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BRL

THE ARMY UNIT RESILIENCY ANALYSIS (AURA) COMPUTER SIMULATION MODEL: A BRIEF OVERVIEW

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13. ABSTRACT (Maximum 200 words)

The primary purpose of this paper is to exhibit the current capabilities, uses, and recent developments with respect to the AURA model. Developed by the Ballistic Research Laboratory (BRL), AURA is a large, inter-connected collection of analysis models which provides a detailed evaluation of the ability of a military unit to accomplish a series of missions in a combat scenario. The AURA methodology consists of a number of models from the various technical communities interfaced into a large, time-dependent event playing and optimization algorithm. The interfaces are varied, involving such diverse technical inputs as lethal footprints for conventional munitions, log normal kill probabilities for nuclear effects, chemical dissemination, chemical deposition and vapor footprints, MOPP degradation, reliability, and target acquisition probabilities. The optimization is a dedicated, non-linear routine which models the commander's decisions regarding reallocation of surviving, degraded assets in order to minimize the choke points in the optimal functional path.

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I. Introduction

AURA, the Army Unit Resiliency Analysis methodology, is a large, interconnected collection of analysis models which provides a detailed evaluation of the ability of a military unit to accomplish a series of missions in a combat scenario. Briefly, AURA is an event sequenced, one-sided combat simulation methodology. The methodology consists of highly detailed models from the various technical communities interfaced into a large, time-dependent event playing and optimization routine. The interfaces are varied, involving such diverse forms of input as lethal footprints for conventional munitions, log normal kill probabilities for nuclear effects, chemical dispersion and evaporation, MOPP degradation, reliability, and target acquisition probabilities. The optimization is a dedicated non-linear routine which models the commander's reallocation of surviving but degraded assets. This permits minimization of the choke points in the optimal functional path. The logic process required the development of a general model for the functional structure of a military unit. Such a model was developed and forms an essential part of the AURA methodology.

AURA is distinctive from other models in several ways. First is the versatility and breadth of the AURA model. Driven by user defined inputs, AURA requires a great deal of detail in describing the unit structure, weapon capabilities, and unit mission to be modeled. Second, unlike many models, AURA inputs are directly related to physically measureable quantities such as the interrelationships between unit tasks and asset deployment. Finally, AURA's most important distinction is the ability to measure unit effectiveness via a realistic commander model, known as the AURA Asset Allocation Algorithm. The calculation of a highly detailed profile of unit effectiveness is based not only on the capability of surviving (including degraded) assets but also on the commander's decisions regarding the reallocation of these assets.

The Integrated Battlefield Assessment Branch, Vulnerability/Lethality Division, U.S. Army Ballistic Research Laboratory (BRL), is the developer, maintainer and a primary user of AURA. However, many other agencies now run the AURA code, as do a number of federal contractors. The AURA code has been run on UNIVAC, VAX, SUN, IBM, CDC, and Data General computers, as well as the CRAY 'supercomputers' on which it resides at the BRL.

As generalized above, the AURA model is an amalgamation of analysis techniques, algorithms, and data sources gathered from the laboratories that specialize in the various areas which impact upon the resiliency of a military unit. AURA currently has the capability to model such phenomena as:

* Quantified Unit Effectiveness (including asset reallocation);
* Deployment of Personnel and Equipment (including dynamically changing deployment postures);
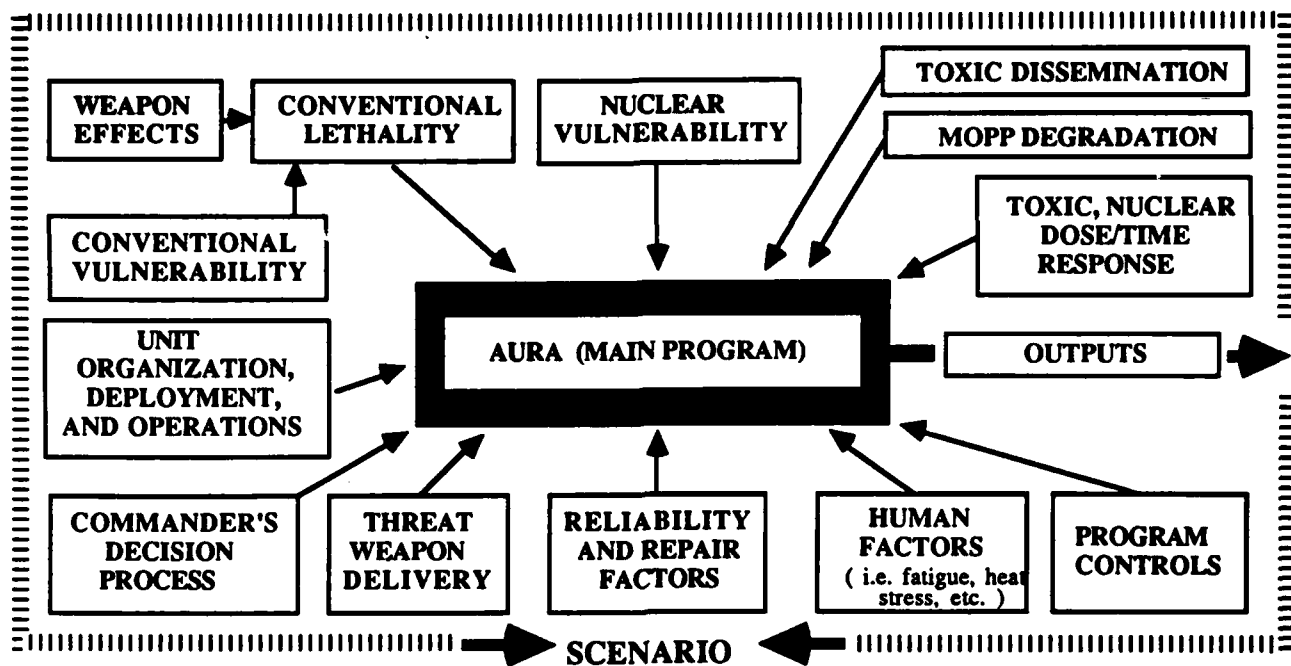* Incoming Weapons;

* Conventional Lethality;
* Chemical Lethality;
* Nuclear Vulnerability;
* Equipment Repair;
* Personnel Factors including:
  - Degradation due to Fatigue;
  - Degradation due to Heat Stress;
  - Suboptimal training;
  - Sub-lethal dose effects.

As a result of its breadth and versatility, AURA is finding application in a variety of studies conducted by a number of agencies. This growth in the number of ongoing studies is increasing the number of analysts who conduct AURA studies and who, therefore, need to fully understand all aspects of the AURA methodology.

In August 1990 and October 1990, the BRL has published two volumes[1][2] of a three volume report which has been designed to provide a comprehensive understanding of the methodologies of the AURA model.

Volume 1 of this report presents the programmer/analyst with a detailed understanding of the methodologies which embody the AURA model. The approach taken was to progress from a general overview of the AURA model to a detailed description of the derivation, capability and primary algorithms for each AURA methodology. Throughout the report, a simple, hypothetical combat support unit is used as a 'working' example to describe the role of each methodology in the overall simulation process. The AURA methodologies are described in detail, concentrating on the areas such as the AURA Asset Allocation Algorithm (the commander's decision model) which were derived especially for AURA, and the spectrum of methodologies which have been combined to form the AURA model. Figure 1 illustrates the AURA "family of methodologies" as well as the corresponding source of each contributing methodology.

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1. R. Sheroke, et al, Programmer/Analyst Guide for the Army Unit Resiliency Analysis (AURA) Computer Simulation Model, Volume 1: AURA Methodology, USA Ballistic Research Laboratory, BRL-TR-3156, (October 90).

2. R. Sheroke, et al, Programmer/Analyst Guide for the Army Unit Resiliency Analysis (AURA) Computer Simulation Model, Volume 2: AURA Source Code, USA Ballistic Research Laboratory, BRL-TR-3103, (July 90).

Figure 1. The AURA Family of Methodologies.

Volume 2 of this report contains a detailed description of the organization and conventions of the FORTRAN source code that embodies the AURA methodology.

The third volume of the report will contain an in-depth description of the conduct of an AURA analysis, from data preparation through output analysis, as presented from an analyst's perspective. Volume 3 will also describe the methods by which to prepare the inputs needed to perform an AURA analysis. Included in the data preparation section of Volume 3 will be detailed examples of how to create both an AURA runstream and threat/lethality file.

II. Operation of the AURA Model

As stated above, AURA is a family of methodologies covering a broad spectrum of technical areas. Figure 1 depicted the methodologies (and associated sources) which comprise the AURA model. As shown, the various models are interfaced together into a combat simulation through a computer program which is also called AURA. Reference 2 contains a comprehensive explanation of the organization, source code preparation and execution, and algorithms of the AURA model. The general operation of the AURA computer code is described in Table 1 and is illustrated in Figure 2.

Table 1. General Operation of AURA

1. User inputs the runstream data, which includes:
   a. Scenario
   b. Threat
   c. Lethality
   d. Unit Information:
      1. Mission(s);
      2. Assets (personnel/equipment);
      3. Organization and Operation.
2. The code processes the data and sets up the simulation.
3. The code runs the simulation a specified number of times.
   a. Time dependent phenomena are updated before each event
   b. Lethality events cause damage, contamination, dosages, etc.
   c. Reconstitution events cause the commander to reallocate his surviving, degraded assets in order to optimize his unit's mission accomplishment
4. The code outputs total and averaged statistics for:
   a. Mission accomplishment;
   b. Asset survival, degradations, dosages, etc;
   c. Reasons for shortcomings;
   d. Decisions made (by commander);
   e. Other items and actions, selected by the user.

General Processing Sequence

MAIN PROGRAM

Set program defaults

Input scenario commands

Check for correctness of inputs

Establish array storage allocation for simulation

Perform Simulation

For each replication ...

Process events for encounter

Total and output replication results

Output results summary (Averaged over all replications)

Update time dependent phenomena

i.e. dosage bins, fatigue, heat stress, etc.

Events

Lethality Events

Reconstitution Events

Other Events

Delivery Error change
Target Location Error change
Fire Direction change
Wind Direction change
Acquisition Probability change

Methodologies

Conventional Lethality

Nuclear Vulnerability

Chemical Lethality
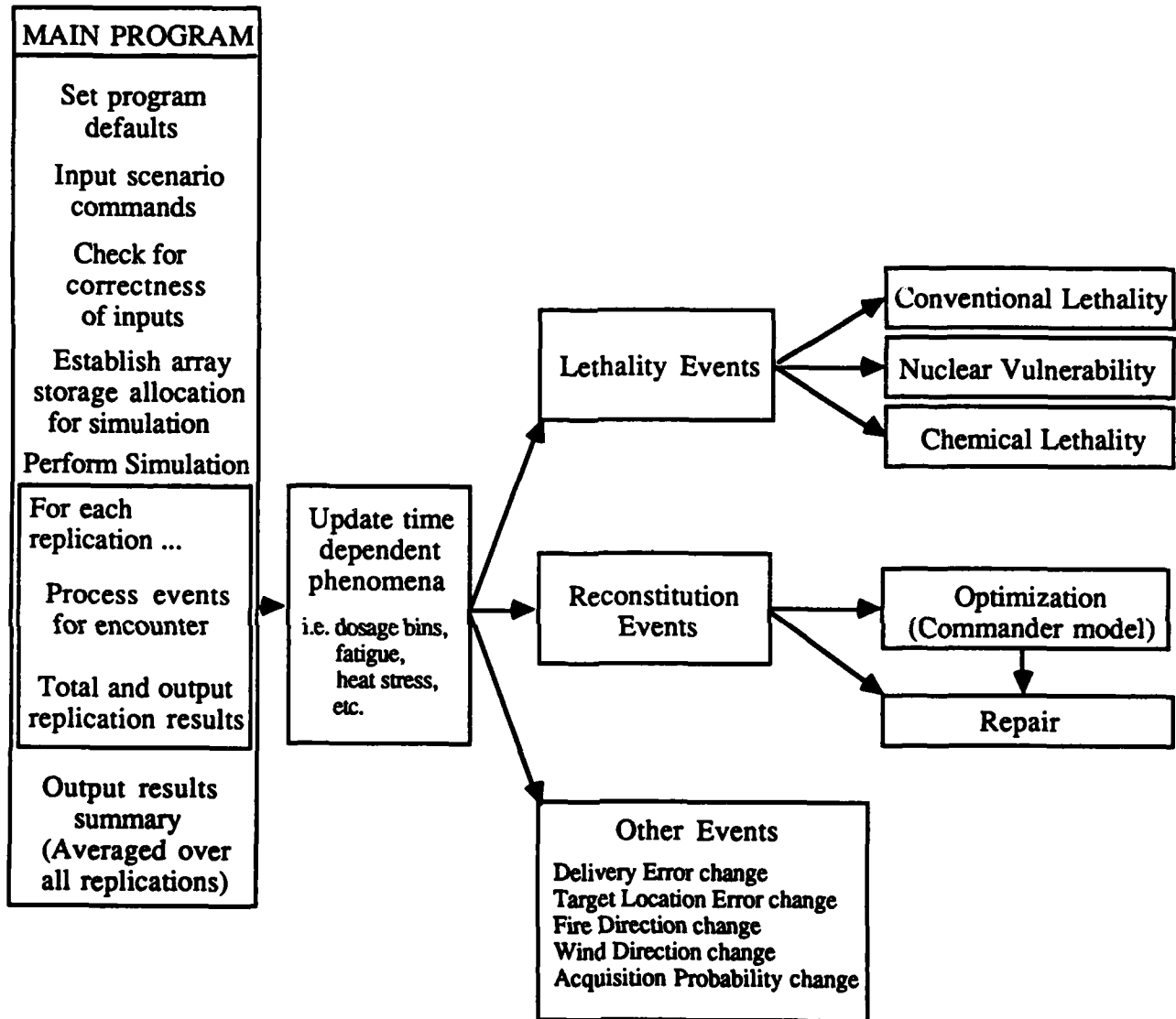
Optimization (Commander model)

Repair

Figure 2. General Operation of the AURA Model

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As described in Table 1, the third stage in the general operation of the AURA model is the processing of the different event types. In AURA, an event is associated with a specific instant in time within the scenario. The processing sequence of the events is user-specified within the input runstream, and represents the aggregation of actions which combine to simulate the scenario. The types of AURA events are: reconstitution events, lethality events, and phenomena such as changes in delivery errors/target location errors, known in AURA as 'other' events. Each of the event types are described below.

A reconstitution event is the process by which the commander simulates taking an inventory of surviving assets and allocating them to subtasks in an effort to improve the effective capability of the unit. By use of the RECONSTI-TUTION option, the user may specify the time points at which a reconstitution should occur, thus providing a 'snapshot' of the unit's status at any given time point during the simulation.

Since a major function of AURA is to measure the effects of events upon a unit, the user generally wants reconstitutions and evaluations to take place at specified times relative to certain events, rather than at specific 'clock' times in the scenario. An example of such an event is a lethality event (discussed in next section). Rather than specifying the effectiveness status at 100, 200, and 1000 minutes into the scenario, the user may be more concerned with the effectiveness at 100, 200, and 1000 minutes after the arrival of a warhead. The INTERNAL RECONSTITUTION TIMES input option enables the user to specify the relative time points to trigger a reconstitution event.

A lethality event is the process by which the AURA model simulates the effects resulting from a conventional, chemical, or nuclear attack. Lethality events are designated time points which signify the arrival of a round (or volley of rounds) and the computation of immediate effects. Table 2 references the data sources for the AURA lethality data.

Table 2.   AURA Lethality Models

Conventional Lethality - Derived from outputs of JTCG/ME FULL SPRAY Model[3]
Nuclear Vulnerability   -   NUDACC Methodology[4]
Chemical Lethality   -   NUSSE3 Methodology[5]

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3. "Computer Program for General Full Spray Material MAE Computations", Joint Technical Coordinating Group for Munitions Effectiveness, 61 JTCG/ME-79-1-1.

4. William L. Vault, "Vulnerability Data Array: The Agreed Data Base - Final Report (U)," Harry Diamond Laboratories, HDL-TR-1906, (July 80).

In AURA, phenomena which impact the general operation of the scenario are categorically called 'other' events. The user can establish the parameters for each 'other' event in the input runstream. For example, in modeling a conventional scenario, suppose the user wants another attack to occur at the 5 hour mark, employing new weapon delivery errors. At the 5 hour mark, AURA will perform its calculations based upon the new delivery errors for the weapon. This would be considered a delivery error change event which falls under the 'other' events catagory. The types of phenomena changes considered by AURA to be 'other' events are as follows:
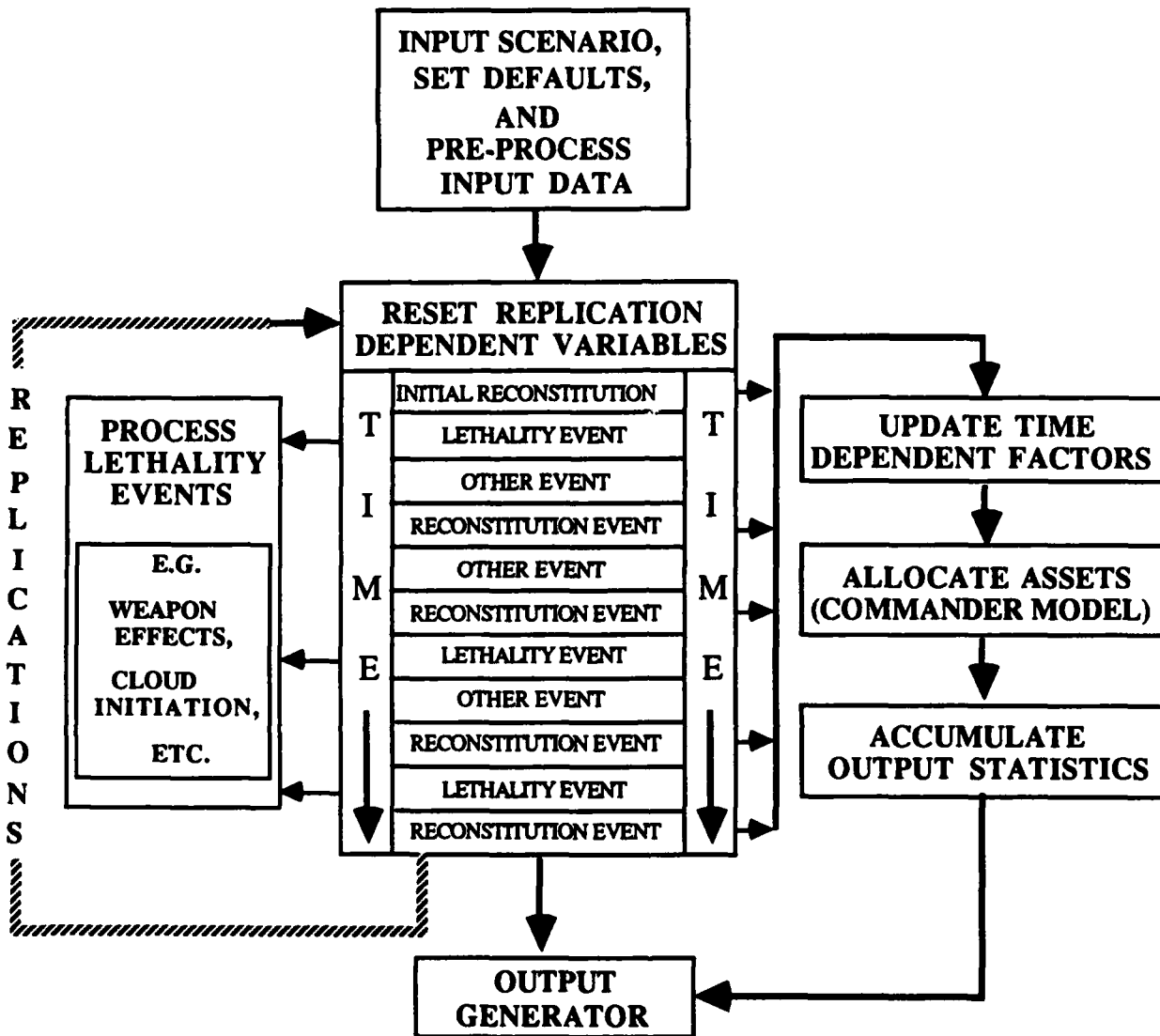
> Delivery Error;
> Target Location Error;
> Incoming Fire Direction;
> Wind Direction;
> Acquisition Probability.

Figure 3 depicts a flowchart of the general processing of the AURA model using an arbitrarily selected user defined event processing sequence. Recall, 'other' events are user inputs which are specified in the runstream. In Figure 5, the 'other' events are assumed to have been declared in the input.

III. AURA Inputs

As described in Table 1, operation of the AURA model requires such inputs as the scenario, weapon threat/lethality data, unit organization, and the mission to be simulated. These inputs are organized into files created by the user. The two types of AURA input files are the runstream and weapon threat/lethality file. Table 3 briefly describes the contents of the AURA input files. A detailed description of the organization and contents of the AURA input files is contained in Reference 2.

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5. Richard Saucier, "NUSSE3 Model Description," U.S Army Chemical Research Development and Engineering Center, Special Publication CRDC-SP-86009, March 1986.

Figure 3. General Flowchart of AURA Model

The flowchart contains the following labeled boxes:

INPUT SCENARIO, SET DEFAULTS, AND PRE-PROCESS INPUT DATA

RESET REPLICATION DEPENDENT VARIABLES

Left vertical label: **R E P L I C A T I O N S**

PROCESS LETHALITY EVENTS

E.G.
WEAPON EFFECTS,
CLOUD INITIATION,
ETC.

Center column (between "T I M E" labels):
INITIAL RECONSTITUTION
LETHALITY EVENT
OTHER EVENT
RECONSTITUTION EVENT
OTHER EVENT
RECONSTITUTION EVENT
LETHALITY EVENT
OTHER EVENT
RECONSTITUTION EVENT
LETHALITY EVENT
RECONSTITUTION EVENT

UPDATE TIME DEPENDENT FACTORS

ALLOCATE ASSETS (COMMANDER MODEL)

ACCUMULATE OUTPUT STATISTICS

OUTPUT GENERATOR

NOTE:

The event ordering sequence shown here has been arbitrarily selected.
The ordering of events is dependent upon the scenario specified in the
input runstream.

Figure 3. General Flowchart of AURA Model

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Table 3. AURA Input Files

File	Contents
runstream	Assets (personnel/equipment) in unit Deployment of assets Weapon parameters Unit organization/function parameters Program controls etc.
lethality file(s)	Weapon effects data for: Conventional Lethality; Chemical Dispersion; Nuclear Vulnerability.

IV. AURA Outputs

Analyses involving the AURA model can generate large amounts of data. It is possible, for example, to output the impact point of every incoming round: for 100 replications of a study involving a heavy artillery barrage, the impact point output alone could consume upwards of 10,000 pages of computer paper. For this reason, AURA provides the capability to optionally output only those quantities that are of interest to the analyst for his/her specific needs. When no options are invoked, the defaults in AURA result in a moderate amount of output which includes a consolidation of the inputs and a report of the final, average result at each time point.

Table 5 provides a general outline of most of the primary AURA outputs. The collection of AURA output options/commands is described in detail in the AURA Input Manual.[6]

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6. J.T. Klopcic, et al, "Input Manual for the Army Unit Resiliency Analysis (AURA) Methodology: 1990 Update", USA Ballistic Research Laboratory, BRL-TR-3187, (December 1990).

Table 5. General Outline of AURA Outputs

I. Consolidation of Inputs

    A. Commands specified
    B. Table of events to be processed
    C. Weapon information
    D. Assets (personnel/equipment)
    E. Functional structure of mission
    F. Link substitutability matrix
    G. Deployment table/plot

II. Intermediate Results

    A. Actual weapon impact points
    B. Casualties, contaminations
    C. Chemical or Nuclear dosages
    D. Repair status
    E. Optimization status (decisions made by commander model)
    F. Replication summaries

III. Final Results -versus- Time

    A. Effectiveness, statistics, and distribution
    B. Survivors
    C. Degradation due to fatigue, dosages, or contaminations
    D. Job status (LINK table)
    E. Mission results (CHAIN table)

IV. Averaged Results (over all replications)

    A. Repair results
    B. Asset status
      1. Degradation
      2. Reliability failures
    C. Unit effectiveness

    The AURA output manual[7] will provide a 'walkthrough' of an AURA study with an emphasis on the analysis and interpretation of the entire spectrum of AURA outputs.

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7. R. M. Sheroke, "Output Manual for the Army Unit Resiliency Analysis (AURA) Computer Simulation Model, Ballistic Research Laboratory, DRAFT REPORT, (January 1991).

V. Applications of the AURA Model

AURA is designed to assess combat unit effectiveness at the battalion level or lower. AURA is capable of assessing larger units (the BRL has used upwards of 1200 people), however, modeling units of larger than battalion size entails an enormous amount of input preparation time and effort by the analyst. Unit effectiveness is specifically tied to a quantifiable unit mission such as to fire x number of rounds per minute, move x number of meters per hour or load x number of stacks per day. While unit effectiveness is considered to be the primary measure of effectiveness (MOE) provided by the AURA model, there are others as well. MOEs are chosen based on the intent of each analysis and may include such things as the number of personnel casualties or deaths, the number of damaged and/or killed items of equipment, the number of repairs made and identification of tasks that are limiting the effectiveness of the unit.

Typically, analyses are accomplished through the systematic variation of the vulnerability and lethality data inputs of interest. The impact of these changes on the chosen MOEs form the database from which weapons effects and unit vulnerabilities may be assessed.

There are a number of areas and/or problems that can be addressed using the AURA model. A sample will be discussed to give the reader an idea of the various uses.

One of the initial applications of the AURA model was the analysis of tables of organization and equipment (T.O. and E.) structure and cross-training of unit personnel. This allowed several proponent schools (such as the Quartermaster School and the Missile and Munition Center and School) to analyze various T.O. and E. changes and decide on the best formulation of the unit.[8][9][10] It also enabled the analysis of personnel cross-training. Using the substitution matrix required by the AURA model, changes could be made and their impact on unit operations studied.

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8. M.M. Stark, J.T. Klopcic, "The Resiliency of an Ammunition Supply Point to Combat Damage (U)", USA Ballistic Research Laboratory Technical Report No. BRL-TR-2614, December 1984.

9. M.M. Stark, J.T. Klopcic, "The Resiliency of Ammunition Supply Points in a Pre-Defined, Integrated Battlefield Scenario (U)", USA Ballistic Research Laboratory Technical Report No. BRL-TR-2609, November 1984.

10. L.K. Roach, "The Resiliency of a Supply and Service Company to Combat Damage (U)", USA Ballistic Research Laboratory Technical Report No. BRL-TR-2669, August 1985.

Equipment reliability can also be studied with the AURA model. Using first a baseline case with current reliability values, the user could then make changes to the reliability numbers and determine their impact on unit operations.[11] A related application is the analysis of the nuclear and Nuclear, Biological, and Chemical (NBC) contamination survivability criteria of equipment. Again, baseline cases using the current survivability criteria are analyzed, followed by cases using alternate survivability criteria. This allows the user, for example, the USA Nuclear and Chemical Agency (USANCA), to study the impact of criteria changes. This approach has been used in the past by the U.S. Army Chemical Research, Development and Engineering Command (CRDEC) and USANCA to determine what impact relaxed criteria have on unit operations.[12]

A recent analysis using the AURA model was performed for Operation Desert Shield [13] to estimate the degradation (due to heat stress) associated with operations in a desert environment. AURA has also been used to assess degradation associated with operations in an NBC environment.[14,15] These studies have concentrated mainly on the effects of MOPP on personnel performance and unit operations. Related phenomena are the effects of heat stress and heat stress casualties on unit operations and the ability of personnel to operate unit equipment while in MOPP.

Other applications of the AURA model include analyses of weapons effectiveness and changes in delivery accuracy.[16] Also, AURA studies have looked

11. S.S. Juarascio, "Evaluation of an 8-Gun M109A2 Artillery Battery with Replacement of Combat Damaged Mission Essential Components (U)", USA Ballistic Research Laboratory Technical Report No. BRL-TR-2682, October 1985.

12. S.S. Juarascio, J.M. Abell, "Impact of Chemical Survivability Criteria on Unit Performance (U)", USA Ballistic Research Laboratory Report No. BRL-TR-2870, November 1987.

13. "(U) Chemical Weapon/Heat Stress Analyses for Southwest Asia Environment", L.K. Roach, S.S. Juarascio, T.P. Hindman, Ballistic Research Laboratory, DRAFT REPORT, November 1990.

14. M.M. Stark, J.T. Klopcic, S.S. Juarascio "The Effects of Chemical Contamination/Decontamination of a M109A2 8-Gun Artillery Battery (U)", USA Ballistic Research Laboratory Technical Report No. BRL-TR-2633, February 1985.

15. L.K. Roach, "The Effects of Chemical Contamination/Decontamination on an M1 Tank Company (U)", USA Ballistic Research Laboratory Technical Report No. BRL-TR-2723, April 1986.

16. L.K. Roach, S.S. Juarascio, "The Resiliency of Selected Soviet Units to Candidate Chemical Warheads for Use in the Corps Support Weapon System (CSWS) (U)", USA Ballistic Research Laboratory Technical Report No. BRL-TR-2724, April 1986.

at the benefits of improved survivability of ammunition stacks and the impact of reducing distances between the stacks.[17] The AURA applications described in this section are only a sampling of the types of analyses that have been, and can be, performed using the AURA model.

VI. Current Efforts in AURA Methodology

Current work at the USA BRL is directed toward the development/improvement of AURA methodologies for disciplines such as:

- Evaluation of capability/effectiveness of 'smart' munitions;

- Improvement to chemical lethality model by incorporating
  a non-linear internal chemical dosage methodology;

- Improvement of modeling for personnel degradation due to heat stress.

VII. Summary

The common use of methodologies like AURA by agencies throughout the Army will result in analyses which are efficiently conducted, utilize the best available data and models from the proponent laboratories and schools, and can be consistently compared. However, it is essential that the use of such tools does not place undo dedicated manpower and training requirements upon the using organizations. Since AURA represents the state-of-the-art in unit resiliency analysis, it is appropriate that newly emerging user interface technology be applied to make AURA easily usable by the Army analysis community. To this end, the BRL and the TRADOC Analysis Center - White Sands Missle Range (TRAC-WSMR) are actively seeking suggestions from prospective users to insure that the enhancements being developed contribute to a state-of-art user oriented model.

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17. M.M. Stark, J.T. Klopcic, op. cit., BRL-TR-2614

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17. M.M. Stark, J.T. Klopcic, op. cit., BRL-TR-2614

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