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MODELING AND SIMULATION OF THE SOLDIER AS A SYSTEM

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14. ABSTRACT

This paper contains two briefings to the 60th Symposium of the Military Operations Research Society: Contingency Operations in a New World Order, Naval Postgraduate School, Monterey, California, 23-25 June 1992. The briefings describe analytical initiatives performed by the Concepts Analysis Division, Advanced Systems Directorate of the US Army Natick Research, Development and Engineering Center and Simulation Technologies, Inc., in support of the Soldier as a System.

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MODELING AND SIMULATION OF THE SOLDIER AS A SYSTEM

This paper contains briefings to the 60th Symposium of the Military Operations Research Society: Contingency Operations in a New World Order, Naval Postgraduate School, Monterey, California, 23-25 June 1992. The briefings describe analytical initiatives performed by the Concepts Analysis Division, Advanced Systems Directorate of the US Army Natick Research, Development and Engineering Center and Simulation Technologies, Inc., in support of the Soldier as a System.

Integrated Unit Simulation System (IUSS)

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JUNE 1992

INTEGRATED UNIT SIMULATION SYSTEM

The US Army Natick Research Development and Engineering Center (Natick), supported by Simulation Technologies, Inc.(STI), is currently developing the Integrated Unit Simulation System (IUSS) to provide a comprehensive analysis environment for the evaluation of Soldier Systems' survivability and effectiveness. The focus of the effort is individual performance within the context of small unit (squad or platoon) mission tasking. The IUSS is initially intended for the assessment of proposed or projected equipment for the individual soldier, although transition is planned to a wide variety of other applications, including training and exercise production, development of operational aids and wargaming support.

The IUSS provides an open, extensible architecture for the integration of current and evolving models of the varied aspects of the modern battlefield - threats, personnel, equipment, and environmental factors. The IUSS is based on the philosophy of the Soldier as a System: equipment and other contributors to the soldier's performance must be considered as a synergistic whole, rather than as a series of isolated factors. The IUSS implements this philosophy by employing object oriented design and programming paradigms to facilitate the modular incorporation of selected models/methodologies into a unified representation of the factors relevant to a given analysis.

Approach

Natick IUSS

Employ Current Advances in Computer Technology

- Multi-Platform Applications
- Object Oriented Programming
- Graphical User Interfaces (GUI)
- Artificial Intelligence (AI) and Expert Systems

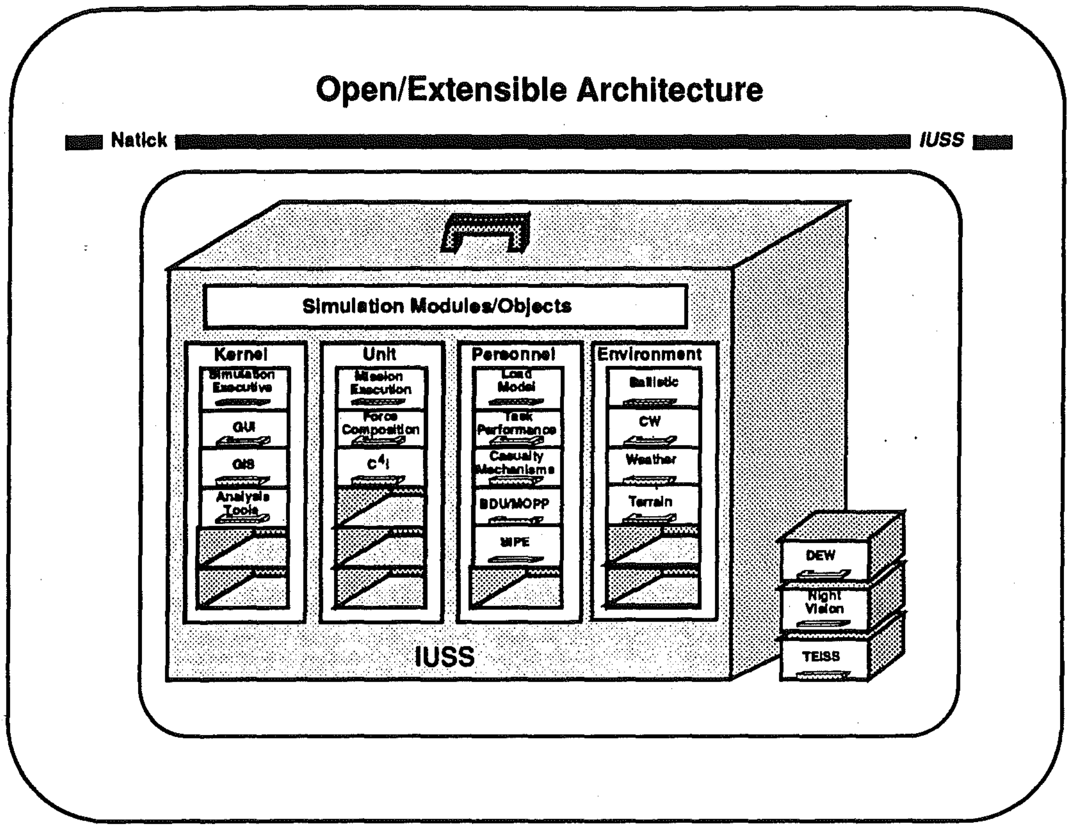
Development Criteria

- Driven by User Concerns
- Supported by Existing Data & Models
- Standardized Methodology / Data Interfaces
- Utilize Existing Models

APPROACH

The IUSS is an attempt to exploit the enormous potential of current technological advances: hardware that is faster, possessed of far greater memory, and with expanding input/output options; object oriented programming with its potential for reusable code and greatly reduced development times; Graphical User Interfaces (GUI's) which simplify user interaction while at the same time providing access to greater functionality, and Artificial Intelligence (AI) with the capability to provide decision aids and context sensitive simulations.

Development priorities are driven by user concerns - the need for specific functionality and driven by data/methodology issues (availability, reliability, completeness, and consistency). There is a wealth of available capability in modeling and simulation, the most cost-effective approach to meet current needs does not call for creation of new models, but rather more effective use of available methodologies. This is done primarily by arranging them in an architecture which standardizes the data flow between component modules, and reconciles potential inter-model conflicts of resolution and fidelity.

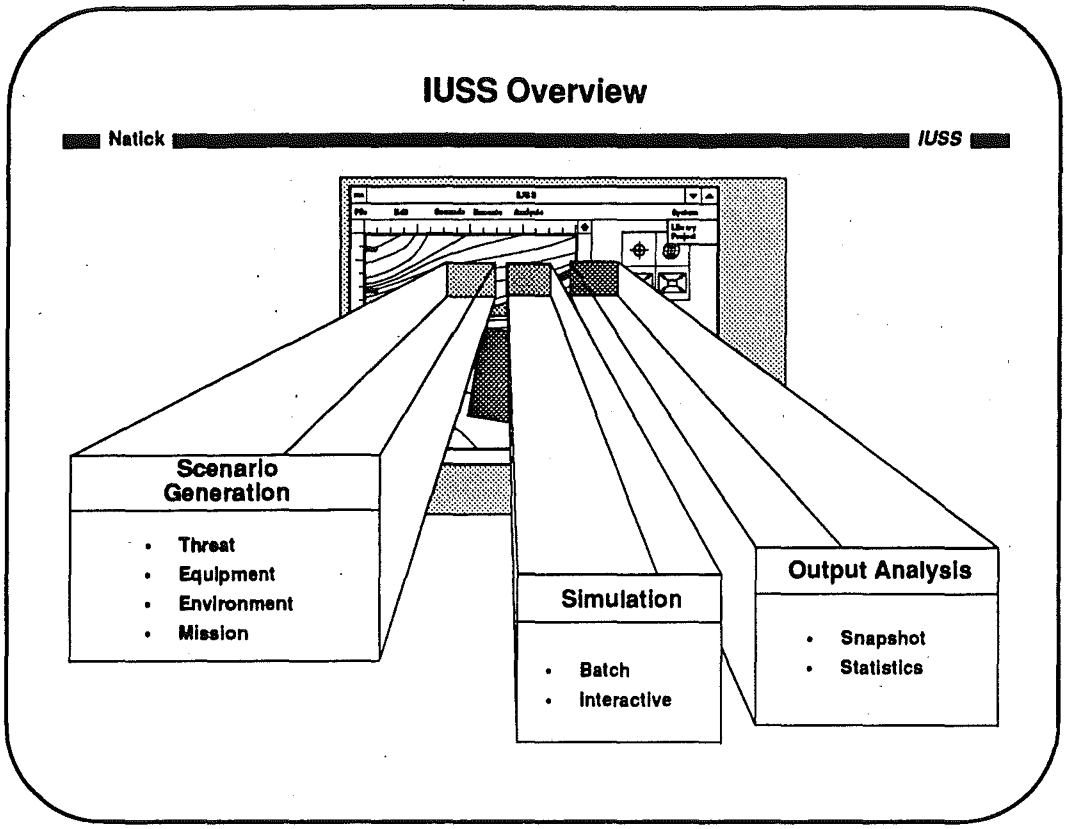


THE IUSS OPEN/EXTENSIBLE ARCHITECTURE

As stated earlier, the IUSS design is based on an architecture which is both open - transportable to multiple hardware/software platforms, and extensible - capable of expansion through the addition of new functional modules. This extensibility is facilitated by the object oriented programming paradigm, which supports encapsulation of the functionality of each module, but also allows easy module replacement and expedites inter-module data flow through overloading of function names. The open architecture will permit a unified representation of the factors relevant to a given analysis by exercising appropriate objects/modules and allowing them to interact with one another.

The IUSS will integrate models which are currently available, but are not now generally used together in coordinated analyses. The IUSS architecture defines inter-module data flow relationships as standardized interfaces; new models are incorporated into the architecture through the construction of shells which encapsulate the function of the model, deriving the model's data requirements from the information contained in the architecture's underlying data structures, and conversely translating its results to standard interface inputs.

Initially, the IUSS will concentrate on those models needed to provide near-term assessment of proposed individual Soldier Systems (e.g. SIPE). However, as shown here, the IUSS architecture is designed to facilitate easy inclusion of additional or new models/methodologies, for example, the effects of new soldier equipment, novel threats/hazards, or theater-specific considerations.



IUSS Overview

The IUSS is designed around the concept of an analysis project, which could be anything from a very small "quick and dirty" effort (e.g.; estimation of soldier travel time over a given terrain set) to much larger multi-year R&D support analyses. A typical project would incorporate an extensive case matrix with a number of different measures of effectiveness, and multiple parametric variations of factors of interest. Such a study would be supported by a library of data bases containing canned inputs, results of previous studies, bibliographic sources, etc. Support and management of such a library or libraries are important functions for the IUSS.

An analysis project has three primary components:

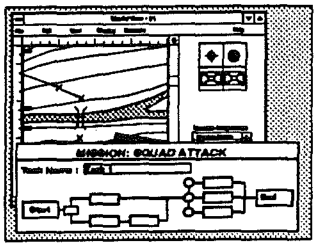
Scenarios: System elements to be analyzed, and the context in which they will function. Scenarios are comprised of such elements as the threat, the simulation environment, unit mission and Soldier System equipment.

Simulations: Models describing scenario outcomes. The IUSS will allow execution of scenarios either interactively (pausing to examine intermediate results), or in batch mode (generally a number of scenario variants executed sequentially).

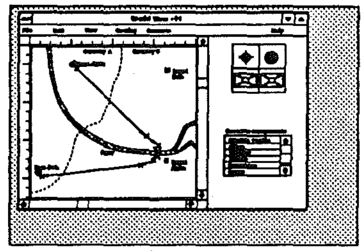
Output Analysis: snapshot views of simulation progress, examining status of systems, the environment, or other factors of interest, or accumulated statistics, e.g., variables over time, Monte Carlo variation within a single scenario, ANOVA or other techniques across scenario variants

Scenario

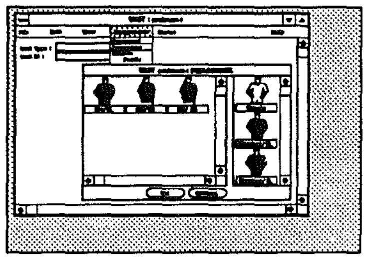
Natick — IUSS



Task Breakdowns



Mission Waypoints



Unit Personnel

SCENARIO

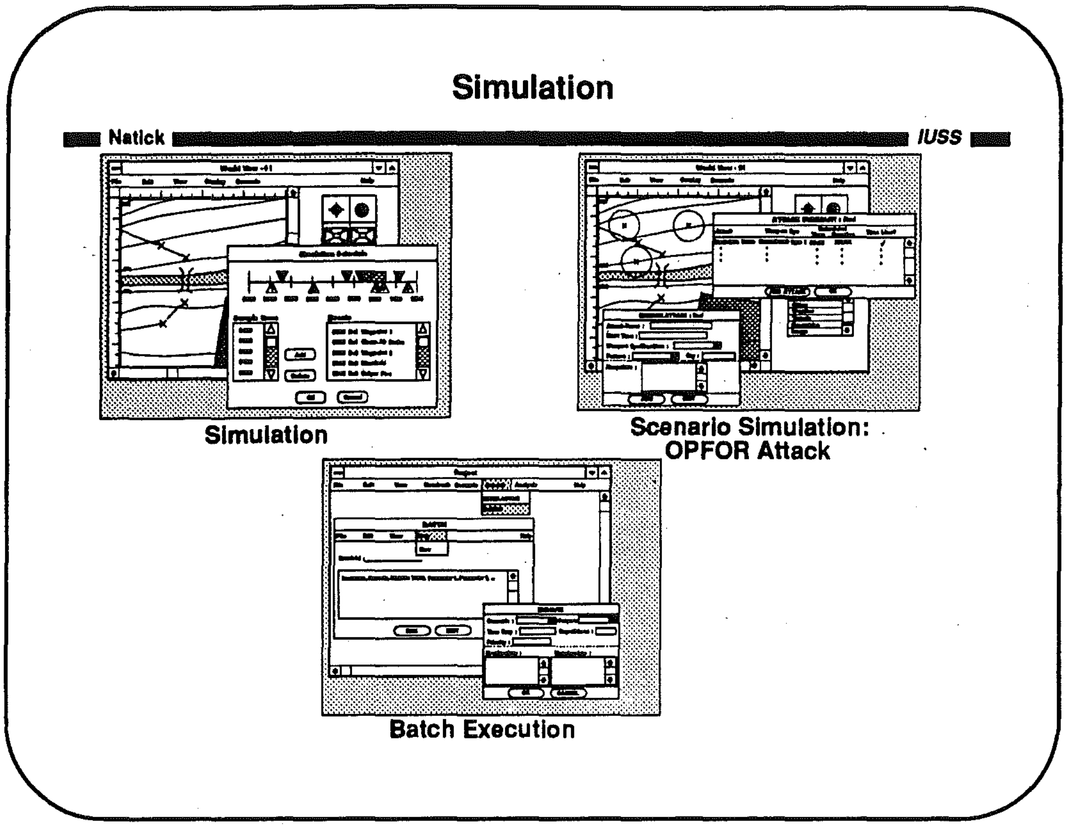
The user's interaction with the research environment is based on the concept of a Graphical User Interface (GUI), an interactive window-based graphic interface which includes such features as pop-up menus for operation selection, color graphics, and keyboard or mouse operations. This approach reduces user training time because the human-machine interface is easy to learn, and provides a simple consistent, and efficient method of system interaction for the performance of analysis application tasks. Use of a GUI expedites free-form communications between the user and machine facilitating such tasks as scenario development, monitoring and directing the execution of models and simulations, and the manipulation of data representing simulation outcomes for statistical and other analyses.

Shown here are illustrations of the IUSS GUI dialogues for representative components of the scenario generation process:

Mission Planning: Missions are described geographically and temporally as a set of waypoints or mission legs.

Task Network Definitions: For each mission leg a set of tasks must be defined, specifying personnel and actions required. These task networks provide a mechanism for the aggregation of individual soldier performance into unit measures of merit.

Unit Personnel: The unit composition must be defined by specifying personnel according to type and equipment configuration.



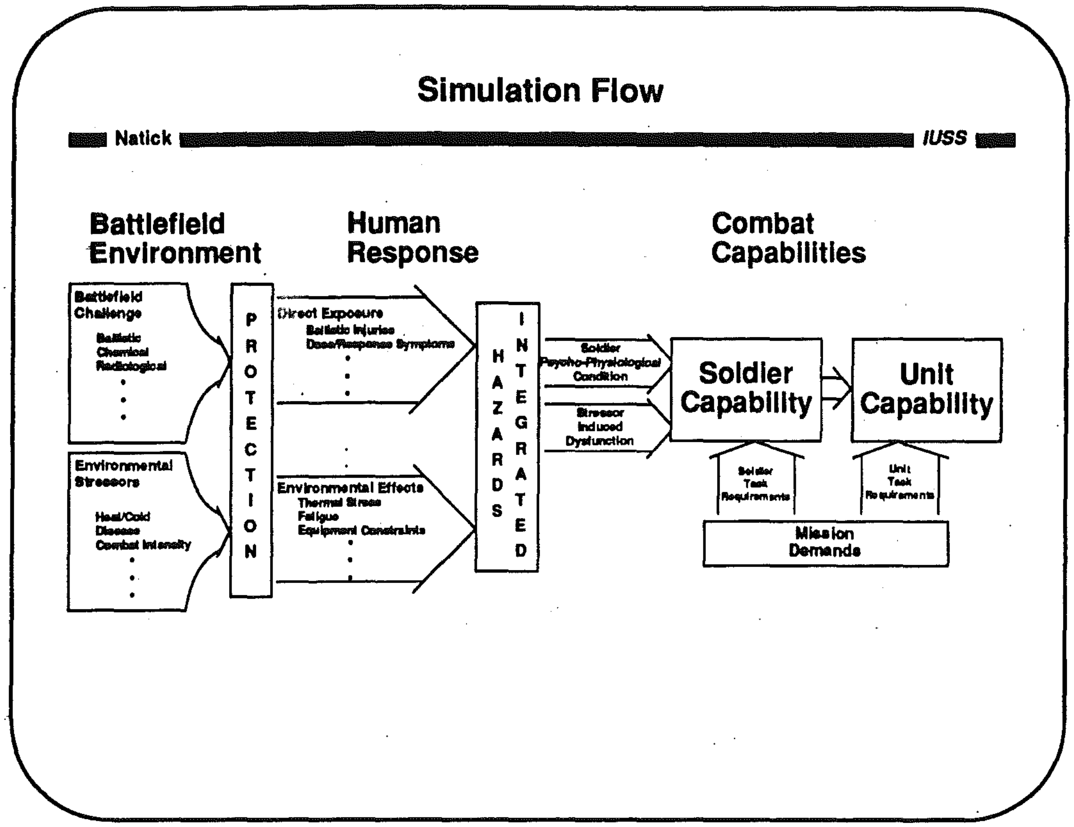
SIMULATION

IUSS simulations may be both clock and event driven or a hybrid of both, and may be executed either interactively or in a batch processing mode. Shown here are representative aspects of IUSS execution:

Simulation: Simulated mission tasks may include scheduled start and duration times which may determine when in the simulation the task is actually performed; more generally task performance time will be dynamic in response to simulation events. In this latter case, the scheduled times may be compared with the actual as a measure of effectiveness (MOE).

OPFOR Attack: The IUSS represents the threat through attack profiles specifying the delivery of weapons including targeting, weapon function, and representation of resultant challenge and hazard.

Batch Execution: This mode of operation allows sets of scenario variants to be stacked and submitted for sequential processing independent of user supervision. In general, the IUSS will achieve its greatest utility through a mix of interactive and batch processing. Scenario definition through iterated application of interactive execution allows fine tuning of scenario descriptors and specification of analysis factors; batch processing facilitates the production of a complex analysis case matrix.



SIMULATION FLOW

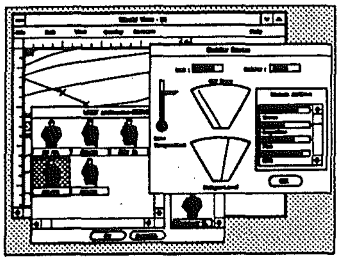
The IUSS implements its analysis scenarios as a series of time and event-driven model calculations, interrupted as required to provide output "snapshots" displaying results of interest. Each of these "snapshots" examines the dynamic interaction of the scenario components, employing three the basic update phases as shown here. The first of these defines the basic features of the battlefield environment, calculating time-dependent challenge profiles for chemical agents, conventional munitions, or other battlefield stressors.

The second phase determines each individual's exposure to these stressors and calculates an appropriate level of human response by relating stressor effects with psycho-physiological condition. Specific levels of each hazard or stressor are correlated with their consequences on human performance, describing each soldier as a set of constrained human performance abilities. The components of the capability data structure will generally correspond to the elements of a human performance taxonomy, usually denied as a hierarchy to permit expansion or collapse of capability data structure according to analysis requirements. This also allows easy marriage of the human taxonomy capability descriptors to hierarchal decompositions of the Soldier System for the calculation of individual measures of performance as are done in the next phase.

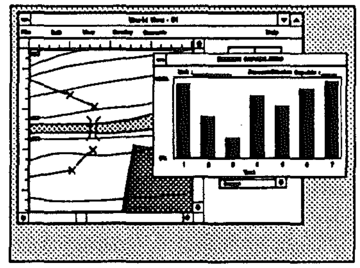
In phase three, these constraints on the soldier are compared with mission task requirements to determine the soldier's capability to perform his mission tasks. Individual performance measures are in turn aggregated to unit mission measures of effectiveness, which are the ultimate metrics of concern to the IUSS target audience.

Analysis

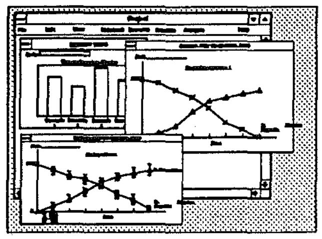
Natick IUSS



Soldier Status



Unit Mission Capability



Statistical Assessment

ANALYSIS

The IUSS provides the capability to examine and analyses simulation results at multiple levels of detail. Shown here are:

Soldier Status: Soldiers from a selected unit may be individually examined at the user's discretion. As pictured, unit and soldier display icons are used to choose a given individual and to examine the current state variables for that soldier. A variety of display formats will be available including rapidly read gauge representations. While icon-driven output selection is natural for an interactive session, the same display formats will be available for output from batch execution. In such a case either icons or other object identifiers will be used to pre-define output screens or other formats and this information will be stored in the batch output/report file specifications.

Unit Mission Capability: Similarly, unit status and capability will be available in a variety of formats. MOE's of interest include mission performance time, percent of mission objectives achievable, and casualties.

Statistical Assessment: The IUSS is designed to provide both internal statistical functions, and to format output for standard interfaces to a number of commercially available statistical packages. As shown here, such statistical assessment may examine multiple iterations of Monte Carlo simulations of a chosen scenario, or examine the distribution of scenario MOE's across multiple scenario variants.

IUSS Features

Natick — IUSS

- Geographic/Time Links to Task Networks Nodes
- Integration of Multiple Battlefield Stressors Effects on Individual Soldier Capabilities
- Explicit Representation of Individual Soldier System Capability/Performance Relationship
- Aggregation of Individual Effects to Unit/Mission Level Measures of Effectiveness

IUSS Features:

The IUSS will present unique new capability, not through the introduction of new models but through the bundled access to current methodologies, providing a simulation package of enormous flexibility to meet the modeling needs of the Soldier System.

The IUSS will provide for the first-time a task network simulation with explicit links to both clock-driven events and geographical features, capable of interrogating a dynamic geographical data base to describe the functional environment of its mission task processes.

The IUSS will also provide a detailed, well-defined, structured, and auditable simulation sequence to map the effects of battlefield stressors and Soldier System equipment component constraints, first to individual soldier capability potential, then to measures of task performance for those individuals, and ultimately to unit /mission performance metrics.

The IUSS is the first analysis package to incorporate the philosophy of the Soldier as a System, employing state-of-the-art software design methodologies in concert with current hardware capabilities to expand the horizons of R&D support tools.

Summary

Natick — IUSS

- Automated Analysis Environment
- Open, Extensible Architecture for Integration of Multiple Models and Data Bases
- Measures Soldier System Performance as a Function of Small Unit Operability & Survivability
- Flexible Paradigm for Integration of Equipment Effects and Battlefield Stressors at Individual and Unit Levels

SUMMARY

This briefing describes an automated research environment in support of the Soldier as a System. The IUSS architecture permits estimation of individual and unit capability for a broad spectrum of applications, through modular substitution of a wide range of battlefield threat representations, acting in concert with models of soldier equipment (and soldiers' performance with that equipment). For a given analysis, each of these factors will be coordinated as part of a simulation scenario, which "sets the stage" for the analysis through the definition of the battlefield environment and specification of unit missions and force composition. By focusing on Soldier Systems' survivability and operability, can the IUSS demonstrate the benefits to be derived from current and evolving equipment technologies, providing a cost-effective tool to examine issues relating to equipment integration and synergisms.

The IUSS focuses on the fundamental relationship between a soldier's psycho-physiological state and the ability to perform discrete mission tasks. Defining module data interfaces in terms of this relationship allows the IUSS to deal with each module in terms of its effects on an underlying data structure - the Soldier System. This facilitates aggregation of effects to unit-level measures of effectiveness, and allows estimation of mission performance and associated costs.

The IUSS methodology does not impose any specific format for the soldier capability data structure, although it does require consistency within the elements of a particular analysis scenario. The number and exact definition of the abilities comprising the capability data structure components can thus be adjusted to fit the needs of a given analysis: the sensitivity of the performance models employed, the availability of supporting data, the types of tasks and the equipment factors to be studied, and the resolution and fidelity of analysis required.

A HIERARCHAL MODEL OF THE SOLDIER SYSTEM

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A HIERARCHICAL MODEL OF THE SOLDIER SYSTEM

This briefing presents a prototype model of the Soldier System as a weighted hierarchy of soldier capabilities. This hierarchy decomposes the human performance requirements of individual soldier tasks or mission components into discrete factors. The effects of the soldier's equipment (e.g., performance enhancements or equipment associated constraints) as well as the adverse effects of battlefield stressors can be more directly (and more easily) applied to these factors than to the tasks themselves. By appropriately weighting and then propagating these effects up the hierarchy, system level effects are calculated.

The methodology used to develop the Soldier System Model is the Analytical Hierarchy Process (AHP) developed by Saaty, and supported by a software implementation, *Expert Choice,* which facilitates development of both the hierarchical decomposition and associated weights. A draft hierarchy was developed by a meeting of experts at Natick (Jan 92) and is currently being circulated throughout the community for definition of factor weights.

The Soldier System Model developed can be used for both stand-alone analyses and as a modular component in a more comprehensive simulation of soldier performance on the battlefield.

BACKGROUND

Natick — HMoSS

- SOLDIER SYSTEM: THE CONCEPT THAT THE INDIVIDUAL SOLDIER AND HIS EQUIPMENT SHOULD BE VIEWED AS A SYSTEM WITH INTEGRATED FUNCTIONALITY FOR ALL COMPONENTS
- SIPE ATD: AN ADVANCED TECHNOLOGY DEMONSTRATION SHOWING THE IMPROVEMENTS POSSIBLE THROUGH THE INTEGRATED APPLICATION OF CURRENT TECHNOLOGIES (THE SOLDIER INTEGRATED PROTECTIVE ENSEMBLE) TO THE CONCEPT OF THE SOLDIER AS A SYSTEM
- TEISS REQUIREMENTS: THE ULTIMATE OBJECTIVE OF THE SIPE DEMO IS DEFINITION OF REQUIREMENTS FOR THE ENHANCED INTEGRATED SOLDIER SYSTEM, THE NEXT GENERATION SOLDIER

BACKGROUND

The Concepts Analysis Division of Natick's Advanced Systems Directorate (Natick CAD ASD) is currently performing a number of efforts in support of the concept of the Soldier as a System. This concept is intended to advance the over-all effectiveness of the individual soldier through the synergistic effects achievable by integrated development and operation of the soldier's equipment.

Natick's efforts include on-going studies and analyses for such initiatives as the Soldier Integrated Protective Ensemble (SIPE) Advanced Technology Demonstration (ATD), in addition to a broader based series of development efforts to address future requirements by providing a comprehensive foundation of analytical support tools. The hierarchical model discussed in this briefing is intended in the near term to support evaluation of SIPE ATD results, which will examine the applicability of current technologies to the development of new Soldier System equipment. Ultimately, however, the goal is to support The Enhanced Integrated Soldier System (TEISS), and the definition of the next generation soldier.

OBJECTIVES

Natick HMoSS

- QUANTIFY SOLDIER CAPABILITY DELTAS TO REFLECT CHANGES IN THE SOLDIER SYSTEM
- DETERMINE OPTIMAL RESEARCH AND DEVELOPMENT ALTERNATIVES BASED ON SOLDIER SYSTEM COMPONENT LIFE CYCLE CONSTRAINTS
  - COSTS
  - BENEFITS
  - DEVELOPMENTAL TECHNOLOGICAL RISKS
  - TIME REQUIREMENTS
  - FUNDING

OBJECTIVES

A critical question facing Soldier System R&D is how to measure the potential benefits of proposed or projected system components. Such measurements are needed to assess cost/benefit trade-offs and to make the decisions for allocating the resources required to develop and field new components. The Natick approach is based on the philosophy that ultimately benefits must be expressed in terms of changes in the soldier's capability, and how these changes affect unit/mission performance. To this end, analysis and analytical tools are needed to translate technological improvements to the Soldier System into quantitative estimates of individual and unit performance. While it is probably unrealistic to expect computer simulations and other analytical tools to produce valid absolute estimates of soldier performance; such tools can and do provide good relative measures of the comparative differences (capability deltas) expected from different equipment configurations. These comparative differences incorporate both the operational benefits possible from improved equipment and the potential operational costs associated with each soldier system configuration. Costs may be due to modifications of the soldier load, increased demands for protection and the associated trade-offs between risk and capability, all of which must be taken into account for a comprehensive evaluation of soldier system performance.

These capability deltas can be used to determine the pay-off from R&D resource investment and to balance the allocation of resources subject to the multiple constraints of the R&D environment, for instance through the application of multi-criteria decision aids such as *Expert Choice.*

APPROACH

- DEVELOP A WEIGHTED HIERARCHY OF SOLDIER SYSTEM CAPABILITY REQUIREMENTS
- USE AS A STAND-ALONE MODEL TO ESTIMATE FIRST ORDER IMPACTS OF PROPOSED/DEMONSTRATED TECHNOLOGIES ON SOLDIER CAPABILITIES
- USE AS A MODULAR COMPONENT OF AN INTEGRATED BATTLEFIELD SIMULATION TO ASSESS TECHNOLOGY IMPACTS ON MISSION TASKS AND OPERATIONAL MEASURES OF EFFECTIVENESS

APPROACH

This effort uses the five soldier capability areas defined by the Soldier Modernization Plan as a basis to develop a model Soldier System capability matrix (or hierarchy or architecture) to address the needs of technology base initiatives (such as SIPE and TEISS) which seek to demonstrate the applicability of current or evolving technologies to the Soldier System. Time and resource constraints limit immediate support efforts (i.e.,SIPE ATD assessment) to currently available tools, while still requiring some method for the translation of laboratory and field measurements to assessment of potential effects on Soldier System capabilities.

The Hierarchical Model of the Soldier System developed here can be used as a stand-alone model with existing software tools (e.g., *Expert Choice*) to support the evaluation of SIPE ATD data; specifically the synthesis of technology alternative rankings based on weighting ATD results by the factors associated with the Hierarchical Model.

Of possible longer term benefit, however, is the potential for incorporating the Hierarchical Model as component of a far more comprehensive simulation of the battlefield mission performance. Such a simulation would integrate the spectrum of battlefield hazards with explicit representation of mission tasking and performance to develop the operational measures of effectiveness most important to the user community, the soldier in the field.

DEVELOPMENT OF SOLDIER SYSTEM MODEL

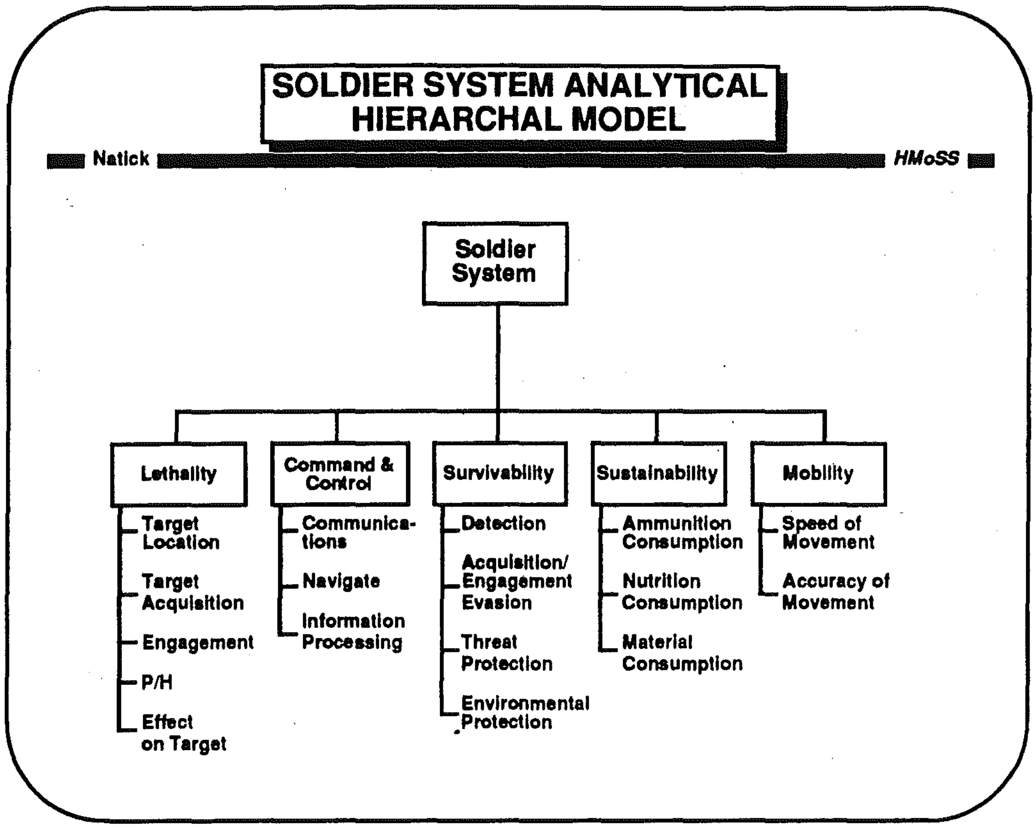
Natick HMoSS

- CONSTRUCT SOLDIER SYSTEM CAPABILITY HIERARCHY
  - IDENTIFY OVERALL CAPABILITY OBJECTIVES
  - FORCE A FRAMEWORK
    - IDENTIFY FACTORS & SUBFACTORS
    - ARRANGE FACTORS & SUBFACTORS IN LEVELS
- DEVELOP PAIRWISE COMPARISONS OF FACTOR IMPORTANCE BY LEVEL
- USE ANALYTICAL HIERARCHY PROCEDURE TO DERIVE FACTOR WEIGHTS

DEVELOPMENT OF THE SOLDIER SYSTEM MODEL

AHP is a mature analytical tool which can be used to assist in the decision-making process when many factors, both quantitative and qualitative are involved. The first stage in AHP model building is to decompose the overall decision/evaluation problem into a hierarchy. This hierarchy is essentially a weighted factor tree, headed by a single overall objective or goal, supported by multiple layers of criteria organized from the general to the specific.

The AHP evaluations for the Soldier System Hierarchical Model are based on subject matter expert judgments about the relative importance of each factor with respect to the others, in terms of contributions to overall capability. These judgments are derived through a sequence of pairwise comparisons of the factors at each level of the hierarchy. The AHP methodology synthesizes these pairwise comparison judgments to derive ratio scale priorities or weights for each factor or factor branch.



SOLDIER SYSTEM HIERARCHICAL MODEL

Members of the SIPE Evaluation and Measures of Performance Teams hosted a meeting at Natick to develop the draft Soldier System Hierarchical Model, the top level of which is shown here. They started with the five capability areas of the Soldier System, as identified by the Soldier Modernization Plan. These areas: Lethality, Command and Control, Survivability, Sustainability, and Mobility; were decomposed into the sub-capabilities shown here, and in some instances, those sub-capabilities were further refined into lower levels of detail.

The decomposition was achieved by application of a modified Delphi procedure with the group of experts achieving consensus upon the most important sub-capabilities from a long list of potential candidates. As may be expected, much of the working group discussion centered on precise definition of the capability areas. The working group decided to address as first level factors only those which directly affected the performance of the individual Soldier System. For example, under sustainability there was considerable debate as to how to handle critical reliability, availability, and maintainability (RAM) factors. The group decided that these factors were most important as they related to the soldier's rate of consumption of essential supplies. The group's focus was the soldier's performance of mission tasks; such factors as RAM function in this context primarily as constraints on the soldier's ability to sustain himself operationally.

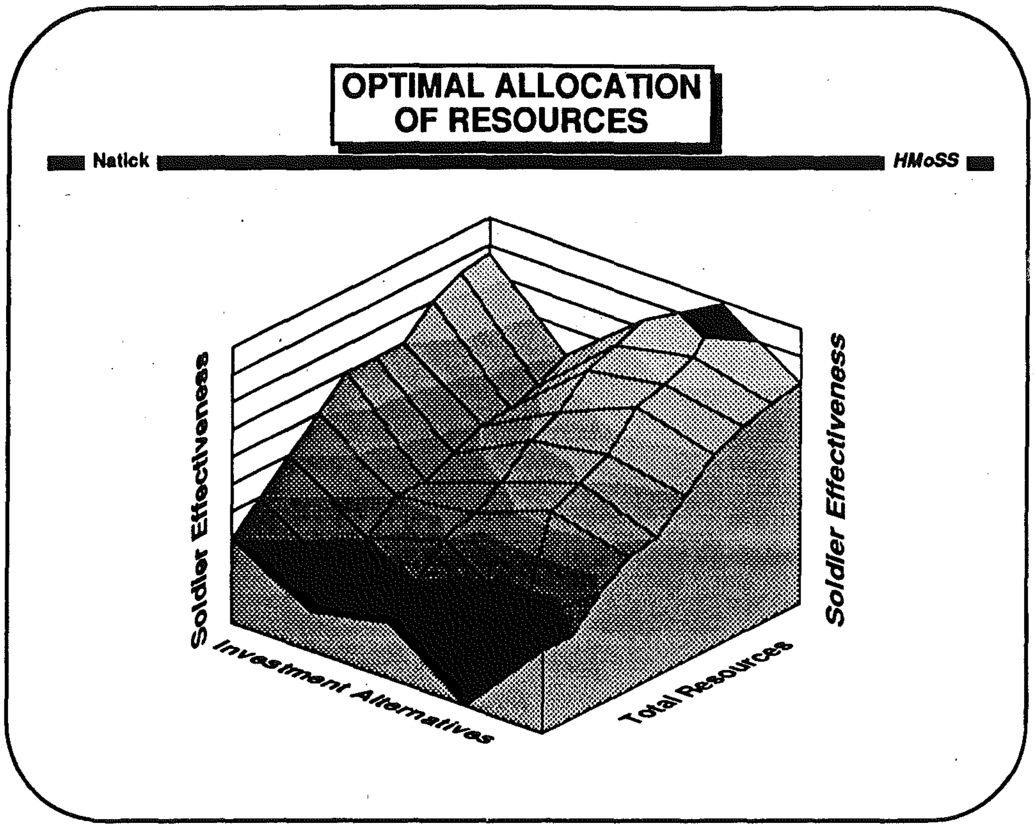
STAND ALONE ANALYSES

Natick HMoSS

- DEVELOP EVALUATION CRITERIA AND SYSTEM ALTERNATIVES
- INTEGRATE EMPIRICAL DATA (RESULTS OF DEMO/TEST) INTO PAIRWISE COMPARISON OF CRITERIA CONTRIBUTIONS TO SOLDIER SYSTEM HIERARCHY FACTORS
- USE ANALYTICAL HIERARCHY PROCEDURE TO SYNTHESIZE OVER ALL RANKINGS OF ALTERNATIVES

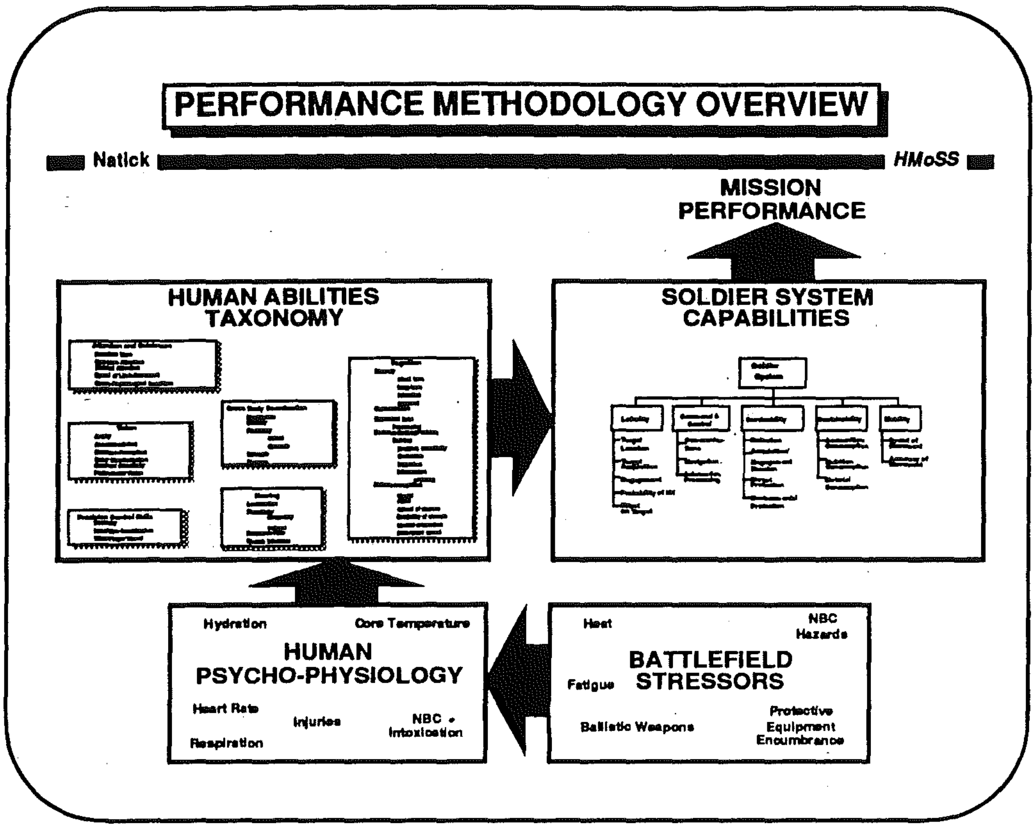
STAND ALONE ANALYSES

The Hierarchical Model of the Soldier System will be applied to the results of the SIPE ATD to evaluate the potential of the demonstrated technologies. The AHP process will be used to rank technology investment alternatives with respect to the ATD scenarios. The Demonstration Working Group will develop scenario-specific evaluation criteria for each of the technology alternatives explored, integrating the various ATD data and relating them to the already identified Soldier System Hierarchy factors. A report ranking each factor branch in relation to overall Soldier System capability will be synthesized by multiplication of these "local" priorities or rankings by corresponding values in the level above and maintaining a "running total" .



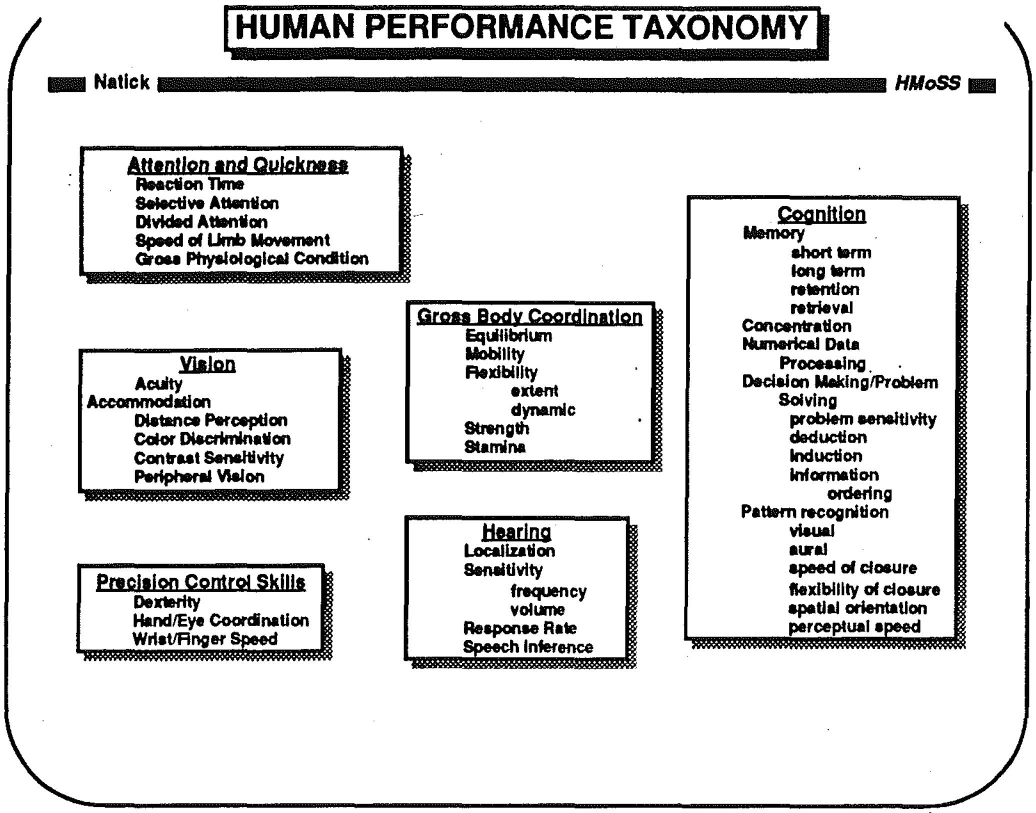
OPTIMAL ALLOCATION OF RESOURCES

The above procedure can be used to define a multi-dimensional response surface relating the benefits (increased Soldier System effectiveness) of various investment alternatives to R&D resources expended for those alternatives. In general, this relationship is not a simple one. The optimal mix of resource allocations is usually not a constant percentage of those available as applied to the technologies of interest. For each application there is usually a threshold or series of thresholds, below which results are not seen, and upper bounds at which the law of diminishing returns comes into play. Viewing this relationship as a response surface illustrates the shift in the desirability of resource allocation alternatives as total resources are constrained to different levels.



PERFORMANCE METHODOLOGY OVERVIEW

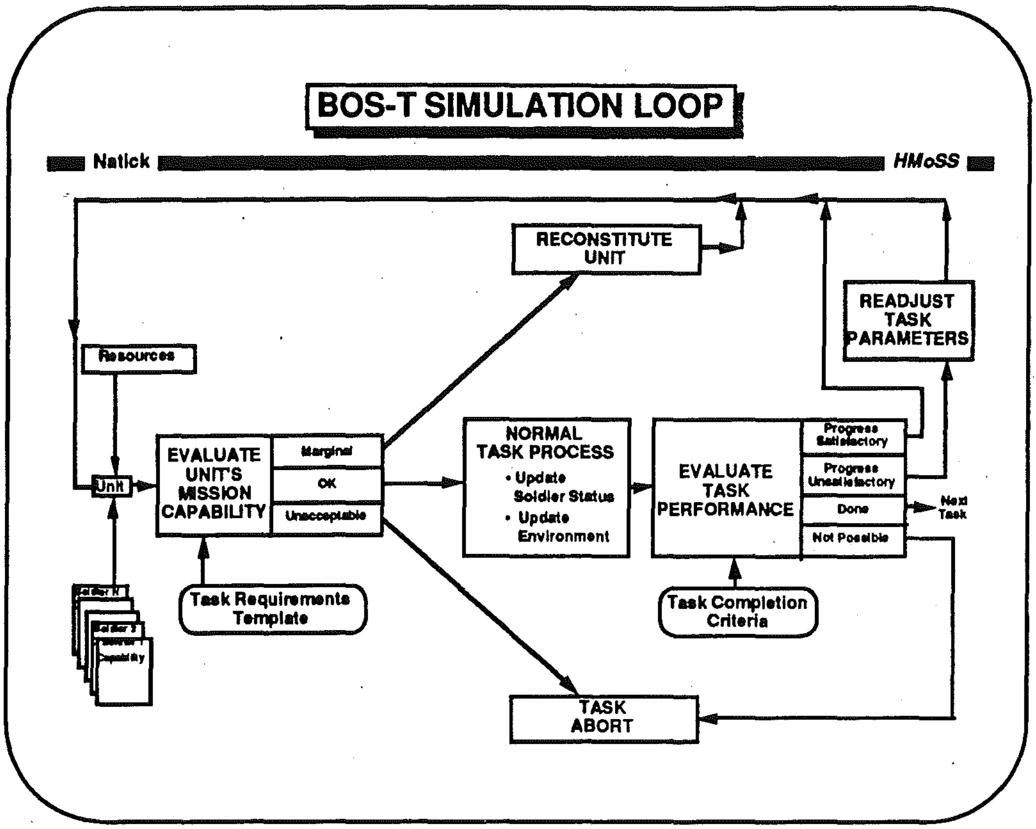
The ultimate objective of Natick's operations research analysts is incorporation of the Soldier System Hierarchical Model into a more comprehensive model of the battlefield. Such a system would represent the individual and unit performance with a multi-phase simulation. The first of these phases defines the basic features of the battlefield environment, calculating time-dependent challenge profiles for chemical agents, conventional munitions, or other battlefield stressors. The next phase determines each individual's exposure to these stressors and calculates an appropriate level of human response by relating stressor effects with psycho-physiological condition. Specific levels of each hazard or stressor are correlated with their consequences on a human abilities taxonomy describing each soldier as a set of constrained human performance abilities. These constraints on the soldier are fed into the Soldier System Hierarchical Model and those capabilities evaluated in the context of specific mission task requirements to estimate of the soldier's overall capability ability to perform those mission tasks. Individual performance measures are in turn aggregated to unit mission measures of effectiveness, which are the ultimate metrics of concern to the IUSS target audience.



HUMAN PERFORMANCE TAXONOMY

The Soldier System Hierarchical Model's decomposition of the set of required mission capabilities must be married to some expression of the erosion of the soldier's capability as a consequence of exposure to battlefield stressors in order to estimate the effects of those stressors. One way to do this is to express those capabilities in terms of residual human abilities - indices indicating the degree to which each human ability is retained by the soldier after exposure to the stressors of a given operational scenario. These indices permit representation of the effects on soldier capability as induced by equipment and protective posture, and will support translation of the effects of Soldier System equipment sets on soldier performance task metrics. The techniques used will represent current, developmental, and theoretical equipment effects, in addition to stressors encompassing the full range of battlefield threats and environmental hazards.

The number and exact definition of the human abilities comprising the each soldier capability can be expressed as a hierarchical human performance taxonomy such as the one shown here. Defining the taxonomy as a hierarchy as illustrated this permits expansion or collapse of capability data structure according to analysis requirements. This also allows easy marriage of the human taxonomy capability descriptors with the a hierarchy decomposition of the Soldier System such as the shown on the previous slide.

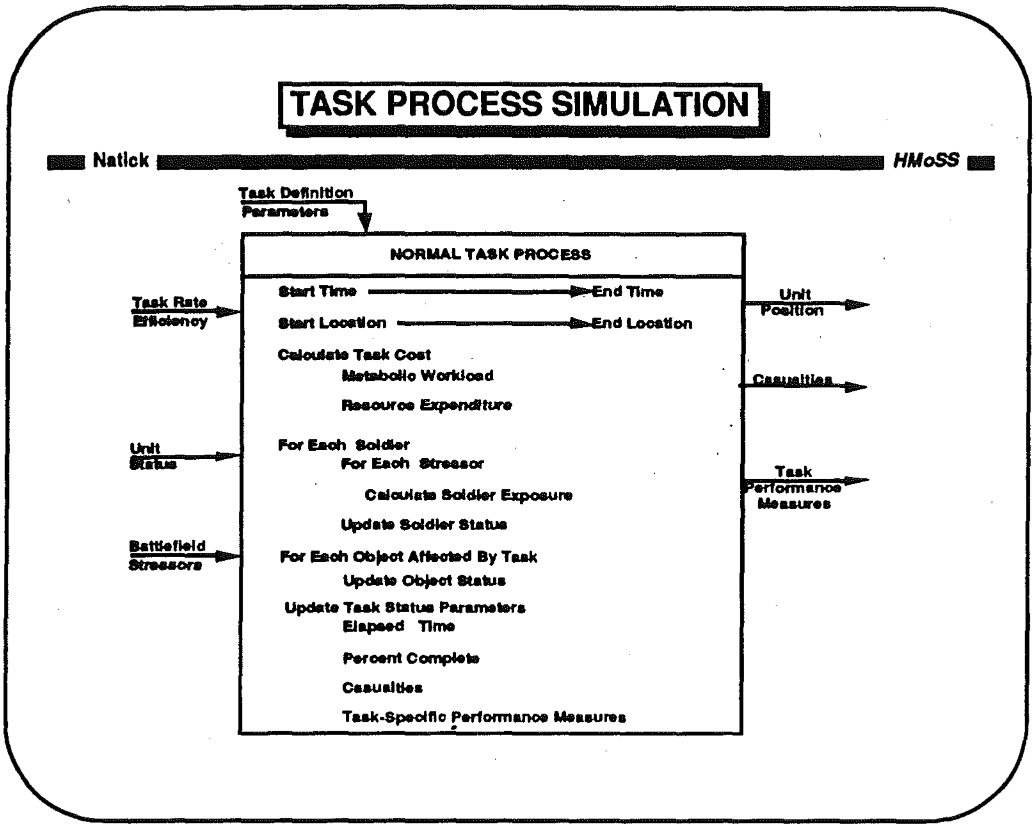


BOS-T SIMULATION LOOP

The Soldier System Hierarchical Model must also be applied to some context of mission tasking, such as a task network structure in which the functional network nodes simulate the Battlefield Operating Systems and Tasks (BOS-T) functions of the US Army Training and Evaluation Program.

As shown here each network task node is basically a simulation loop. The primary node input is the unit resource stream which represents the individual soldiers and equipment assigned to the simulated mission tasks. The node loop begins with an evaluation of the assigned unit's ability to perform the given task. The unit may be fully mission capable, in which case the normal simulation process for this task type is initiated. Alternatively, the unit may require some form of reconstitution (e.g., reassignment of unit duties to alternate personnel, replenishment of unit resources, addition of new personnel) before proceeding with task performance. In the worst case, the unit may be unable to continue, necessitating a task abort and mission failure.

For each iteration of the loop, evaluation of unit capability results in the assignment of performance parameters (e.g., rate, efficiency) followed by incremental simulation of task processes. At the conclusion of each iteration the system evaluates the task progress. If the task is complete, the simulation proceeds to the next network task. If the task is incomplete, but progressing normally, the loop for this task node is repeated, evaluating current unit capability (as updated after performance of the simulation process during the last time step) to continue with the task. If the task is not proceeding within defined parameters (e.g., on a move tactically task if the directional errors induced by navigational difficulties have drawn the unit off course), some readjustment of task parameters may be required (e.g., the unit commander must calculate a new course). If the task performance is not correctable (e.g., the unit is hopelessly lost) a task abort is activated.



TASK PROCESS SIMULATION

The core of the above network task node is the task process simulation, the actual model of the task function as opposed to the logics which determine process alternatives and functional parameters. The task process simulation implements those phases of the performance methodology which modify the status of the soldiers simulated or the battlefield itself. The process begins by calculating the performance costs of the task, examining the battlefield environment for the stressors affecting the unit's soldiers, updating the status of the soldiers based on the effects of those stressors and the task performance costs, and in turn updating the status of the battlefield in response to the results of task performance.

The task process approach follows the object oriented programming paradigm, allowing simulation of the task as an encapsulated function, a "black box" which can be replaced according to the resolution requirements of a given analysis, and the fidelity of available data to support that process. This also allows the incremental inclusion of the representation of multiple stressors, and the replacement of specific process models as more sophisticated (and hopefully more accurate) models become available.

ISSUES

Natick — HMoSS

- AGGREGATION OF INDIVIDUAL SOLDIER SYSTEM CAPABILITIES TO UNIT MEASURES
- PROPAGATION OF EQUIPMENT EFFECTS AND BATTLEFIELD STRESSORS
- LINKS BETWEEN EXPERIMENTAL/FIELD DATA AND HIERARCHY WEIGHTS

ISSUES

Decomposing the Soldier System in terms of soldier capabilities and corresponding human abilities provides a mechanism to study the effects of equipment and battlefield stressors on Soldier System performance, but there are a number of issues which must still be resolved.

The transition form individual measures of performance to unit measures requires some from of aggregation of the individual measures. While this can be accomplished through addition of another level of the hierarchy, a dynamic simulation technique (e.g.; task network modeling) provides greater resolution and fidelity.

The hierarchical model discussed here calculates integrated effects of battlefield stressors on the component capabilities of the soldier system: lethality, command and control, survivability, sustainability, and mobility. Propagation of these through the levels of the hierarchy combines them to assess the performance of individual soldiers, but this propagation requires implicit assumptions of linearity and independence. Care must also be taken to ensure that scenario dependencies are explicitly addressed.

In general, equipment effects are most easily measured with respect to individual abilities, but operational concerns center on mission (i.e.; unit) capabilities. Bridging this gap requires a series of model interfaces which integrate data from laboratory tests, field trials, and expert opinion into aggregate measures at multiple levels of concern.

CURRENT STATUS

As described above, the analytical hierarchical model criteria have been defined and efforts are currently focused on development of pairwise comparisons of the factors. As listed here, a large number of questionnaires have been distributed soliciting expert judgments from a variety of expert constituencies, including the Technology Base Executive steering Committee (TBESC), a group of comprised of laboratory directors and senior government officials responsible for determining the direction of Soldier System Research and Development. Questionnaire results are currently being compiled; Natick will employ the AHP software to synthesize factors weights, and ultimately as the SIPE ATD results become available, to evaluate demonstrated technologies' performance with respect to a current equipment baseline.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TP-10/005 in a series of reports approved for publication.

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