason this has occurred is that the training headquarters exercising at the WPC have had only one choice, GRWSIM—CBS was not available to the training audiences using the WPC suite of models. In addition to all U.S. corps, other nationalities that have used or are planning to use CBS include the United Kingdom, Germany, Korea, and Japan. The last two nations selected CBS as the model of choice for two allied training exercises next year. Now that the WPC is allowing CBS as an alternative to GRWSIM, the number of nations that use CBS will also increase.[5]

Selecting the JTLS model for higher-echelon exercises and replacing the GRWSIM model with CBS could save the WPC millions of dollars in the long term. Central funding for model development means that the WPC will be able to pay less for model development and spend more on supporting specific exercises. Once again, there is a good chance that costs will increase during the transition period, similar to the temporary increase in personnel described in the preceding subsection. For example, the WPC will require the Simscript computer language compiler to run CBS or JTLS.[6]

[5]To date, only the Netherlands and the Belgian corps have expressed interest in continuing to use GRWSIM over CBS, because of the number of changes they were able to get implemented in GRWSIM to support their exercises. The author requested the WPC to forward any concerns our NATO allies have about CBS to the CBS model proponent so that these concerns can be addressed.

[6]The current suite of WPC models runs on FORTRAN, with all of the limitations of 1977 computer language concepts, such as fixed array sizes. The licensing fee for a Simscript compiler for the DEC computer in the United States is currently $40,000,

A TIME OF DWINDLING BUDGETS AND MANPOWER POOLS

Because of the rapid changes in the European and global international environment, the perceived threat has significantly decreased. This has led to a significant cutback in current and projected military spending and manpower allocations in all NATO nations.

In addition, citizens of most NATO nations, especially in Germany, are much less tolerant of low-flying aircraft and armored vehicles creating noise pollution and property damage. As large-scale field exercises decrease in frequency, large-scale computer-assisted exercises are likely to increase. One bit of good news for the WPC from these changes is that the number of computer-assisted exercises will increase. However, this increase in computer-assisted exercises will still take place in an environment of manpower and monetary reductions that are due to the projected international climate.

With regard to manpower and cost requirements for exercises, the higher-echelon training headquarters questioned the need for the massive manpower and communication cost requirements previously required and projected by the WPC. These headquarters were not happy with paying $1,000,000 for communications and providing 500 additional training support personnel per exercise and therefore helped motivate the search for alternative and aggregated models. In addition, model development requires personnel with unique computer software and sometimes hardware skills. During this time of budget and manpower reductions, the WPC approved the investigation into alternative models, having first examined the institutional assumptions that previously had precluded these models from serious consideration.

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with a $7,000 annual fee for updates. The fee is reported to be slightly higher in Europe.

5. ALTERNATIVE MODELS

This section describes the available alternative models that the Models Investigation Project team examined for use at the WPC.[1] Although other models also existed at the time of the investigation, we considered the models listed here to be the likely candidates in terms of level of resolution and availability to the WPC.

The availability of alternative models was not by itself sufficient for the WPC to change the way it provided exercise support. As described earlier, the institutional assumptions tended to filter out the benefits of alternative models and highlight those of the existing suite of models. Therefore, only by reevaluating the existing assumptions could the WPC consider changing its existing suite of models.

After reevaluating the old assumptions, we identified the filters that made the existing suite of models the only alternative. The team viewed the existing alternative models in a new light and investigated them with a fresh outlook during the Models Investigation Project. These resulted in the recommendation for the new WPC model suite, as described in Section 6.

Although these brief descriptions do not do any of the listed models justice, the descriptions serve as an example of the reasoning process and the factors considered during the model investigation process. The WPC commander and vice commander based their decisions to pursue the JTLS model and the CBS model on these and other inputs, subject to SOSC approval.

AGATHA

The first model closely examined was the AGATHA theater-level model from the German organization Industrial Arbeit Betrieb Gesellschaft. AGATHA consists of an air model (called AIDA) and a ground model (called AFRA). AIDA is a well-designed model with sufficient detail to support higher-echelon WPC exercises. AFRA is less resolved, because of the history of projects for which AGATHA was developed. With some substantial, relatively costly, but low-risk

[1]The Models Investigation Project was headed by the author, who was assigned a WPC functional area expert from each of the major functional areas. Reports on each model were written by the author, reviewed by the WPC staff representatives, and presented to the WPC commander and vice commander.

modifications, the AFRA model might be able to support WPC exercises. The main feature the AGATHA model lacks is a naval model.

METRIC-V

The next model examined was the Metric-V model from BDM. The model is based on object-oriented programming and is quite flexible in its design. Air, land, and sea assets are all represented. However, the player interface is extremely slow and cannot support WPC exercises without significant software improvement, especially in the graphics displays. In addition, the special bit-packing techniques used in the database make it difficult to detect database errors.

THE JOINT THEATER-LEVEL SIMULATION

The next model examined was JTLS, which Roland and Associates primarily built and modified. Although originally designed as an analytic model, the manpower intensity of the player interface made it more appropriate for training support. The current version of JTLS includes air, land, and sea operations (except for subsurface naval operations then under development). Different databases exist with different-sized units and hexes, although the one most appropriate for the WPC is the brigade-sized units with 16-km hexes. Units do not have to be in the center of the hex, which precludes a lot of problems usually associated with hex-based models, such as GRWSIM. The player interface has significantly improved since the model was first tested at the WPC. (Overcoming the WPC's previous poor experience with JTLS was essential to the WPC taking a solid look at the current version of the model and its capabilities.) Configuration control, funding, and sponsorship are all centrally located at the JCS through the Joint Warfare Center. Therefore, the WPC will not have to pay for model development or modification, which are paid for by the central model proponent. In addition, use of the JTLS will bring the WPC into the larger community of facilities that use common training simulations.

THE RAND STRATEGY ASSESSMENT SYSTEM

The RAND Strategy Assessment System (RSAS) has been used for the last four years at the U.S. Joint Global Wargame, held annually at the Naval War College. The level of resolution of the RSAS is designed for strategic and operational-strategic echelons. The RSAS includes a strategic mobility model and a theater-level model. In the theater-level model the terrain features, model assessment processes,

and unit status can be changed while the model is running. Although the RSAS is primarily an analytical tool, it has been used to support theater-level and multitheater training exercises. The RSAS tends to be useful to support exercises with very large time compression (e.g., an exercise including build-up and conflict covering 100 days in a 10-day exercise), but is much less suitable for support of real-time or near-real-time exercises.

THE THEATER ANALYSIS MODEL

The Theater Analysis Model (TAM), by Booz-Allen Hamilton, is a very aggregated model designed to run on a desktop computer. TAM is designed around a relational database with incremented time steps to assess outcomes. Because of the very aggregated nature of the model, it was not considered a viable candidate to support WPC exercises. TAM might be useful as a small and inexpensive battle-staff exercise driver, assuming the database has been tailored for that staff.

TACWAR

The Institute for Defense Analysis's (IDA's) Tactical Warfare (TACWAR) was briefly considered for use at the WPC. However, TACWAR is an analytical model with very limited training support capabilities, with predominantly ground, limited air, and no naval representation.

THE CORPS BATTLE SIMULATION

CBS (previously called JESS) is also a hex-based model in which units do not have to be located in the center of the hex. This makes the assessment of indirect fire much more realistic in CBS than in GRWSIM, in which units must always be in the center of the hex and are always hit by indirect fire that must land in the center of the hex. CBS connects to standard Army communications equipment, thereby allowing digital inputs and outputs to be passed between the model and the communications equipment. This allows the players to use communications equipment with which they are familiar. A recent addition to CBS is the Combat Outcome Based on Rules of Attrition (COBRA). This addition allows the CBS model to account for basic combined arms effects, such as infantry performing better than armor in urban and mountainous terrain. Most ground combat models, including GRWSIM, do not represent many of these basic combined arms effects. A similar methodology for aggregated models was developed at RAND four years ago and has been implemented in the

RSAS (Allen, 1992b). Like JTLS, CBS has central configuration control, funding, and sponsorship. In addition, use of CBS will bring the WPC into the larger community of facilities that use common, service-approved, training simulations.

OTHER MODELS

Other models listed for consideration were TAC Thunder, for strictly air exercises, and a hexless version of the GRWSIM model from E-Systems. There was insufficient time to adequately evaluate either of these two options.

6. RESULTS

The new international environment has led to significant changes in the WPC training environment, as well as the future availability of manpower and funds for both the WPC and future training exercises. Although these changes imply that more training exercises will use computer support, less manpower and less funding are likely to be available.

This section presents the results to date on RAND's proposals for a future WPC suite of models. The following factors, previously discussed in detail, contributed to this proposed design: the needs of higher-echelon training headquarters, the reevaluation of the old assumptions, the availability of alternative models, and the projected shortage of manpower and funding for exercise support and model development.

Early WPC experiences led to a number of assumptions that filtered perceptions regarding the benefits of alternative existing models and exercise designs. These assumptions were reevaluated during a project the author initiated and presented to the WPC commander and vice commander. *Assumptions* regarding the need for the WPC to be in the in-house model development business, with all of its associated overhead tasks, were reexamined during this project.

The author recommended that the WPC use two sets of models to satisfy the training requirements of the recently expanded customer base—one for army group and above exercises and one for army group and below exercises.

SET ONE: ARMY GROUP AND ABOVE EXERCISES

An aggregated theater-level model is more appropriate for higher-echelon exercises. The manpower and cost requirements are lower for aggregate-level models than for detailed models, while attention may be focused on sustainability, strategic deployment, and other long-term issues. In addition, time compression is available in a more aggregated model, and this allows the scope of the exercise to adequately address higher-echelon sustainability issues.

The decision as to whether to have an aggregated model at the army group level depends on the composition of the training audience and the training objectives. If only the army group commander and senior

staff are in the training audience and if all subordinate staffs are represented by response cells, a continuous air picture is not required and an aggregated model is both adequate and cost effective. If the full army group staff and the staffs of several subordinate headquarters are included in the training audience, the aggregated model (JTLS) may not be sufficient to satisfy the training objectives. In this case, however, the WPC suite of models using the two service-approved models, AWSIM and CBS, will be able to support the army group exercise.

Either model suite can be used for army group, depending upon the composition of the training audience and the training objectives. If the training audience includes the army group staff and many staff elements from subordinate echelons, a continuous air picture may be required, and therefore the more detailed suite should be used. If, instead, the training audience includes only the army group staff in the training audience and if any subordinate echelons are represented as response cells, a continuous air picture is not required, and the less detailed model(s) may be used.

The Models Investigation Project team recommended JTLS as the aggregate model of choice for a number of reasons. The first was that it is a combined air, land, and sea model. The shortcoming of limited undersea representation could be handled either by projected model improvements (currently under way) or by controller intervention during the exercise. The level of resolution is appropriate for higher-echelon exercises. The logistics model components can be tailored to track selected items of interest. (One caution on tracking logistics items is that the more items tracked, the slower the model runs.) The model is well documented, and the supporting staff is responsive and experienced. JTLS is already available to all Unified commands. The acceptance of JTLS at the WPC for higher-echelon exercises would bring the WPC into a larger community that uses the same service-approved training models.

Regarding the status of the first proposal, the WPC's SOSC has already approved the attempt to use JTLS to support a higher-echelon exercise (ACE 92), and this decision has been enthusiastically received at SHAPE headquarters.[1]

[1]Because of recent and dramatic world events, however, it appears that ACE 92 will be significantly different from what SHAPE originally planned. Because of the understandably large uncertainties in the scenario and the training objectives, ACE 92 may be run as a seminar game rather than as a computer-assisted exercise.

SET TWO: ARMY GROUP AND BELOW EXERCISES

Army group and corps-level exercises will still require a more detailed set of models. The basis for the more detailed set of models is the existing WPC suite of models, with the exception of the GRWSIM ground model, for reasons described below.

Air Model

AWSIM is currently the Air Force service-approved model for exercises that require a continuous air picture. One important feature of AWSIM is the EIFEL emulator—a software tool that displays model outputs in a form familiar to NATO air forces personnel. The model proponent for AWSIM is currently Blue Flag, although most of the model changes occur at the WPC. The rate of code changes to AWSIM, however, was significantly lower than the rate of code changes to GRWSIM during the author's tour.

As mentioned earlier, the major concern about AWSIM is that the overall engagement rates appear to be high, although this is a problem most air combat models share.

Ground Model

The Models Investigation Project team also recommended that the CBS model be preferred over the existing GRWSIM model for a variety of reasons. The level of resolution of the two ground models is virtually identical. Both models can track units to company level, and the terrain hex sizes are 3 km in CBS and 3.2 km in GRWSIM. Manpower requirements to operate either model in the same exercise design are equivalent. From there on, CBS has many advantages over GRWSIM for any U.S. or NATO customer:

- Units in CBS can be combined and divided dynamically during the course of the game, increasing model flexibility and making database preparation significantly easier in CBS. In GRWSIM, once the game begins, the total number of units the model can track cannot change.
- Units in CBS do not have to be located in the center of the hex, thereby making the fire-support algorithms more realistic. Units in GRWSIM are always located in the center of the hex, thereby making all indirect fire assessments unrealistically accurate.
- The COBRA addendum to CBS allows the model to account for basic combined arms effects that are lacking in most ground combat

models, including GRWSIM. (By combined arms effects, we mean such effects as infantry performing better than armor in urban and mountainous terrain and forces with infantry, armor, and artillery tending to perform better than single combat-arm forces.) COBRA consists of code run on a separate computer, but linked to the CBS model so that COBRA can modify the CBS combat assessment process to account for combined arms effects.

- Communications costs to distribute CBS are lower than for GRWSIM because updates consist only of changes to the CBS database.
- CBS uses standard Army communications equipment for digital model interfaces.
- CBS is part of the U.S. Army Family of Simulations, every U.S. corps uses it and it is the training support tool the U.S. Army Battle Command Training Program (BCTP) uses. The United Kingdom and Germany have also used CBS for training, the United States, Japan, and Korea selected it to support two upcoming allied training exercises (Ulchi Focus Lens and Yamasakura), in 1992 and 1993.

The WPC specified three specific changes for model modifications so that CBS could support WPC exercises:

- CBS must be connected with the AWSIM air model.
- CBS must allow training multiple corps in the same exercise, including the representation of the rear and deep battle areas.
- CBS graphics interface must be compatible with the GIAC player interface, whose development was sponsored by the WPC.

These three requirements have already been accomplished and are being tested for use in REFORGER 92.[2] As a result of these advantages, the WPC accepted the use of CBS as an alternative to

[2]Multiple corps were played in CBS during Caravan Guard 91, and the CBS-AWSIM link was tested during Caravan Guard 91 and again in March and May 1992. These tests have demonstrated sufficient feasibility to proceed with the use of CBS and AWSIM together during REFORGER 92. According to the USAREUR Assistant Deputy Chief of Staff, Operations for Training, "REFORGER 92 (Certain Caravan 92, 23 September to 9 October 1992) will be the first major exercise to use linked service approved simulations to support joint training and will be a precursor for all future JCS Exercises." Reference letter from COL Montgomery C. Meigs, USAREUR ADCSOPS-1, 6 January 1992.

GRWSIM, but declared that GRWSIM would remain available for customers who preferred to use it.

Intelligence Model

The current ICM needs improvement, as described in the RAND Note on the Centurion Shield exercise (Allen, 1992a). The CBS model currently uses BICM, a variant of ICM adapted for use in the Battlefield Command and Training Program. Unfortunately, BICM currently shares many of the same faults as the WPC's ICM.

However, there is another alternative available for training intelligence staffs at the WPC. The CBS model already has an operational interface with the TACSIM intelligence model. WPC exercises might be able to employ the TACSIM model in its exercises, subject to security restrictions.[3]

OVERALL EFFECTS

The effects of these changes on WPC exercises will be to significantly reduce manpower and communications cost requirements for higher-echelon exercises. The use of JTLS for higher-echelon exercises will significantly reduce both the manpower and communication costs. For lower-echelon exercises, the manpower costs remain the same, but the communication costs may be reduced. The use of the CBS instead of GRWSIM will significantly reduce the required communication bandwidth; therefore, the communication costs for a distributed exercise. It costs about $3,000 per day using the 9.6 KB line to distribute CBS alone to remote sites, while it costs about $100,000 per day using the 2 MB line to distribute GRWSIM to the same number of remote sites. When the AWSIM air model is connected with CBS, so that a 64 KB line will be required to distribute them both, the cost will increase to around $20,000 per day. If the current form of the VTC is used in an exercise, however, the communication costs are likely to remain at the higher costs associated with the larger bandwidth.

The quality of WPC exercises will probably improve as a result of the acceptance of these recommendations. For higher-echelon exercises, the level of resolution is more appropriate because of the use of an aggregated model. In addition, the JTLS model's features and new

[3]For example, TACSIM runs at a high U.S. level of classification, and has not been cleared for a NATO level of classification.

exercise designs will allow for a focus on long-term sustainability issues. These sustainability issues will be better addressed by focusing on tracking selected logistics items and unit arrivals, as well as allowing the time compression necessary to address most mid- to long-term sustainability issues.

The quality of lower-echelon exercises will also improve. The CBS model represents many features lacking in the GRWSIM model. The advantages of the CBS model include: an adequate representation of basic combined arms effects (absent in the GRWSIM model), easier database preparation, units being located away from the center of the hex, and the ability to combine and separate units dynamically during model execution.

Both the JTLS and the CBS model will bring the WPC into a larger community that uses the same tools. The JTLS model is available to every unified commander, and the CBS model is available to every U.S. corps, the Battle Command Training Program, and to the United Kingdom. In addition, Germany, Japan, and Korea have used or are planning to use CBS to support allied exercises.

With these changes, the WPC will be able to adapt to the changing training requirements and provide higher-quality training support in the face of projected reductions in manpower and budget.

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