Human and Organizational Behavior Modeling (HOBM) Technology Assessment

MSIAC Project MS-00-0019/0028

Modeling and Simulation Information Analysis Center (MSIAC)
Contract No. SPO700-99-D-0300

July 2, 2001

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EXECUTIVE SUMMARY

Purpose

This report delivers an overview assessment and evaluation of technologies relevant to the successful development of the field of Human and Organizational Behavior Modeling (HOBM). The MSIAC Behavior Analysis Team has prepared this report for the Defense Modeling and Simulation Office (DMSO) Concepts Application Division as specified by the MSIAC Contract Number SPO700-99-D-0300 Statement of Work. The purpose of the project and this report is to provide DMSO with insight and recommendations for making programmatic decisions and for supporting DMSO's role in modeling and simulation (M&S) science and technology (S&T) planning within the Department of Defense (DoD). This effort can also be considered as part of a response to recommendations from a National Research Council report on HOBM. Finally this effort leverages the results of three DMSO Behavior Representation Workshops in training and analysis, acquisition, and experimentation.

Approach

The Behavior Analysis Team used the following steps in developing this assessment of technologies:

- determine M&S HOBM needs
- review HOBM-related technologies
- develop and categorize HOBM-relevant technologies
- develop HOBM-relevant technology metrics
- evaluate/assess HOBM-relevant technologies

The actual evaluation/assessment included the following steps:

- relate HOBM needs to HOBM-relevant technologies (cross reference map or matrix)
- identify technology centers of excellence and subject matter experts
- estimate technology trends and deficiencies: current, near term, far term
- assess technology impact on HOBM
- identify target applications and M&S systems
- relate evaluations to existing technology assessments (S&T Initiatives)
- determine desirability of DMSO involvement in technologies
- recommend support materials for DoD technology assessments

Several of these steps were limited in their scope for this project, but they could easily be completed in subsequent efforts.

The project divided the HOBM-relevant technologies into four categories: broad computing technologies, broad HOBM technologies, high level HOBM technologies, and fundamental HOBM technologies. The relevant technologies, and their categories, are displayed in the following table:

HOBM-Relevant Technologies

Broad Computing Technologies

High Performance Computing
Human Computer Interactions
Fundamental Computing Infrastructure

Broad HOBM Technologies

Architectures, Frameworks, and Data Interchange Formats and Standards
Knowledge Engineering

High Level HOBM Technologies

Cognitive Models
Expert Systems
Natural Language Processing

Fundamental HOBM Technologies

Agent Based Simulations	Neural Networks
SWARM	Pattern Recognition
Case Based Reasoning	Robotics
Fuzzy Systems	Intelligent Tutoring
Genetic Computing	Decision Support Systems
Machine Vision	Advanced Distributed Learning Systems

<u>Results</u>

This report contains recommendations allowing DMSO to choose the best course for offering the most service to the Warfighter. These present special opportunities for DMSO to lead the DoD HOBM effort, leverage agency and service programs, and integrate a diverse collection of efforts to achieve the M&S vision that will support JV2010/2020.

The project assessed the HOBM-relevant technologies as belonging to four major classes. These classes are characterized as follows:

- Recommend that DMSO invest
- Recommend that DMSO influence
- Recommend that DMSO monitor
- Recommend that DMSO periodically review

The following table summarizes the overall technology assessment:

Summary Assessment Table of Technologies

Recommend that DMSO Invest in Development of these Technologies	***Recommend that DMSO Influence Development of these Technologies***	***Recommend that DMSO Monitor Development of these Technologies***	***Recommend that DMSO Periodically Review the Development of these Technologies***
Architectures, Frameworks, and Data Interchange Formats and Standards Cognitive Models Knowledge Engineering Agent Based Simulations	Fuzzy Systems Genetic Computing Robotics SWARM Intelligent Tutoring Decision Support Systems	Human Computer Interactions Expert Systems Case Based Reasoning Neural Networks Pattern Recognition Advanced Distributed Learning Systems	High Performance Computing Fundamental Computing Infrastructure Natural Language Processing Machine Vision

The detailed evaluations of the individual HOBM-relevant technologies are provided in the body of the report.

As of the conclusion of the project's current funding increment, the MSIAC has produced and delivered this executive level insight into the importance of specific HOBM-related technologies and their recommended investment requirements from a DMSO viewpoint. The next steps would include providing DMSO an expansion of these technology reviews containing greater technical depth and more details on experts and developing organizations; an identification of specific short, near, and far-term target HOBM applications for the technologies; a quantification (in terms of the included metrics) of the trends in these technologies and their deficiencies with respect to the identified target applications; and preparation of technology requirements and reviews tailored for use in broad DoD technology assessments.

1. Introduction/Background

Joint Vision 2010/2020 [Ref. 1] and Objective 4 of the U.S. Department of Defense (DoD) Modeling and Simulation (M&S) Master Plan [Ref. 2] recognize the importance to the DoD of establishing authoritative representations of human behavior including both as individuals and groups. DoD simulations must include authoritative and accurate representations of human behavior so as to be sufficiently credible and variable to provide valid analytical results, effective training and supportable acquisition decisions.

The Defense Modeling and Simulation Office (DMSO), through its Concepts Application Division (CAD), supports the accurate representation of Human and Organization Behavior Modeling (HOBM) within modeling and simulation. DMSO funded a National Research Council study [Ref. 3] in 1998 that laid the foundation for enterprise-level HOBM exploration and development. DMSO implemented several of the National Research Council's recommendations. For instance, DMSO established a HOBM Special Interest Area (SIA) to facilitate the exchange of information. Further, DMSO amplified the portion of its Modeling and Simulation Staff Officers Course (MSSOC) program of instruction addressing the modeling of human and organizational behaviors. DMSO continues to sponsor professional conferences including the annual Computer Generated Forces and Behavior Representation (CGF&BR) Conference that bring together the human behavior representation modeling community to share their research and program expectations. These on-going efforts have increased the awareness of HOBM and significantly furthered the development of human and organizational behavior representations within the M&S community.

Acting as coordinator, organizer and catalyst for HOBM, the DMSO has established the following goals:

- Identify a set of consensus-based, community-supported, prioritized HOBM requirements.
- Obtain a clear assessment and understanding of the current state of practice of HOBM.
- Develop a well-defined action plan and milestones for future research and development investments.

The purpose of this project is to identify HOBM technologies that should be monitored for DoD and DMSO support to the Warfighter. The MSIAC Behavior Analysis Team has prepared this report for the DMSO Concepts Application Division. The purpose of this report is to deliver an assessment and evaluation of those HOBM technologies as required by MSIAC Contract Number SPO700-99-D-0300.

2. Technology Assessment Overview

Building upon previous HOBM efforts, the team first focused on identifying HOBM needs from Command and Service M&S. The results and decomposition of the recently completed Warfighter Survey of HOBM needs have also been included in the assessment and approach of this report. The collection methodology included analyzing the results of three Behavior Representation Workshops (Training and Analysis, Acquisition, and Experimentation) [Ref. 4, 5, 6] to determine aspects of human and organizational behavior in military organizations that require explicit representation in M&S. This effort included an assessment of the value or importance of the HOBM requirement to the M&S user. Finally, the team surveyed personnel located at military locations to provide information concerning pertinent HOBM activities being conducted, developed, and/or pursued by the agencies which they support. This assessment also included work with non-M&S agencies currently engaged in expanding existing HOBM concepts.

The team has performed the following within this assessment:

- Identified Enabling Technologies

  The team has conducted a comprehensive survey of HOBM enabling technologies to determine, assess, and catalog emerging pertinent areas. These technologies are in various stages of use and new technologies could be added and assessed as they mature to the point where they have the potential to impact and be utilized in HOBM M&S areas. Those enabling technologies deemed to be of sufficient importance are subject of the assessment, evaluation, and benefit analysis addressed in the remainder of this report.

- Developed a Technology List

  The team canvassed the HOBM Technology areas in the commercial world, Department of Defense, academia, and other government agencies to develop the candidate technologies for assessment and evaluation. In order to prioritize and categorize the emerging efforts, the team divided the HOBM technologies into four groups:
    - Broad Computing Technologies
    - Broad HOBM Technologies
    - High Level HOBM Technologies
    - Fundamental HOBM Technologies

  The results of the survey of these groups will be addressed and evaluated in Section 4 of this report. Finally a listing of all the technologies considered by the team is shown in Appendix A.

- Assessed the Technologies

  As a general approach to the conduct of this assessment, the team utilized the three Behavior Representation Workshop results and the Warfighter Needs Survey to identify HOBM needs. This approach was used to point the way toward a capabilities and benefits analysis and provided the means for the evaluation phase of the study by assessing the impact of emerging requirements and emerging capabilities. The team used the benefit analysis to identify those technologies and conditions that have potential high impact on HOBM capabilities in DoD M&S development.

- Developed Metrics

  Several iterations of metrics were discussed by the team with inputs from the M&S community and applied to candidate technologies in order to assess their relevance. The team emphasized supporting DoD leadership and leveraging the DoD and service 6.1 and 6.2 programs in addition to emerging commercial and academic endeavors. The factors utilized for the metrics are shown in Section 3. The metrics were used to provide a matrix relating needs to technologies as a cross-reference map. The metrics also provided categories to indicate locations and authors/research organizations for these technologies.

- Evaluated Technologies

  The final phase of this project was the evaluation of the most relevant HOBM technologies to assess their "state of the art". An analysis was then conducted to evaluate the benefit derived from the use of the addressed technologies and to define what is meant by progress and to define the benefit of the progress. Continuing efforts would estimate trends and determine the deficiencies as they impact HOBM. In addition, the analysis would provide a roadmap for identification of HOBM applications as applied to M&S Systems. Finally, the evaluation would support relating needs to on-going S&T Initiatives and their potential for impacting DoD trends.

<u>Benefits Analysis</u>

In addition to the technology summary, a benefits analysis is included to define those HOBM areas where the various technologies will most likely be incorporated into M&S development.

<u>Lead, Integrate, Leverage</u>

Recommendations are included to advise DMSO as to the possible options to better support the Warfighter. These present special opportunities for DMSO to lead the DoD

HOBM effort, leverage agency and service programs, and integrate a diverse collection of efforts to achieve the M&S vision that will support JV2010/2020 [Ref. 1].

3. Methodology

The Behavior Analysis Team used the following methodology to perform the HOBM technology assessment and benefits analysis of the areas of interest.

3.1 Determine M&S HOBM Needs

As the community experiences increased reliance on M&S to support training, analysis, acquisition, and experimentation, HOBM insertion grows in importance. The team assessed these HOBM needs by examining the results from previous efforts focused on identifying the current and future needs for the use of M&S by DoD and the Services. The data collection effort included the DoD M&S Master Plan [Ref. 2], the Defense Technology Area Plans (DTAP) [Ref. 7], the Joint Warfighter Science and Technology Plan [Ref. 8], Technology Area Review and Assessment [Ref. 9], and community efforts to identify HOBM needs. The team also interviewed users for their assessments of how well current HOBM capabilities satisfied their needs. This effort also analyzed the results of the three DMSO-sponsored Behavior Representation Workshops in Training and Analysis, Acquisition, and Experimentation [Ref. 4, 5, 6] produced insights into the value and importance of HOBM for use by military organizations in their M&S. In addition, the results and decomposition of the DMSO-sponsored Warfighter Survey of HOBM needs were reviewed to augment the list of HOBM needs. These needs have been formally documented in a DMSO-sponsored Warfighter Modeling and Simulation Online Needs Database (WARMOND) [Ref. 10]. Finally, team personnel located onsite at military locations were tasked to survey the HOBM needs of the agencies they support. The specific M&S areas addressed by this report for special notice and for use in the Cross Reference Matrix with high potential for HOBM use are noted below:

- Computer Generated Forces/Semi-Automated Forces (CGF/SAF)

  As the size and scope of CGF/SAF utility continues to expand in all of military training and operations, HOBM is needed immediately in all related models to create realistic, timely, and useful evaluations.

- Organizational Decision Making

  This area was one of the two primary needs identified by the recently conducted Experimentation Behavior Representation Workshop and is closely related to several other “needs” areas in which HOBM can play a significant role.

- Course of Action Analysis (COAA)

  Course of Action Analysis needs for HOBM inputs are being addressed by several areas. Specifically, the Joint Warfare Systems Office is sponsoring the “Commander

Behavior Model (CBM)" development. [Ref.11]. In addition, studies such as the Course of Action Analysis Report by the Naval Air Warfare Center Training Systems Division [Ref. 12] are addressing the issue.

- Decision Aids

  HOBM has the potential to play a major role in this area. DoD is currently funding development of the "Decision Support System (DSS)" which is funded under the Defense Technical Objective (DTO) HS.21 [Ref. 13].

- Mission Rehearsal

  As costs and material associated with actual mission rehearsal training continues to escalate, HOBM offers considerable value to model realistic virtual mission rehearsal.

- Situational Awareness (SA)

  The simulation of SA training for the Warfighter has major requirements for HOBM inputs in order to capture the essence of the variability and uncertainty associated with human behavior intervention in a given operational scenario.

- Information Operations/Information Warfare (IO/IW)

  IO/IW efforts, whether directed against a large civilian population or a small military contingent, requires *a priori* knowledge of expected reaction. HOBM can develop the effects of these efforts and help predict the results of IO/IW operations. Defensive IO/IW efforts must also be considered.

- Simulation Design and Evaluation

  HOBM factors are needed to evaluate training effectiveness and for planning future training evolutions. Similarly HOBM is required for analysis and acquisition. Realistic scenarios replicating cognitive skills are needed to evaluate effectiveness factors.

- Simulator Effectiveness

  The knowledge of human and organizational behavior can be a valuable tool in the design of trainers and simulators. In addition, human factor elements caused by simulation effects such as motion sickness, performance degradation due to fatigue, and physical limitations of the trainer can be enhanced with HOBM technological inputs.

- Simulation of C4I Systems

  New C4I systems will fuse sensors, communication systems, and simulators to provide the commander with near real time decision aids. In order to accomplish this, an integration of C4I and HOBM technologies must be accomplished in order to realistically simulate the human-in-the-C4I-loop.

- Virtual Prototyping of Weapons Effects Simulation

  Human and group reaction to weapons effects are critical to a commander's election of the appropriate weapons and their utilization especially in the terminal aspects of a battle. These weapons effects simulations also pertain to defensive protection for friendly forces and the deployment and utilization of those forces when confronted with different weapons.

- Dynamic Simulation Model of Complex Business Systems

  Commercial enterprises have developed significant HOBM simulations to test the market place. These efforts have resulted in simulating several iterations of complex business cycles. These efforts continue to be HOBM rich areas for development.

3.2 Review HOBM-Related Technologies

The team canvassed commercial enterprises, the Department of Defense, academia, and other government agencies as part of a comprehensive review of technologies to determine those that have existing or potential applications to the field of HOBM. This review included attendance at conferences and workshops, and a literature review utilizing the MSIAC library and the Internet. Additionally, team personnel contacted subject matter experts in HOBM and in technology planning for their inputs. The result was a master list of technologies related to HOBM.

3.3 Develop and Categorize HOBM-Relevant Technologies

A filtering process was then applied to the master list of HOBM-related technologies to yield a set of technologies of sufficient importance to be the subject of the assessment, evaluation, and benefit analysis addressed in the remainder of this report. In order to prioritize and categorize the emerging efforts, the team divided the HOBM technologies into four groups:

- Broad Computing Technologies
- Broad HOBM Technologies
- High Level HOBM Technologies
- Fundamental HOBM Technologies

The master list contains technologies in various stages of development and new technologies could be selected for assessment as they mature to the point where they have the potential to affect and be utilized in HOBM.

3.4 Develop HOBM-Relevant Technology Metrics

The team developed a set of technology metrics to support a quantitative basis for this technology assessment. These metrics are designed to answer questions asked by developers, program managers and users. The metrics utilized include:

- applicability to HOBM (physical, cognitive, organizational behaviors)
- technology maturity (published, reviewed, implemented in software, applied)
- technology characterization (availability, acceptance, uniqueness, potentials)
- direct measures (numbers per second, numbers of entities, execution time)
- additional technology characterizations (cost drivers, range of applicability, implementation cost, COTS/GOTS availability, proprietary status)
- DoD funding
- funding profile
- funding adequacy, and
- developers/users.

In addition, the metrics as applied to individual technologies provided a place to list those HOBM needs that are amenable to resolution by the technology.

3.5 Evaluate/Assess HOBM-Relevant Technologies

The most important step of this project was the evaluation or assessment of HOBM-relevant technologies to determine their "state of the art", their benefits to HOBM, and the requirements for DMSO to be involved with their development. This assessment utilized the material prepared in the previous parts and then proceeded in the several steps that are outlined below.

3.5.1 Relate HOBM Needs to HOBM-Relevant Technologies (Cross Reference Matrix)

The HOBM needs identified in an earlier step were related to the technologies chosen for assessment by means of analysis, research of applicable documents, and collation of the completed HOBM metrics tables in Appendix B. The culmination of this effort is depicted in the Cross Reference Matrix that indicates the relation between the HOBM needs and the assessed technologies. This matrix is provided in the Summary (Section 5) and also in Appendix C. This indicates those areas where a given technology has the potential to satisfy, or is currently satisfying, HOBM needs. The matrix also serves as a guide to those technologies that will serve Warfighter needs most expeditiously. For example, by reading across a row, the user can determine which technologies are relevant for satisfying a particular HOBM need. Similarly, by reading down a column of this matrix, the user can determine which HOBM needs can be partly satisfied by a particular technology. By examining the number of occurrences of a given technology, one can gain some insight into the breadth of importance of that technology to HOBM.

3.5.2 Identify Technology Centers of Excellence and Subject Matter Experts

The team determined the performing centers, agencies, organizations, sponsors, performers, and experts promoting and developing the HOBM-relevant technologies. The results are summarized in the remarks and annotations of the Metrics Tables for each technology chosen for assessment. These tables also serve as a summary of those attributes and simultaneously provide a reference source for further analysis and information.

3.5.3 Estimate Trends and Deficiencies: Current, Near Term, Far Term

The team estimated the trends of the selected HOBM-relevant technologies. These estimates utilized the technology metrics whenever possible. As appropriate, important HOBM-related targets or goals for these technologies were also estimated in terms of the metrics. The combination of trends and goals yielded a forecast of current and future gaps for the technologies relevant to their applications to HOBM. The Cross Reference Matrix is a primary source of information that indicates trends.

3.5.4 Assess Impact on HOBM

The team summarized the benefits of each relevant technology to the advance of HOBM. These summaries are provided in the "Benefits Analysis" paragraphs for the individual technologies. This assessment also includes a summary of the relation between the relevant HOBM technologies and the DoD S&T initiatives and discusses their potential ability for influencing DoD trends. Finally, this section serves as a source of information for determining DMSO priorities for promotion or funding of these HOBM-relevant technologies.

3.5.5 Identify Target Applications and M&S Systems

The team endeavored to identify applications in HOBM for each of the HOBM-relevant technologies. Where possible, the team noted specific M&S systems that could benefit by the infusion of the technologies.

3.5.6 Relate Evaluations to Existing Technology Assessments

The team reviewed existing science and technology assessments including the Defense Technology Area Plan (DTAP) [Ref. 7], the 1999 DDR&E Basic Research Plan [Ref.

14], the 2000 Defense Science and Technology Strategy [Ref. 15], and the Joint Warfighter Science and Technology Plan [Ref. 8], to determine the consistency of the current HOBM-related assessments with those more general assessments. In particular, the goal was to identify for DMSO those HOBM-relevant technologies that are of the most importance to the development of M&S but are not stressed in existing technology assessments. These technologies will require the most involvement. A related goal was to identify those HOBM-relevant technologies that are strongly needed in other areas of DoD since these will probably require the least involvement by DMSO.

3.5.7 Determine Desirability of DMSO Involvement in Technologies

The team assessed the degree of DMSO involvement needed in the development of the HOBM-related technologies. Recommendations on involvement were categorized as follows:

- Recommend that DMSO invest
- Recommend that DMSO influence
- Recommend that DMSO monitor
- Recommend that DMSO periodically review

The justification for including a specific technology into a category was based on its relevance to satisfying HOBM needs, its relevance for satisfying other DoD and commercial needs, its maturity, its funding level, and its trends and goals, among others. These factors help answer the question of the ability or the necessity of DoD/DMSO influencing the technology trends.

Specific investment and leveraging recommendations are included in the report as “Lead, Leverage, Integrate” discussions and also serve to provide programmatic direction into other areas such as the DoD M&S Master Plan and DTAP.

3.5.8 Recommend Support Materials for DoD Technology Assessments

The team recommends assembling raw inputs, technology metrics, and technology evaluations and assessments to support the DMSO inputs into other technology reviews and assessments. These include the DTAP, the Technology Area Review and Assessments (TARA) [Ref. 9], the Weapons Systems Technology Area Review and Assessment [Ref. 16], Robotics Technology Area Review and Assessment [Ref. 17], the Joint Vision 2010/2020 [Ref. 1], and the DoD M&S Master Plan [Ref. 2].

4. HOBM Technologies Evaluation

The Behavior Analysis Team conducted the HOBM technology evaluation and assessment using the HOBM needs identified by the Behavior Representation Workshops and other reviews and analyses. This effort determined that HOBM technologies could play a significant role in the following applications:

- Computer Generated Forces/Semi-Automated Forces
- Organizational Decision Making
- Course of Action Analysis
- Decision Aids
- Mission Rehearsal
- Situational Awareness
- Information Operations/Information Warfare
- Simulator Effectiveness
- Simulation of C4I Systems
- Virtual Prototyping of Weapons Effects Simulation
- Dynamic Simulation Models of Complex Business System

4.1 Broad Computing Technologies

4.1.1 High Performance Computing

Summary

In the ISP glossary [Ref. 18], *High Performance Computing* (HPC) is defined as a branch of computer science that concentrates on developing supercomputers and software to run on supercomputers. The High Performance Computing and Communications Glossary [Ref. 19] defines *supercomputer* as a time dependent term which refers to the most powerful class of computer systems at the time of reference. The Top 500 web site [Ref. 20] (which describes the 500 fastest computers) listed machines with speeds above 60 GigaFlops in the June 2001 list. Thus, a reasonable current definition of HPC is *machines having speeds of 60 GigaFlops or greater*. HPC was included in this study because it has been shown to be vital for many classes of modeling problems.

Table of Examples of High Performance Computing Users

Developer / Type	Machine Location	HOBM Use	Expert
HP V2500	SPAWAR Systems Center San Diego	None	N/A
Cray SV1 Sun HPC 10000 SGI Origin 2000	Major Shared Resource Center Aberdeen Proving Ground	System of Systems CHSSI program	R. Cozby
HP Exemplar	Caltech	SAF Demonstration	T. Gottschalk
Intel Paragon	Oak Ridge National Laboratory	SAF Demonstration	N/A
IBM SP2 IBM SP2 Cluster of Windows NT Machines	Maui High Performance Computing Center	SAF Demonstration ISAAC SAF Port ISAAC SAF Port	N/A A. Brandstein A. Brandstein
IBM SP2	NASA Ames	SAF Demonstration	N/A

Benefits Analysis

Very little use has been made of HPC machines for HOBM to date. One relevant program is a recently completed DARPA-sponsored effort to demonstrate 50K-100K vehicle ModSAF exercises [Ref. 21]. Another program is the Marine Corps Combat Development Command port of the Irreducible Semi-Autonomous Adaptive Combat (ISAAC) Semi-Automated Forces code to HPC machines [Ref. 22]. The Common High Performance Computing Software Support Initiative (CHSSI) program of the High Performance Computing Modernization Program [Ref. 23] has requested proposals for the use of HPC assets for activities including HOBM. As of this writing, these proposals have not been reviewed. Discussions with HOBM experts employed by the Army, Navy, and Air Force revealed that there is no perceived need for HPC as applied to HOBM at present.

Lead, Integrate, Leverage

HPC is useful for a variety of problems and will be developed by government and commercial sponsors. It is recommended that DMSO periodically review HPC until it is demonstrated to be useful for HOBM. Following this demonstration, it is recommended that DMSO begin monitoring HPC developments, but need not fund HPC technology improvements.

4.1.2 Fundamental Computing Infrastructure

Summary

Since HPC proved to be of limited relevance for HOBM, and since most HOBM problems are solved using COTS equipment, it was decided to ascertain the impact on HOBM of fundamental computing infrastructures. Fundamental computing infrastructure is taken to include COTS computers and networking capabilities commonly found in an office or laboratory. A non-exhaustive list of examples is given below.

Table of Examples of Infrastructure Developers and Products

Developer	Product
Intel	Processor chips
Motorola	Processor chips
Microsoft	Operating system
Apple	Operating system, hardware
Sun	Operating system, hardware
Hewlett-Packard	Operating system, hardware
Gateway	Hardware
Compaq	Hardware
3Com	Networking

Benefits Analysis

Interviews with HOBM experts and reviews of the literature from the services indicated that there are no limitations for HOBM imposed by the available computer equipment. Most HOBM models run on either Macintosh or Windows/Intel platforms without networking. Some models have been implemented on more extensive COTS equipment. However, one expert commented that any machine that would be required for HOBM would be available COTS if one has the funding to purchase it.

Lead, Integrate, Leverage

It is recommended that DMSO periodically review fundamental computing infrastructure improvements for HOBM purposes. It is also recommended that DMSO not attempt to directly fund or influence this technology since it is not limiting, and relatively small amounts of government funding could not affect developments, because of the enormous commercial investment.

4.1.3 Human Computer Interactions (HCI)

Summary

Human Computer Interactions, or HCI for short, is an extremely active field in both computer sciences and psychology. HCI is concerned with three major groups of human processes. These include *motor* processes (hand movements, hand grasp, hand control operations, feet movement, head movement, eye movement, trunk movement), *perceptual* processes (perception of visual scene features, reading of text, listening), and *cognitive* processes (decision making, short term memory). All of these processes are of interest to HOBM.

Important HOBM models correspond to these processes, namely perceptor (sensory), cognitive, and motor (effector) models. Perceptor models process external world stimuli. Cognitive models represent the human decision making process (see 4.3.1). Motor models simulate behavioral responses. The outputs of perceptual models include detection and identification, and the times to perceive and interpret; the outputs of cognitive models include the time to calculate or reach a decision; and the outputs of motor models include time and accuracy estimates.

Benefits Analysis

HCI and HOBM interact along a "two way street", with the results of HCI being applied by some researchers and developers to HOBM, and the results of HOBM being applied by others to HCI.

Many aspects of HOBM rely on HCI. A primary use of HCI in HOBM models is to represent and implement human interactions such as speech, smell, and touch. One example application is the ability to augment one's own forces in a simulation used for mission rehearsal or for representing C4I. Another use of HCI in HOBM is to present situations to users via visual, audio, and haptic displays for decision aids or in situational assessments. One additional use of HCI is to implement input and output methods to control HOBM models. However, these interfaces, implemented via HCI, are no different than those used for other models or simulations.

In turn, there are several aspects of HCI that rely on HOBM. These include the design of interfaces. A better design can be developed using a model of a human to interact with (vice a real person) since the ability to perform many replications of interactions can produce better timelines and more accurate predictions. Another aspect is the development and use of testbeds for human performance research such as human factors analysis in industry.

Lead, Integrate, Leverage

HCI is a "big" field in computer sciences. It is currently very well funded but bears watching for niche opportunities to improve its applications to HOBM. For example, the use of HCI/HOBM to augment forces in a distributed simulation is a problem specific to DoD. This application may need guidance or occasional funding. The use of HCI/HOBM to aid situational assessment is a situation common to many systems, not just M&S or HOBM. Consequently, these developments and situations may need monitoring and/or guidance.

4.2 Broad HOBM Technologies

4.2.1 Architectures, Frameworks, and Data Interchange Formats and Standards

Summary

Architecture is the structure of components in a program/system, their interrelationships, and the principles and guidelines governing their design and evolution over time. In object-oriented systems, a *framework* is a set of classes that embodies an abstract design for solutions to a number of related problems. A *data interchange format* or *standard* is a formally defined protocol for the format and content of data messages used for interchanging data between networked simulation and/or simulator nodes used to create and operate a distributed, time and space coherent synthetic environment.

Common software architectures include mainframe software architectures, file sharing architectures, and client/server architectures (both two-tier architectures and various types of three-tier architectures). Additional software architectures include the Common Object Request Broker Architecture (CORBA) [Ref. 24] and the distributed/collaborative enterprise architecture. A closely related concept is that of a reference model, which is a description of all of the possible software components, component services (functions), and the relationships between them (how these components are put together and how they will interact). The DoD standard architecture is the Joint Technical Architecture, or JTA [Ref. 25].

An M&S architecture describes the structural representation of simulation components at various levels of detail; their reuse, portability, and scalability; legacy interfaces; technological evolution; and distributed operation. A major goal for an M&S architecture (such as the High Level Architecture, or HLA [Ref. 26]) is the promotion of interoperability among models and simulations. Within the DoD today, there is a major push towards developing standard architectures like JTA and HLA, a segment under JTA, that support a wide array of communities and depart from traditional stovepipe applications.

The same is true when specialized to HOBM: the efficient development of HOBM will require a comprehensive software architecture that supports integral cognitive processing and decision architectures such as blackboard systems and distributed agents. One concept for HOBM architecture is CHRIS – the Common Human Behavior Representation and Interchange Specification [Ref. 27]. This is modeled after the SEDRIS [Ref. 28] program (for the interchange of synthetic environment information) and is being designed to include knowledge, perception and cognition, motion, and performance moderators. Specific cognitive processing architectures and specific software agent control architectures are discussed in the sections on cognitive modeling and intelligent agents below.

A standard is a definition or format that has been approved by a recognized standards organization or is accepted as a *de facto* standard by the industry. Standards exist for programming languages, operating systems, data formats, communications protocols, and electrical interfaces. The development of data interchange standards for HOBM will be extremely important because they enhance the ability to combine separately-developed simulation components from different developers into large systems. One of the first M&S data interchange standards was Distributed Interaction Simulation (DIS) [Ref. 29]. Although DIS is not directly applicable to the entire field of HOBM, it has made the benefits of such standards extremely clear. The CHRIS architecture will also attempt to standardize HOBM data interchange.

<u>Benefits Analysis</u>

Benefits of a standard HOBM architecture include enhanced composability and flexibility, quicker construction of large systems, faster import and export of knowledge bases, and the ability to develop high quality applications by domain experts vice computer science experts. Standard architectures and interchange formats will allow agents or agent systems produced by different developers to cooperate with each other in the ways needed to build large applications supporting military capabilities, and will eliminate the need to build specially designed, monolithic agents for handling each new task. Additional benefits would include more rapid evaluation of modeling results, easier VV&A of simulations, and the more timely application of the range of technologies discussed elsewhere in this report.

<u>Lead, Integrate, Leverage</u>

Since the development of Architectures, Frameworks, and Data Interchange Formats and Standards will permit great improvements in the development of HOBM, and because there is no other overarching organization with such great interest in the development and application of HOBM to the military arena, DMSO should focus considerable efforts and resources into this area. Although the computer science community as a whole places great efforts into developing new technologies in these areas, the specialized need of

HOBM dictate that DMSO should invest in selected Architectures, Frameworks, and Data Interchange Formats and Standards programs and closely monitor emerging technology thrusts. DMSO should also be the primary agency that oversees the development and integration of these technologies into appropriate military applications. DMSO should make Architectures, Frameworks, and Data Interchange Formats and Standards a high priority technology effort.

4.2.2 Knowledge Engineering

Summary

Knowledge engineering is the field concerned with designing and applying systems for using and storing knowledge. The field developed historically as a part of expert systems and Artificial Intelligence (AI). The first applications included collecting and disseminating rules about specific domains to improve performance and train newcomers. Another early application of knowledge engineering was to code and encapsulate tactics for military situations and physical entities within models and simulations. Knowledge engineering applied to HOBM includes capturing and codifying human responses for use in these same models and simulations. This need to capture and encode knowledge has been recognized by DMSO's HOBM Needs Workshops to be of the highest priority.

A domain expert is an authority in the area of expertise (the domain) being investigated. The knowledge engineer captures the expertise and programs it into a knowledge base. Knowledge engineering can take place more quickly and with less cost by using knowledge engineering tools. These tools are software programs designed to capture the information, insights, procedures, and processes used by experts or experienced professionals. Knowledge engineering tools preserve the expert knowledge of professionals and permit this knowledge to be shared across space and time. That is, the captured knowledge is available even after the domain expert has retired or moved on to a different job, and this knowledge can also be applied in multiple locations at the same time. Knowledge engineering tools are used by specially trained individuals or groups supporting the analyses of specific problems.

Knowledge engineering tools support interviews with domain experts and the encoding of their knowledge. Certain tools offer a direct interface to a model's formal language for encouraging the expert's direct encoding of knowledge. This can streamline knowledge acquisition by eliminating the "middle-man," allowing the domain expert more control, and enabling early "buy-in" to the process. Other knowledge engineering tools include hypertext, graphics, brainstorming, cause-and-effect routines, and histograms. These tools can also be applied by users, managers and domain experts to add and adjust knowledge, apply measurements to the model, inspect the model, animate the model, and attempt to verify or validate the model.

The active capture of knowledge usually begins with a series of interviews between the domain expert and the knowledge engineer. The goal of the knowledge engineer is to learn how the expert's domain decisions are made and to bring what is learned into a form that the computer can use. To encode domain knowledge into a computerized application, the knowledge engineer filters and refines the information into specific formats, usually rules and facts, and stores them in a knowledge base. The encoding process can be enhanced by applying expert system shells. Two well-known expert system shells are CLIPS (developed by NASA) and Jess (developed by Sandia National Laboratory). CLIPS provides an environment for expert system development written entirely in C. CLIPS is easily embedded in other programs and used on systems that support an ANSI-compliant C compiler. Jess, derived from CLIPS, is written in and supports expert system development in Java. Expert systems developed in Jess, using Java, can be sent directly to a web browser for execution.

Benefits Analysis

Knowledge engineering can be used to capture military and civilian personnel’s domain expertise and likely behavior to support the development of all HOBM models. Knowledge engineering tools reduce the cost, risk, and schedule for developing HOBM models. Specific applications include capturing and storing knowledge for:

- developing models of complex, dynamic human tactical decision making that accurately portray the processes and decisions of commander and command staff personnel for integration into constructive and SAF models,
- developing models of human behavior in non-traditional warfare (OOTW, MOUT, SASO),
- developing support tools and decision aids that can help manage an operator’s mental workload and assist in making decisions,
- developing models of the effects of stress (e.g., heat, cold, fatigue, NBC factors, etc.) on human behavior, and
- developing unmanned systems and defining their interactions with humans.

Lead, Integrate, Leverage

Since the use of knowledge engineering will enhance the development of the entire HOBM area, it is recommended that DMSO should focus considerable efforts and resources into adopting or adapting selected knowledge engineering products for the needs of the military. In leveraging commercial knowledge engineering developments into military M&S areas, DMSO should be the primary agency that oversees the integration of emerging knowledge engineering programs from commercial, academic, and other government agencies into appropriate military applications. The applications of knowledge engineering to the specialized field of HOBM should be a high priority technology effort for DMSO.

4.3 High Level HOBM Technologies

4.3.1 Cognitive Models

Summary

This section will focus on integrative architectures that implement a coherent representation of human behavior. These architectures model human beings as information processing systems. A person receives an input, processes it, and creates some output. Functions modeled include perception, motor behavior, memory, situational awareness, multitasking, learning, and decision making. The architectures have been primarily used to model individual behavior rather than organizational behavior, although small teams have been modeled. Cognitive models can be useful role-players in training exercises, where they could function as adversaries or teammates.

Table of Cognitive Models

Model	Developer	Sponsor	User	Use	Expert
ACT-R	Carnegie-Mellon University	Various	ARL, AFRL, others	Air traffic control, flight, others	J. Anderson
COGNET	CHI Systems	NAVAIR, AFRL, CHI, Others	Various	Flight, air traffic control, Navy training	W. Zachary
D-COG	AFRL	AFOSR, DMSO	AFRL	Air traffic control	M. Young
EPIC	U. Michigan	AFRL	Air Force	Air traffic control, military exercises	D. E. Kieras
EPIC-SOAR	U. Michigan / Soar Technology	AFRL, DMSO, Others	AFRL, Others	Air traffic control, air operations	J.R. Rosbe
HOS V	ARL	Army Materiel Command	Army	Flight, armor	L. Allender
IMPRINT	ARL	Army Materiel Command	ARL, Army Aviation	Flight	L. Allender
JWARS CBM	CACI, Inc.	JWARS Program Office	All services, PA&E, JWARS PO	Commander behavior	G. Degeovanni
Micro Saint	Micro Analysis and Design	COTS	Commercial, all services	Ergonomics, healthcare, aviation, etc	K. R. Laughery
MIDAS	NASA Ames	NASA, Army Aviation	NASA, Army, Commercial	Flight	J. Shivley
OMAR	BBN, Inc.	AFRL, AFOSR	Air Force	Air traffic control, flight	M. Young
SAMPLE	Charles River Analytics	ASC WPAFB	Phase I SBIR	Air tactics, pilot response	G. L. Zacharias
SOAR	Soar Technology	All Services	All Services	Air Operations	J.R. Rosbe

Benefits Analysis

All of the architectures developed have been successfully demonstrated in one or more applications [Ref. 3, 30, 31]. The extent of use beyond the developing organization varies. Several of the architectures have been compared to each other for an air traffic control task in the Agent-Based Modeling and Behavioral Representation (AMBR) program [Ref. 32]. Preliminary results from this program indicate good agreement between the architectures and the architectures and human behavior. Other testing indicates that architectures perform well except in situations where the human response is unexpected or difficult to predict. Each separate problem addressed with any architecture requires a separate solution. The table of models is not exhaustive, but is meant to provide a representative selection of current applications. Details of the evaluation of each architecture are discussed below.

Lead, Integrate, Leverage

It is recommended that DMSO follow developments in cognitive modeling in detail, as this is a key technology for HOBM. Since separate models are developed for each application, these models are not recommended for funding, although DMSO may wish to influence the efforts of developers. Cognitive architectures, as opposed to uses of these architectures for specific problems, are recommended for potential funding by DMSO. Interfaces, comparisons, and integration into federations may also be of value.

4.2.2 Expert Systems

Summary

An expert system applies stored knowledge obtained from one or more experts in a particular domain to solve problems in that domain. The knowledge is most commonly expressed in the form of a rule base, which is a set of rules used by experts to solve problems. An inference engine then applies the rules to solve problems.

Table of Selected Expert Systems

Model	Developer	Sponsor	User	Use	Expert
Army Ground Command Entity (AGCE)	SAIC, Institute for Simulation and Training	DARPA Army	ModSAF, OneSAF	Route planning	W. Foss
Automated Mission Planner (AMP)	Institute for Simulation and Training	Army	Army, ModSAF	Course of action analysis	D. Parsons
Computer Controlled Hostiles	Institute for Simulation and Training	Marine Corps	Marine Corps	Planning, small unit team training	D. Reece
Marine Computer Generated Force	Hughes Research	DARPA	Marine Corps, ModSAF	Route planning	
NSS Behavior Model	Metron	SPAWAR PMW 131, CNO N6	Navy	Commander behavior	D. Merritt
WARSIM 2000 Command and Control Model	SAIC, Lockheed-Martin	Army	WARSIM	Command and Control, agent-based expert system	C. Karr

Table of Selected Commercial and Government Expert Systems Tools

Tool	Organization
CLIPS (Windows Version)	JAGware
Jess	Sandia National Laboratory
ESIEWin	Granite Bear Development
XpertRule	Attar Software
CLIPS	National Aeronautics and Space Administration

Benefits Analysis

The primary value added in the construction of an expert system is the knowledge engineering needed to capture knowledge and describe it in the form of a rule base, which may contain thousands of rules. Separate expert systems must be developed for every problem in question. Commercial products have been created to assist in the process of knowledge capture and expert system development. Expert systems have been successfully demonstrated in several domains, including domains related to military simulations.

Lead, Integrate, Leverage

It is recommended that DMSO influence but not fund technology for the development of expert systems. The expert systems field is mature, but not stagnant. It is recommended that the end user should fund development of expert systems for specific problems. Recommendations about knowledge engineering will be made in later iterations.

4.3.3 Natural Language Processing

Summary

Natural language processing is a discipline at the boundary of linguistics and computer science. One main goal is the development of computer systems that can interpret and act upon ordinary speech. Another goal is the extraction of information from text. A considerable amount of work is underway in the European Union and at various commercial and academic institutions in the United States. A detailed, if slightly dated, review may be found in "Survey of the State of the Art in Human Language Technology" edited by Cole *et al*. [Ref. 33].

Table of Selected Developers

Developing Organization	Sponsor	Expert
German Research Center for Artificial Intelligence	German Ministry for Research and Technology	H. Uszkoreit
Austrian Research Institute for Artificial Intelligence	European Union, Austria	H. Trost
SRI	U.S. Government	D. J. Israel
Microsoft	Microsoft	Many individuals
University of Delaware	National Institute for Disability and Rehabilitation Research	K. E. McCoy, L. N. Michaud
University of Massachusetts	DARPA	W. C. Lehnert

Benefits Analysis

At present, this is a fairly theoretical field without a great deal of relevance to DoD M&S. If practical natural language processing is ever developed it will be important for human-computer interaction applications and will receive substantial publicity. The technology also will be relevant to intelligence community applications.

Lead, Integrate, Leverage

It is recommended that DMSO periodically review Natural Language Processing for its applications to HOBM.

4.4 Fundamental HOBM Technologies

4.4.1 Agent Based Simulations (ABS)

Summary

Agent Based Simulation (ABS) involving the use of intelligent agent technology has emerged in current R&D efforts and has now matured into a wide variety of operational applications in all organizational regimes (DoD, other government agencies, commercial and academia). Agents are objects with a set of associated states. These agents are situated within a computational environment within which they can sense and interact. Transitions between states and behaviors are specified through probabilistic behavior networks. Although each agent has only a relatively small repertoire of behaviors, when a number of agents interact the external appearance is of a complex system that evolves over time. The agents interact with their environment by means of actions; typically these are movements or attempts to change other objects in their world. As the agent's world is simulated, something must arbitrate whether the actions attempted are successful; this role is performed by a referee, either human or software.

Benefits Analysis

ABS is especially well suited for combat situations that require replication of various forms of computer generated forces (CGF). The annual conference on Computer Generated Forces and Behavior Representation (CGF-BR) fosters this research. Agent based human behavior models have applications in all three DoD M&S functional areas (training, analysis, and, acquisition). In addition, ABS is useful in the simulation of C4I systems and in the dynamic simulation of complex business systems. Warfighter needs are especially well fulfilled by ABS since most applications are complex and involve a large number of diverse elements such as vehicles (logistic and armored) and personnel and their interactions. When developed, mature, and operational, this technology will serve to answer many Warfighter needs for group and organizational behavior representations.

Lead, Integrate, Leverage

Since this technology's use is pervasive in the HOBM area, it is recommended that DMSO should focus considerable efforts and resources into selected ABS programs and closely monitor emerging technology thrusts. By leveraging commercial ABS developments into military M&S areas, DMSO should be the primary agency that oversees the integration of emerging ABS programs from commercial, academic, and other government agencies into appropriate military applications. An agent-based architecture should be pursued for the military M&S environment. ABS should be a high priority technology effort that DMSO pursues.

4.4.2 SWARM

Summary

Organizational unit-level modeling languages or frameworks have been developed offering a comprehensive approach for implementing agent-based models. These systems offer the means to model extensive computer generated force structures as well as opposing forces (OPFOR).

SWARM is a multiagent simulation language for modeling collections of concurrently interacting agents in a dynamic environment. It was developed in 1994 at the Santa Fe Institute as an artificial-life simulation. It is best utilized to explore complex systems comprising large numbers of relatively simple agents that can dynamically restructure themselves to accommodate changes in incoming data or the objective function. In the aggregate over time, SWARM entities come to display collective intelligence beyond the simple summation of agent knowledge. Within this framework, SWARM is independent of the model implemented since no domain specifics are required. SWARM has a wide area of applications in chemistry, economics, physics, biology, computer science, geography, anthropology, ecology, political science, logistics, and defense.

Benefits Analysis

SWARM is a subset of ABS and has applications in CGF/SAF, dynamic simulation of complex business systems, and in the simulation of C4I systems. It has the same potential to answer Warfighter needs for group and organizational human behavior representation as ABS.

Lead, Integrate, Leverage

Since SWARM is a proven, mature HOBM technology, DMSO should monitor new thrusts or development efforts. Significant program development or funding by DoD is not warranted.

4.4.3 Case Based Reasoning (CBR)

Summary

In Case Based Reasoning (CBR) the primary knowledge source is not generalized, but consists of a stored memory of cases depicting specific prior episodes. New solutions are generated not by chaining these episodic events, but by retrieving the most relevant cases from the memory and adapting them to fit the new situation. Thus in CBR, reasoning is based on remembering. The CBR approach is based on two tenets in the natural environment. The first tenet is that regularity exits in the world, i.e., similar problems have similar solutions. This leads to the fact that useful starting points for a new problem are prior similar problems. The second tenet is the fact that the types of problems that a specific agent faces tend to recur due to the nature of their environment. This leads to the knowledge that future problems are likely to be similar to past and current problems. When these two tenets apply, CBR can be a valuable tool. In addition, CBR can be beneficial when a reasoner must solve problems that are quite unique from prior experiences. As the CBR approach is applied to novel problems, the CBR process evolves from simple reuse to more creative solutions as experience is gathered.

The CBR process can be divided into two classes, interpretive and problem-solving. Interpretive CBR uses prior cases as reference points for classifying and characterizing new situations; problem-solving CBR uses prior cases to suggest solutions that might apply to new circumstances.

CBR has been applied to a full spectrum of AI tasks, such as classification, interpretation, scheduling, planning, design, diagnosis, explanation, parsing, dispute mediation, argumentation, projection of effects, and execution monitoring. CBR can be used for creative reasoning when the interpretive CBR technology is utilized in a flexible retrieval process. Case-based aiding systems utilizing automated case memories can provide successful prior solutions and warn of prior failures to the user. Knowledge sharing aspects of CBR may be very valuable in providing corporate memory to multiple agents. In addition, Case-based education research is being conducted on a large scale to apply lessons from the cognitive model of CBR to training and education.

Benefits Analysis

CBR is a pervasive technology whose use is increasing in ever-widening areas of human behavior modeling. The core of CBR is the importance of past experience and lessons learned which are very germane to military applications since these factors are the heart of military strategy and tactical doctrine evolution. CBR offers significant opportunities for use in Organizational Decision-Making, Course of Action Analysis, Decision Aids, Simulation Design/Effectiveness and in C4I Simulation Systems.

Lead, Integrate, Leverage

CBR offers dramatic opportunities for representing decision management processes rapidly. Since “lessons learned” is of critical importance to the military decision maker, CBR offers the possibility of providing prioritized alternative courses of action. The developments in CBR should be monitored closely to ensure that new research breakthroughs in data management and retrieval methods are incorporated into M&S areas that can aid the Warfighter.

4.4.4 Fuzzy Systems

Summary

Many problems faced in engineering, science, and the military can be modeled mathematically. However, when constructing these models many assumptions have to be made which are often gross approximations to the real world. Real world problems are characterized by the need to be able to process incomplete, imprecise, vague or uncertain information. This can be described as the process by which a robot is controlled in a hostile environment. The robot’s sensors are often error prone and therefore may provide inaccurate information as to the position and/or situation of the robot. This quandary leads one into the technology and mathematics that deal with imprecision, uncertainty, and in particular linguistic terms that cannot be defined precisely.

Fuzzy systems are an alternative to traditional notions of set membership and logic that has its origins in ancient Greek philosophy, and applications at the leading edge of AI. Yet, despite its long-standing origins, it is a relatively new field, and as such leaves much room for development. Ultimately, the use of fuzzy systems may form a valuable addition to the field of AI and control theory.

For example, when one is designing an expert system to mimic the diagnostic powers of a physician, one of the major tasks is to codify the physician's decision-making process. The designer soon learns that the physician's view of the world depends upon precise, scientific tests and measurements, but also incorporates evaluations of symptoms, and relationships between them in a "fuzzy," intuitive manner. That is, deciding how much of a particular medication to administer will have as much to do with the physician's sense of the relative "strength" of the patient's symptoms as it will their height to weight ratio. While some of the decisions and calculations could be done using traditional logic, fuzzy systems afford a broader, richer field of data and the manipulation of that data than do more traditional methods.

The first major commercial application was in the area of cement kiln control, an operation which requires that an operator monitor four internal states of the kiln, control four sets of operations, and dynamically manage 40 or 50 "rules of thumb" about their interrelationships, all with the goal of controlling a highly complex set of chemical interactions. Other applications which have benefited through the use of fuzzy systems theory have been information retrieval systems, a navigation system for automatic cars, a predicative fuzzy-logic controller for automatic operation of trains, laboratory water level controllers, controllers for robot arc-welders, feature-definition controllers for robot vision, graphics controllers for automated police sketchers, and more.

<u>Benefits Analysis</u>

Expert systems have been the most obvious recipients of the benefits of fuzzy logic, since their domain is often inherently fuzzy. Examples of expert systems with fuzzy logic central to their control are decision-support systems, financial planners, and diagnostic systems for determining soybean pathology. Since fuzzy systems have the unique capability to process incomplete, uncertain, and suspect information (a dilemma consistently facing the military decision maker), they offer excellent potential in organizational decision making, course of action analysis, decision aids, virtual prototyping of weapons effects simulation, and Information Operation/Information Warfare (IO/IW) operations. Fuzzy systems also can be useful for the control and feedback loops for autonomous robotics.

<u>Lead, Integrate, Leverage</u>

Fuzzy systems, including fuzzy logic and fuzzy set theory, provide a rich and meaningful addition to standard logic. Many systems may be modeled, simulated, and even replicated with the help of fuzzy systems, not the least of which is human reasoning itself. There is a considerable research effort in this field in the scientific, engineering, academic, and commercial areas. It is recommended that DMSO remain cognizant of these efforts and be prepared to rapidly leverage them into military M&S HOBM areas as quickly as they mature.

4.4.5 Genetic Computing

Summary

One of the central challenges of computer science is to get a computer to do what needs to be done, without telling it how to do it. Genetic programming addresses this challenge by providing a method for automatically creating a working computer program from a high-level problem statement. Genetic programming achieves this goal of automatic programming (sometimes called program synthesis or program induction) by genetically breeding a population of computer programs using the principles of Darwinian natural selection and biologically inspired operations. The operations include reproduction, crossover (sexual recombination), mutation, and architecture-altering operations patterned after gene duplication and gene deletion in nature.

The main generational loop of a run of genetic programming consists of the fitness evaluation, Darwinian selection, and the genetic operations. Each individual program in the population is evaluated to determine how fit it is at solving the problem at hand. Programs are then probabilistically selected from the population based on their fitness to participate in the various genetic operations, with reselection allowed. While a fit program has a better chance of being selected, even individual programs known to be unfit are allocated some trials in a mathematically principled way. That is, genetic programming is not a purely greedy hill-climbing algorithm. The individuals in the initial random population and the offspring produced by each genetic operation are all syntactically valid executable programs. After many generations, a program may emerge that solves, or approximately solves, the problem at hand.

Benefits Analysis

Genetic computing offers excellent potential in organizational decision making, course of action analysis, decision aids, virtual prototyping of weapons effect simulation, and IO/IW operations. It also can be useful for as the central processor for the control of autonomous robotics.

Lead, Integrate, Leverage

Genetic Computing is useful in the algorithm applications in artificial intelligence. DMSO should remain cognizant of the latest R&D efforts and be prepared to rapidly leverage them into military M&S HOBM areas as quickly as they mature.

4.4.6 Machine Vision

Summary

Machine vision is the technology that integrates devices for optical non-contact sensing to automatically receive and interpret an image of a real scene, in order to obtain information and/or control machines or processes. The first step in machine vision operations is image acquisition. The next step in this process is to transform the analog signal into digital form to allow the computer to interpret the light intensities of the captured image. An analog-to-digital converter is used to accomplish this by sampling the incoming signal and assigning a numerical value based on the brightness of the signal. Image processing is usually the next step in the computer vision process. This step eliminates unwanted features (e.g., noise) and enhances the desired features (e.g., edges, contrast, and motion).

Benefits Analysis

Machine vision has direct utility in military applications for situational awareness, remote sensing, fault detection, autonomous robotics, and security.

Lead, Integrate, Leverage

This technology is not of high priority in the HOBM area, but should be periodically reviewed as applications emerge especially in the areas of robotics and should be promoted and integrated as it matures.

4.4.7 Neural Networks

Summary

Neural Networks are a different paradigm for computing. They are based on the parallel architecture of animal brains. Neural Networks can be useful tools where one is unable to formulate an algorithmic solution, unable to obtain lots of examples of the behavior required, or must pick out a structure from existing data. Neural networks are a form of multiprocessor computer system with simple processing elements, a high degree of interconnection, simple scalar messages, and adaptive interaction between elements.

Neural networks are being used in investment analysis to attempt to predict the movement of stocks and currencies from previous data where they replace earlier simpler linear models. They are also being extensively used in handwriting signature analysis as a mechanism for comparing signatures made (e.g., in a bank) with those stored. This was one of the first large-scale applications of neural networks, and was one of the first to use a neural network chip. Neural networks are used in process control since most processes cannot be determined as computable algorithms. Neural networks have also been used to monitor the state of aircraft engines. By monitoring vibration levels and sound, early warning of engine problems can be given.

Benefits Analysis

Neural networks offer the potential for use in course of action analysis, decision aids, simulation of C4I systems, and for complex military logistic systems.

Lead, Integrate, Leverage

Neural networks clearly have a role in the development of AI programs and in the HOBM areas that we have discussed. The latest research should be monitored and leveraged into M&S programs as they mature.

4.4.8 Pattern Recognition

Summary

Pattern recognition is the research area that studies the operation and design of systems that recognize patterns in data. It encompasses sub-disciplines like discriminant analysis, feature extraction, error estimation, cluster analysis, grammatical inference, and parsing. Important application areas are image analysis, character recognition, speech analysis, man and machine diagnostics, person identification and industrial inspection.

Pattern recognition has a long and respectable history within engineering, especially for military applications in the areas of targeting, but the cost of the hardware both to acquire the data (signals and images) and to compute the answers made it for many years a rather specialist subject. Hardware advances have made the concepts of pattern recognition much more widely applicable.

Benefits Analysis

Pattern recognition offers similar attributes to some of the other technologies discussed. As signal processing efforts improve, pattern recognition can have an impact on decision aid development, modeling complex logistic systems, and course of action analysis.

Lead, Integrate, Leverage

This technology is not of high priority in the HOBM area, but should be monitored as applications emerge especially in the areas of advanced signal processing, and should be promoted and integrated as it matures.

4.4.9 Robotics

Summary

The dictionary definition of robotics is: "An automatic device that performs functions normally ascribed to humans or a machine in the form of a human." [Ref. 34]. The Carnegie Mellon University Robotics Institute [Ref. 35] stated in1979 that a robot was: "A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks."

Modern industrial arms have increased in capability and performance through controller and language development, improved mechanisms, sensing, and drive systems. In the early to mid 80's the robot industry grew very fast primarily due to large investments by the automotive industry. In the research community the first automata were probably Grey Walter's machina (1940's) and the Johns Hopkins beast. Teleoperated or remote controlled devices had been built even earlier with at least the first radio controlled vehicles built by Nikola Tesla in the 1890's. SRI's Dr. J. Shakey navigated highly structured indoor environments in the late 1960's, and Dr. Peter Moravec's Stanford Cart was the first to attempt natural outdoor scenes in the late 1970's. From that time on there has been a proliferation of work in autonomous driving machines that cruise at highway speeds and navigate outdoor terrains in commercial and military applications.

Benefits Analysis

Robotics enter the realm of human behavior representation for applications in the area of autonomous operation. DARPA estimates that by 2020, robotics will begin battlefield autonomous operations replicating human behavior characteristics. This new capability must be carefully managed in terms of all technologies required.

Lead, Integrate, Leverage

As robotic battlefield autonomy is approached and issues forth from the R&D world, DMSO should be ready to leverage the programs into HOBM areas. It is recommended that DMSO consider adding "robotic behavior" to the HOBM mission/vision as these behaviors will be required for the analysis, training and acquisition of future autonomous systems, that would be robotic and human organizational behavior modeling (RHOBM).

4.4.10 Intelligent Tutoring Systems (ITS)

Summary

Intelligent Tutoring Systems are computer-based training systems that incorporate techniques for communicating and transferring knowledge and skills to students. These systems emerged from the combination of Computer-Aided Instruction (CAI) and AI technology. ITS emerged in the 1970s to address the deficiencies of CAI. By making use of the results of research work in artificial intelligence, ITS were able to employ knowledge representation strategies to model a student's cognitive processes. Using an accurate models of the student's and expert's knowledge, an ITS is able to provide instruction at the appropriate pace and level of abstraction for the student. Although there is no standard architecture for an ITS, four software components emerge from the literature as part of an ITS. These are the Expert Model, the Student Model, the Curriculum Manager, and the Instructional Environment.

Like a human expert, the Expert Model in an ITS has knowledge about a particular domain. The type of knowledge maintained by the Expert Model is referred to as domain or content knowledge. Typically, this knowledge is both factual and procedural, and is maintained in databases by an expert system. A factual database stores pieces of information about the problem domain, while a procedural database contains knowledge of procedures and rules that an expert uses to solve problems within that domain. Although factual and procedural databases may adequately model knowledge in an expert system, a method of knowledge encoding known as cognitive, or qualitative, modeling provides for a closer simulation of the human expert's reasoning process. The Expert Model in an ITS may employ cognitive modeling by using structured knowledge of causality and human-like inference mechanisms.

An ITS would not be a tutoring system if it did not contain facilities for teaching. Problems, or exercises, are the vehicle that an ITS uses to instruct the student. By solving problems, the student builds upon concepts already mastered. The facility in the ITS for sequencing and selecting problems is the Curriculum Manager. To select the appropriate problems for the student, the Curriculum Manager extracts performance measurements from the profile stored in the Student Model.

Teaching involves more than presenting material to the student. An effective instructor monitors a student's progress and provides coaching when the student requests assistance or is struggling. Like a human instructor, an ITS coaches the student through the use of an Instructional Environment. It is the Instructional Environment that provides the student with tools for proceeding through a tutorial session and obtaining help when needed. The Instructional Environment also determines when the student needs unsolicited advice and triggers its display.

These four components, the Expert Model, the Student Model, the Curriculum Manager, and the Instructional Environment interact to provide the individualized educational experience promised by ITS technology.

Benefits Analysis

This technology offers the opportunity to leverage advanced training into the HOBM areas of interest and should be pursued as the systems mature. ITS requires some ability to predict students' reaction to their actions, so behavior models are required for this purpose. Also the behavior models developed for ITS can be used for HOBM.

Lead, Integrate, Leverage

DMSO has the opportunity to integrate and leverage ITS into the Warfighter M&S system training at very early stages of new program implementation.

4.4.11 Decision Support Systems

Summary

Decision Support Systems (DSS) cover a wide variety of systems, tools and technologies. In terms of operations research, optimization, and simulation, DSS offers considerable advantages. In terms of enhancing the decision-making efforts of military commanders and their staffs, DSS offers to process robust computational models of human cognition, relational databases, powerful computational algorithms, advanced multi-modal workstations, and innovative designs for embedding training strategies. The object of this process is to provide improved situational awareness, options generation, response selection, and recommendations for resource allocation while reducing procedural mistakes in tactical decision making and reducing own force and non-combatant incidents.

Benefits Analysis

DSS have a wide range of applicability in organizational decision processes, course of action analysis, decision aids, IO/IW operations, and simulation design, evaluation, and effectiveness. DSS can also support intelligence preparation for the battlefield (IPB).

Lead, Integrate, Leverage

System development and new technologies should be pursued to provide an ever-increasing range of tactical and strategic applications. New capabilities should be investigated to integrate knowledge bases and computational algorithms for both rapid data retrieval and workstation display management to provide threat deconfliction.

DMSO should also pursue advances in Human Computer Interaction (HCI) concepts for rapid analysis and selection of appropriate courses of action.

4.4.12 Advanced Distributed Learning Systems

Summary

In November 1997, the Department of Defense (DoD) and the White House Office of Science and Technology Policy (OSTP) launched the Advanced Distributed Learning (ADL) Initiative. The ADL Initiative is a collaborative effort between government, industry and academia to establish a common framework that permits the interoperability of learning tools and content on a global scale. The Office of the Secretary of Defense, the Department of Labor and the National Guard have established the ADL Co-Lab as a forum for cooperative research, development and assessment of new learning technology prototypes, guidelines and specifications. From its inception, the ADL initiative has been focused on involving a myriad of interests and groups in its work. On the academic side, more than 19 major colleges and universities have signed research-sharing agreements with the Academic ADL Co-Lab at the University of Wisconsin. The Joint ADL Co-Lab, which serves the military interests of ADL, has also awarded more than $2 million in prototype funding for ADL efforts within the DoD. Finally, ADL has been able to work with the major international standard setting groups, the Integrated Measurement Systems (IMS) [Ref. 36], the Institute for Electrical and Electronic Engineers (IEEE) [Ref. 37], the Aviation Industry CBT Committee (AICC) [Ref. 38]; and has also brokered consensus among the major e-learning vendors.

The goal of the ADL Initiative is to pursue emerging network-based technologies; facilitate development of common standards; lower development costs; promote widespread collaboration that satisfies common needs; enhance performance with next-generation learning technologies; and work with industry to influence commercial-off-the-shelf product development.

Benefits Analysis

ADL benefits: Studies have shown that the use of ADL technology-based instruction reduces cost of instruction by 30 percent to 60 percent; reduces time of instruction by 20 percent to 40 percent; increases effectiveness of instruction by 30 percent; increases student knowledge and performance by 10 percent to 30 percent; and improves organization efficiency and productivity. ADL also improves costs and efficiencies by distributing instructional components inexpensively to physically remote locations and simulating expensive devices for operator and maintenance training. Success of the ADL initiative will be measured by the extent to which: (1) consumers are able to purchase high-quality learning software less expensively than they do today; (2) the size of the learning software market increases; and (3) producers of learning software are able to achieve a higher return on their investments.

Lead, Integrate, Leverage

It is recommended that DMSO monitor this technology with a goal to integrate and leverage ADL into the Warfighter M&S system training at very early stages of new program implementation.

5. Summary

This summary section provides the overall HOBM technologies assessment together with the cross reference matrix that relates the technologies to the HOBM needs.

5.1 Broad Computing Technologies

The Broad Computing Technology areas (High Performance Computing, Fundamental Computing Infrastructure, and Human Computer Interactions) do not presently place barriers to the development of improved HOBM capabilities. Considerable resources are devoted to these technology areas by government and industry for other purposes, and it is recommended that DMSO not invest time or funding in these areas.

5.2 Broad HOBM Technologies

The Broad HOBM Technologies area (Architectures, Frameworks, and Data Interchange Formats and Standards; and Knowledge Engineering) are critical to the improvement of human behavior representations. Successes in the first area (architectures, etc.) will permit more rapid and less costly development of major applications constructed from separately-developed individual components. Developments in this area can leverage the somewhat mature efforts found in software engineering and elsewhere in modeling and simulation, but specific architectures tailored for HOBM still must be produced. Successes in the second area (knowledge engineering) will allow the capture and reuse of critical data for developing applications utilizing a wide variety of human behavior including tactical decision making. Developments in this area can leverage the mature efforts from expert systems, but the capture of HOBM-specific data is so important that this remains a critical task. It is recommended that DMSO invest in both of these areas.

5.3 High Level HOBM Technologies

The High Level HOBM Technology areas (Cognitive Models, Expert Systems, and Natural Language Processing) all require different strategies. Cognitive models are specific to HOBM and key to certain applications. It is recommended that DMSO invest in this area, since the technology is not completely mature. Expert systems must be developed for each problem addressed. The technology is mature to the point that COTS development tools are available. It is recommended that DMSO monitor this area. Natural language processing is still immature. It is peripheral to M&S, but important for other government and commercial applications. It is recommended that DMSO periodically review this area.

5.4 Fundamental HOBM Technologies

The Fundamental HOBM Technology areas offer several opportunities to impact HOBM development in many critical areas. The primary area for immediate action is Agent Based Simulations. This area has the best chance of answering Warfighter needs in the most expeditious manner and also meets many of the priority needs from the Behavioral Representation Workshops. It is recommended that DMSO invest in this technology. The next most important technologies from this category are Fuzzy Systems, Genetic Computing, Robotics, SWARM, Intelligent Tutoring, and Decision Support Systems. It is recommended that DMSO influence the development of these technologies. The next set of technologies from this category are Case Based Reasoning, Neural Networks, Pattern Recognition, Advanced Distributed Learning Systems. These technologies are of great value to HOBM, but are being funded adequately elsewhere. It is recommended that DMSO monitor the development of these technologies. The final Fundamental HOBM Technology is Machine Vision. This is peripheral to HOBM development. It is recommended that DMSO periodically review this technology.

5.5 Summary Assessment

The following table summarizes the assessments of the HOBM-relevant technologies.

Summary Assessment Table of Technologies

Recommend that DMSO Invest in Development of these Technologies	***Recommend that DMSO Influence Development of these Technologies***	***Recommend that DMSO Monitor Development of these Technologies***	***Recommend that DMSO Periodically Review the Development of these Technologies***
Architectures, Frameworks, and Data Interchange Formats and Standards Cognitive Models Knowledge Engineering Agent Based Simulations	Fuzzy Systems Genetic Computing Robotics SWARM Intelligent Tutoring Decision Support Systems	Human Computer Interactions Expert Systems Case Based Reasoning Neural Networks Pattern Recognition Advanced Distributed Learning Systems	High Performance Computing Fundamental Computing Infrastructure Natural Language Processing Machine Vision

5.6 Cross Reference Matrix

The cross reference matrix serves as a tool for determining technology applicability into HOBM areas of interest. It indicates those areas where a given technology has the potential to satisfy, or is currently satisfying, HOBM needs. The matrix also serves as a guide to those technologies that will serve Warfighter needs most expeditiously.

For example, by reading across a row of one of the cross reference matrix, one can determine which technologies are relevant for satisfying a particular HOBM need.

Similarly, by reading down a column of this matrix, one can determine which HOBM needs can be satisfied (partly) by a particular technology. Also, by examining the number of occurrences of a given technology, one can gain insight into the breadth of importance of that technology to HOBM.

The cross reference matrix is shown below and in Appendix C.

Cross Reference Matrix – Part 1

Broad HOBM, High Level HOBM, and Broad Computing Technologies vs. HOBM Needs

	High Performance Computing	Fundamental Computing Infrastructure	Human Computer Interactions	Architectures, Frameworks, Data Interchange Formats and Standards	Knowledge Engineering	Cognitive Modeling	Expert Systems	Natural Language Processing
CGF/SAF	X	X	X	X	X	X	X	
Organizational Decision Making		X		X	X	X	X	
COAA		X		X	X	X	X	
Decision Aids		X	X	X	X	X	X	X
Mission Rehearsal		X	X	X	X	X	X	
Situational Awareness		X	X	X	X	X	X	
IO/IW		X		X	X	X	X	
Simulation Design and Evaluation		X	X	X	X			X
Simulator Effectiveness		X	X	X				X
Simulation of C4I	X	X		X	X	X	X	
Weapons Effectiveness	X	X		X				
Complex Business Systems		X		X	X	X	X	

<u>Cross Reference Matrix – Part 2</u>

Fundamental HOBM Technologies

vs. HOBM Needs

	Agent Based Sim.	SWARM	Case Based Reason-ing	Fuzzy Sys-tems	Genetic Com-puting	Machine Vision	Neural Net-works	Pattern Recog-nition	Robot -ics	Intel-ligent Tutor-ing	Decision Support	Advanced Distributed Learning
CGF/SAF	X	X	X	X			X		X		X	
Organizational Decision Making	X	X	X	X	X		X				X	
COAA	X		X	X	X		X	X			X	
Decision Aids	X		X	X	X		X	X			X	
Mission Rehearsal	X									X	X	X
Situational Awareness	X		X	X			X	X	X		X	
IO/IW	X		X	X			X	X			X	
Simulation Design and Evaluation			X	X								
Simulator Effectiveness			X					X				
Simulation of C4I	X	X	X	X			X		X			
Weapons Effectiveness	X	X		X	X							
Complex Business Systems	X	X	X	X	X		X				X	

APPENDIX A

TECHNOLOGY LIST

HOBM RELEVANT TECHNOLOGIES

Broad Computing Technologies

- Fundamental Computing Infrastructure
- High Performance Computing
- Human Computer Interactions

Broad HOBM Technologies

- Architecture, Frameworks, Data Interchange Formats, Standards
- Knowledge Engineering

High Level HOBM Technologies

- Cognitive Modeling
- Expert Systems
- Natural Language Processing

Fundamental HOBM Technologies

- Advanced Distributed Learning
- Agent Based Simulations
- Case Based Reasoning
- Decision Support Systems
- Fuzzy Systems
- Genetic Computing
- Intelligent Tutoring Systems

- Machine Vision
- Neural Networks
- Pattern Recognition
- Robotics
- SWARM

CLOSELY RELATED TECHNOLOGIES

- Adaptation and Survivability
- Adaptive Control
- Advanced Distributed Learning
- Circadian Timing System Modeling
- Cognition, Learning, and Memory
- Decision Logic Design
- Human Dynamic Modeling
- Human Operator Cognitive Modeling
- Human Performance Modeling
- Human Representation Models for SAF
- Human/Sensor Modeling
- Intelligent Agents
- Intelligent Control
- Intelligent Real-Time Problem Solving
- Intelligent Simulation Objects
- Machine Intelligence
- Machine Learning
- Multi-level Modeling
- Multi-resolution Modeling
- Organizational Modeling
- Personality Modeling
- Resolution and Fidelity
- Security Traits

- Security Traits
- Simulation Query Languages for KB Systems
- Small Team Situational Training and Mission Planning/Rehearsal
- Stress and Performance
- Tactile Information Processing
- Visual Perception

OTHER RELATED TECHNOLOGIES

- Advanced Modeling Methods
- After Action Review
- Audio Modeling
- Automatic Target Recognition
- Biometrics
- Cultural Factors Modeling
- Data Base Support for Target Recognition and Decision Making
- Display Support for Target Recognition and Decision Making
- Distributed Simulation for Heterogeneous Models
- Embedded Training
- Emerging Computing Technologies
- General Object-Oriented Simulation Environment
- Genetic Algorithms
- Haptics
- Head Mounted Displays
- Novel Computing Paradigms
- Object-Oriented Modeling/Simulation
- Real-Time Man-in-the-Loop Weapons System Simulation
- Three Dimensional, Stereoscopic, Real-Time Displays Training Models
- Treadmills

APPENDIX B

HOBM TECHNOLOGY METRICS

METRICS

Broad Computing Technologies

Broad HOBM Technologies

High Level HOBM Technologies

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
ACT-R (Adaptive Control of Thought)						
Scientific Basis of Applicability	High	Medium	Low	**Remarks**		
Physical Behavior (Physiology)		X		ACT-R is a model for higher level cognition in the individual. A perceptual motor variant has been developed.		
Cognitive Behavior (Psychology)	X					
Organizational Behavior (Managerial)			X			
Technology Maturity				**Remarks**		
Research Stage		YES				
Widely Published		YES				
Widely Reviewed		YES				
S/W Developed		YES				
S/W Tested		YES		Software has been published.		
S/W Reviewed		YES				
Applied in Simulations		YES				
Applied in Distributed Simulations		YES				
Applied in Models that have VV&A		SOMEWHAT		Part of ICARUS		
Standards Approved		NO				
Technology Characterization	Red	Yellow	Green	**Remarks**		
Availability			X	COTS software and machine		
Community Acceptance			X	Widely used by non-developers		
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving		X				
Potential to be Transitioned			X	Programs to implement in HLA-comliant orm and in federations ongoing.		
Potential to be Integrated			X			
Computing Resources Required			X			
Hardware			X	Several platforms		
Software			X	LISP needed		
Networks			X	Not required		
Direct Measures		**Current SOTA**		**Target**	**Trends**	
(# / sec)	NOT KNOWN					
(# entities)						
(Execution time)						
(...)						
Additional Technology Characterizations				**Remarks**		
Cost Drivers		Personnel time for improvements.				
Range of Applicability		Individual cognition.				
Implementation Cost (H, M, L)		Low				
COTS/GOTS Availability	Book and s/w can be purchased or s/w can be downloaded.					
Proprietary Status		Not known				
DoD Funding (RDT&E)		**1998**		**1999**	**2000**	**2001**
Exploratory (6.1)						X
Basic (6.2)						
Advanced (6.3)						X
Prototype (6.4)						
Production (6.5)						
Funding Profile		**1998 ($1000)**		**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD						X
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy		**Minimal**		**Adequate**	**Oversubscribed**	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity						
Origin	Carnegie Mellon University					
User	Army Research laboratory, Air Force Research Laboratory					

HOBM TECHNOLOGY METRICS						
Name of HOBM Technology:						
Automated Mission Planner (AMP)						
Scientific Basis of Applicability	High	Medium	Low	**Remarks**		
Physical Behavior (Physiology)			X	Company commander model for ModSAF		
Cognitive Behavior (Psychology)	X			Evaluates courses of action, so fit is as expert system.		
Organizational Behavior (Managerial)			X			
Technology Maturity				**Remarks**		
Research Stage	YES					
Widely Published	NO					
Widely Reviewed	NO					
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	NO					
Applied in Simulations	YES			Company commander model for ModSAF Upgraded in OneSAF.		
Applied in Distributed Simulations	YES					
Applied in Models that have VV&A	YES					
Standards Approved	NO					
Technology Characterization	Red	Yellow	Green	**Remarks**		
Availability		X		GOTS but need to contact developer		
Community Acceptance		X				
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving		X		Upgrades to ModSAF (OneSAF) ongoing.		
Potential to be Transitioned			X			
Potential to be Integrated			X			
Computing Resources Required		NOT KNOWN				
Hardware		NOT KNOWN				
Software		NOT KNOWN				
Networks		NOT KNOWN				
Direct Measures	**Current SOTA**			**Target**	**Trends**	
(# / sec)	NOT KNOWN					
(# entities)	NOT KNOWN					
(Execution time)	NOT KNOWN					
(...)						
Additional Technology Characterizations				**Remarks**		
Cost Drivers	Personnel time for improvements.					
Range of Applicability	Decisions of unit planners					
Implementation Cost (H, M, L)	Low					
COTS/GOTS Availability	GOTS					
Proprietary Status	Government owned?					
DoD Funding (RDT&E)	**1998**			**1999**	**2000**	**2001**
Exploratory (6.1)						
Basic (6.2)	500			180	0	Not known
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	**1998 ($1000)**			**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD	500			180	0	Not known
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	**Minimal**			**Adequate**	**Oversubscribed**	
Past				X		
Current	X					
Future				X		
Developer/User						
Developing Activity	US Army Simulation and Training Command					
Origin	Institute for Simulation and Training					
User	Army					

HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:					
Computer Controlled Hostiles					
Scientific Basis of Applicability	High	Medium	Low	**Remarks**	
Physical Behavior (Physiology)			X	Goal directed planning software for small unit operations in urban terrain. Maximizes utility.	
Cognitive Behavior (Psychology)		X			
Organizational Behavior (Managerial)		X			
Technology Maturity				**Remarks**	
Research Stage		YES			
Widely Published		NO			
Widely Reviewed		SOMEWHAT		Review exists	
S/W Developed		YES			
S/W Tested		NOT KNOWN			
S/W Reviewed		SOMEWHAT		Review exists	
Applied in Simulations		YES		For Small Unit Team Trainer	
Applied in Distributed Simulations		NOT KNOWN			
Applied in Models that have VV&A		NOT KNOWN			
Standards Approved		NO			
Technology Characterization	Red	Yellow	Green	**Remarks**	
Availability	X			Unknown utility.	
Community Acceptance		X		Limited use.	
Potential to Solve Real Problems			X		
Uniqueness of Problem Solving			X		
Potential to be Transitioned			X		
Potential to be Integrated			X	Developed for SUTT	
Computing Resources Required		X			
Hardware		X		Equipment available to government. Details uncertain.	
Software		X			
Networks		X			
Direct Measures		**Current SOTA**		**Target**	**Trends**
(# / sec)		NOT KNOWN			
(# entities)		NOT KNOWN			
(Execution time)		NOT KNOWN			
(...)					
Additional Technology Characterizations				**Remarks**	
Cost Drivers	Personnel time for impreovements.				
Range of Applicability	MOUT small unit planning.				
Implementation Cost (H, M, L)		Low			
COTS/GOTS Availability	Unclear how widely this can be used.				
Proprietary Status	Government owned				
DoD Funding (RDT&E)		**1998**		**1999**	**2000**	**2001**
Exploratory (6.1)		NOT KNOWN				
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile		**1998 ($1000)**		**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD		NOT KNOWN				
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy		**Minimal**		**Adequate**	**Oversubscribed**	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity	NOT KNOWN					
Origin	Institute for Simulation and Training University of Central Florida					
User	US Marine Corps Small Unit Team Trainer					

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
COGNET (Cognition as Network of Tasks) now iGen						
Scientific Basis of Applicability	High	Medium	Low	**Remarks**		
Physical Behavior (Physiology)		X		Some perceptual motor aspects as well as team training have been incorporated into implemeentations of this architecture.		
Cognitive Behavior (Psychology)	X					
Organizational Behavior (Managerial)		X				
Technology Maturity				**Remarks**		
Research Stage	YES					
Widely Published	YES			Publications mostly by developers.		
Widely Reviewed	YES					
S/W Developed	YES					
S/W Tested	YES			iGen most current and COTS		
S/W Reviewed	YES					
Applied in Simulations	YES					
Applied in Distributed Simulations	YES			As iGen, part of ICARUS		
Applied in Models that have VV&A	SOMEWHAT					
Standards Approved	NO					
Technology Characterization	Red	Yellow	Green	**Remarks**		
Availability			X	COTS		
Community Acceptance			X	Used for several projects		
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving			X	Only agent based architecture		
Potential to be Transitioned			X			
Potential to be Integrated			X	Has been used for embedded training and CGF.		
Computing Resources Required			X			
Hardware			X	COTS		
Software			X			
Networks			X			
Direct Measures	**Current SOTA**			**Target**	**Trends**	
(# / sec)	NOT KNOWN					
(# entities)	NOT KNOWN					
(Execution time)	NOT KNOWN					
(...)						
Additional Technology Characterizations				**Remarks**		
Cost Drivers	Personnel time for improvements.					
Range of Applicability	Individual and team behavior.					
Implementation Cost (H, M, L)	Low					
COTS/GOTS Availability	COTS					
Proprietary Status	Proprietary					
DoD Funding (RDT&E)	**1998**			**1999**	**2000**	**2001**
Exploratory (6.1)						
Basic (6.2)	Some DoD funding, details indeteminate.					NAVAIR funding.
Advanced (6.3)						X
Prototype (6.4)						
Production (6.5)						
Funding Profile	**1998 ($1000)**			**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD	X			X	X	X
Government (Non-DoD)						
Academia						
Commercial	X			X	X	X
Funding Adequacy	**Minimal**			**Adequate**	**Oversubscribed**	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity	CHI Systems, Inc.			Has been funded by NAVAIR and AFRL.		
Origin	CHI Systems, Inc.					
User	Services, Commercial					

HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:					
Computing Infrastructure					
Scientific Basis of Applicability	High	Medium	Low	**Remarks**	
Physical Behavior (Physiology)	X			HOB models mostly run on desktop environment.	
Cognitive Behavior (Psychology)	X				
Organizational Behavior (Managerial)	X				

Technology Maturity		**Remarks**
Research Stage	YES	Technology mature. Several standards exist with some interoperability issues.
Widely Published	YES	
Widely Reviewed	YES	
S/W Developed	YES	
S/W Tested	YES	
S/W Reviewed	YES	
Applied in Simulations	YES	
Applied in Distributed Simulations	YES	
Applied in Models that have VV&A	YES	
Standards Approved	YES	

Technology Characterization	Red	Yellow	Green	**Remarks**
Availability			X	COTS
Community Acceptance			X	Widely accepted
Potential to Solve Real Problems			X	Used routinely
Uniqueness of Problem Solving		X		Primary advantage is convenience
Potential to be Transitioned			X	Easily accomplished due to large user base and availability of ruggedized units.
Potential to be Integrated			X	
Computing Resources Required			X	
Hardware			X	Cheap and getting cheaper
Software			X	Improvements continue
Networks			X	Not presently limiting.

Direct Measures	**Current SOTA**	**Target**	**Trends**	
MegaHertz	1000	1400	Increasing	Represents near-term developer plans
Megabytes RAM	512	NOT KNOWN	Increasing	
Mbits/second data transfer	100	NOT KNOWN	Increasing	
Gigabytes Disk	80(2 drives)	NOT KNOWN	Increasing	

Additional Technology Characterizations		**Remarks**
Cost Drivers	Networking	Installation of broadband networks will drive costs. Networking does not presently limit HOBM, installation driven by other factors.
Range of Applicability	Entire Domain	
Implementation Cost (H, M, L)	Low	
COTS/GOTS Availability	Available	
Proprietary Status	Proprietary	

DoD Funding (RDT&E)	**1998**	**1999**	**2000**	**2001**
Exploratory (6.1)				
Basic (6.2)				
Advanced (6.3)				
Prototype (6.4)				
Production (6.5)				

Funding Profile	**1998 ($1000)**	**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD				
Government (Non-DoD)				
Academia				
Commercial	Primary funding	Primary funding	Primary funding	Primary funding

Funding Adequacy	**Minimal**	**Adequate**	**Oversubscribed**
Past		X	
Current		X	
Future		X	

Developer/User	
Developing Activity	Commercial
Origin	Commercial
User	Ubiquitous

	HOBM TECHNOLOGY METRICS				
Name of HOBM Technology:					
Distributed Cognition(D-COG)					
Scientific Basis of Applicability	High / Medium / Low	**Remarks**			
Physical Behavior (Physiology)	Medium: X	Agent based cognitive model, some perceputal motor modeling. Team behavior not reported.			
Cognitive Behavior (Psychology)	High: X				
Organizational Behavior (Managerial)	Low: X				
Technology Maturity		**Remarks**			
Research Stage	YES				
Widely Published	SOMEWHAT	Publications exist			
Widely Reviewed	SOMEWHAT				
S/W Developed	YES				
S/W Tested	YES				
S/W Reviewed	YES	AMBR program			
Applied in Simulations	YES	AMBR program			
Applied in Distributed Simulations	YES				
Applied in Models that have VV&A	SOMEWHAT	Part of ICARUS			
Standards Approved	NO				
Technology Characterization	Red / Yellow / Green	**Remarks**			
Availability	Red: X	Contact developers for software. Software still at V1.0. Recent review places at research stage.			
Community Acceptance	Yellow: X				
Potential to Solve Real Problems	Green: X				
Uniqueness of Problem Solving	Yellow: X	Demonstrated utility			
Potential to be Transitioned	Green: X				
Potential to be Integrated	Green: X	ICARUS federation and AMBR program.			
Computing Resources Required	Green: X				
Hardware	Green: X	COTS hardware			
Software	Green: X	COTS			
Networks	Green: X	COTS			
Direct Measures	**Current SOTA**	**Target**	**Trends**		
(# / sec)	NOT KNOWN				
(# entities)	NOT KNOWN				
(Execution time)	NOT KNOWN				
(...)					
Additional Technology Characterizations		**Remarks**			
Cost Drivers	Personnel time for impreovements.				
Range of Applicability	Individuat behavior.				
Implementation Cost (H, M, L)	Low				
COTS/GOTS Availability	GOTS when developed.				
Proprietary Status	Government owned.				
DoD Funding (RDT&E)	**1998**	**1999**	**2000**	**2001**	
Exploratory (6.1)	NOT KNOWN				
Basic (6.2)					
Advanced (6.3)	X	X	X	X	
Prototype (6.4)					
Production (6.5)					
Funding Profile	**1998 ($1000)**	**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**	
DoD	X	X	X	X	
Government (Non-DoD)					
Academia					
Commercial					
Funding Adequacy	**Minimal**	**Adequate**	**Oversubscribed**		
Past		X			
Current		X			
Future		X			
Developer/User					
Developing Activity	Air Force Office of Scientific Research? DMSO paying to federate.				
Origin	Air Force Research Laboratory				
User	AFRL				

	HOBM TECHNOLOGY METRICS						
Name of HOBM Technology:							
Executive-Process Interactive Control (EPIC)							
Scientific Basis of Applicability	High	Medium	Low	Remarks			
Physical Behavior (Physiology)		X		Information processing architecture for modeling perceptual, motor and cognitive aspects of human performance. Intended for man-machine interface.			
Cognitive Behavior (Psychology)	X						
Organizational Behavior (Managerial)			X				
Technology Maturity				Remarks			
Research Stage		YES					
Widely Published		YES		Publcations by developers.			
Widely Reviewed		YES					
S/W Developed		YES					
S/W Tested		YES					
S/W Reviewed		YES					
Applied in Simulations		After integration into SOAR		AMBR project and ICARUS federation.			
Applied in Distributed Simulations		After integration into SOAR					
Applied in Models that have VV&A		After integration into SOAR					
Standards Approved		NO					
Technology Characterization	Red	Yellow	Green	Remarks			
Availability			X	Downloadable from web. Contact developer before use.			
Community Acceptance		X		Integrated into SOAR and used in AMBR.			
Potential to Solve Real Problems		X					
Uniqueness of Problem Solving		X					
Potential to be Transitioned			X				
Potential to be Integrated			X				
Computing Resources Required			X				
Hardware			X	COTS hardware and software. No network required.			
Software			X				
Networks			X				
Direct Measures		Current SOTA		Target	Trends		
(# / sec)		NOT KNOWN					
(# entities)		NOT KNOWN					
(Execution time)		NOT KNOWN					
(...)							
Additional Technology Characterizations				Remarks			
Cost Drivers		Personnel time for improvements.					
Range of Applicability		Information processing architecture for human performance.					
Implementation Cost (H, M, L)		Low					
COTS/GOTS Availability		Distributed over Internet.					
Proprietary Status		Distributed over Internet.					
DoD Funding (RDT&E)		1998		1999	2000	2001	
Exploratory (6.1)		NOT KNOWN					
Basic (6.2)							
Advanced (6.3)							
Prototype (6.4)							
Production (6.5)							
Funding Profile		1998 ($1000)		1999 ($1000)	2000 ($1000)	2001 ($1000)	
DoD					X		
Government (Non-DoD)							
Academia							
Commercial							
Funding Adequacy		Minimal		Adequate	Oversubscribed		
Past				X			
Current				X			
Future				X			
Developer/User							
Developing Activity		Air Force Research Laboratory					
Origin		University of Michigan					
User		Air Force / DMSO					

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
Expert Systems						
Scientific Basis of Applicability	High	Medium	Low	**Remarks**		
Physical Behavior (Physiology)			X	Expert systems are rule based attempts to replicate human behavior. Potentially useful for organizational behavior.		
Cognitive Behavior (Psychology)	X					
Organizational Behavior (Managerial)	X					
Technology Maturity				**Remarks**		
Research Stage	YES			Mature technology. New system must be developed for each application. COTS expert system creation packeage exist.		
Widely Published	YES					
Widely Reviewed	YES					
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	YES					
Applied in Simulations	YES					
Applied in Distributed Simulations	YES					
Applied in Models that have VV&A	YES					
Standards Approved	NOT KNOWN					
Technology Characterization	Red	Yellow	Green	**Remarks**		
Availability			X	Use and applicability widely demonstrated.		
Community Acceptance			X			
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving			X			
Potential to be Transitioned			X			
Potential to be Integrated			X	Have been used in military simulations.		
Computing Resources Required			X			
Hardware			X			
Software			X	Systems have been developed for COTS equipment/		
Networks			X			
Direct Measures	**Current SOTA**			**Target**	**Trends**	
(# / sec)	NOT KNOWN					
(# entities)	NOT KNOWN					
(Execution time)	NOT KNOWN					
(...)						
Additional Technology Characterizations				**Remarks**		
Cost Drivers	Personnel time for knowledge engineering.					
Range of Applicability	Duplication of task decisions by humans.					
Implementation Cost (H, M, L)	Medium			Systems are one-off at present. Extensive knowledge engineering required.		
COTS/GOTS Availability	COTS/GOTS					
Proprietary Status	Depends on tool and system.					
DoD Funding (RDT&E)	**1998**			**1999**	**2000**	**2001**
Exploratory (6.1)	NOT KNOWN					
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	**1998 ($1000)**			**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD	x			x	x	x
Government (Non-DoD)	x			x	x	x
Academia						
Commercial	x			x	x	x
Funding Adequacy	**Minimal**			**Adequate**	**Oversubscribed**	
Past				x		
Current				x		
Future				x		
Developer/User						
Developing Activity	Various					
Origin	Various					
User	Numerous					

	HOBM TECHNOLOGY METRICS				
Name of HOBM Technology:					
High Performance Computing					
Scientific Basis of Applicability	High	Medium	Low	**Remarks**	
Physical Behavior (Physiology)			X	Not widely used for HOBM.	
Cognitive Behavior (Psychology)			X		
Organizational Behavior (Managerial)			X		
Technology Maturity				**Remarks**	
Research Stage	YES			High performance computing is an accepted but rapidly growing technology that has not been widely used for HOBM.	
Widely Published	YES				
Widely Reviewed	YES				
S/W Developed	YES				
S/W Tested	YES				
S/W Reviewed	YES				
Applied in Simulations	YES				
Applied in Distributed Simulations	YES				
Applied in Models that have VV&A	YES				
Standards Approved	YES				
Technology Characterization	Red	Yellow	Green	**Remarks**	
Availability		X		Available at limited number of sites.	
Community Acceptance	X			HOBM use just beginning.	
Potential to Solve Real Problems		X		Too early to predict	
Uniqueness of Problem Solving		X		Too early to predict	
Potential to be Transitioned	X			Expensive specialized facilities available at a limited number of sites.	
Potential to be Integrated	X				
Computing Resources Required		X			
Hardware			X	Trend is toward mnny COTS processors.	
Software		X		Specialized software required	
Networks		X		Networking key to current approach.	
Direct Measures	**Current SOTA**			**Target**	**Trends**
Gigaflops	4938			100000	Increasing
Gigabytes of RAM	512			100000	Increasing
Additional Technology Characterizations				**Remarks**	
Cost Drivers	Software, Networking Technology				
Range of Applicability	NOT KNOWN				
Implementation Cost (H, M, L)	High				
COTS/GOTS Availability	Available COTS/GOTS				
Proprietary Status	Proprietary (except for clusters.)				

DoD Funding (RDT&E)	**1998**	**1999**	**2000**	**2001**
Exploratory (6.1)				
Basic (6.2)				
Advanced (6.3)	139023	151613	164262	164027
Prototype (6.4)				
Production (6.5)				
Funding Profile	**1998 ($1000)**	**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD	139023	151619	164262	164027
Government (Non-DoD)				
Academia				
Commercial				
Funding Adequacy	**Minimal**	**Adequate**	**Oversubscribed**	
Past		Little HOBM Interest		
Current		Little HOBM Interest		
Future		Too Early to Predict		
Developer/User				
Developing Activity	DOE ASCI, DARPA, NSA, DoD HPC Moderniazation Office			
Origin	Cray, IBM, Sun, Silicon Graphics, Compaq			
User	HOBM is at Aberdeen Proving Ground, SPAWAR Systems Center (C4i), others			

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
IMPRINT						
Scientific Basis of Applicability	High	Medium	Low	**Remarks**		
Physical Behavior (Physiology)			X			
Cognitive Behavior (Psychology)	X			Adapted for modeling individual and crew interactions with systems.		
Organizational Behavior (Managerial)		X				
Technology Maturity				**Remarks**		
Research Stage	YES					
Widely Published	SOMEWHAT			Presentations and publications exist. Has been used by non-developers. No evidence of large number of publications. Based on MicroSaint.		
Widely Reviewed	SOMEWHAT					
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	SOMEWHAT					
Applied in Simulations	YES					
Applied in Distributed Simulations	YES			HLA compliant		
Applied in Models that have VV&A	YES					
Standards Approved	NO					
Technology Characterization	Red	Yellow	Green	**Remarks**		
Availability		X		GOTS but need to contact developer.		
Community Acceptance			X	Used for several Army/Air Force needs.		
Potential to Solve Real Problems			X	Used in CART and Air Warrior		
Uniqueness of Problem Solving			X	Adapted to particular niche.		
Potential to be Transitioned			X			
Potential to be Integrated			X	HLA integration done. USed by several programs.		
Computing Resources Required			X			
Hardware			X	COTS Windows hardware.		
Software			X			
Networks			X	Not required		
Direct Measures	**Current SOTA**			**Target**	**Trends**	
(# / sec)	NOT KNOWN					
(# entities)						
(Execution time)						
(...)						
Additional Technology Characterizations				**Remarks**		
Cost Drivers	Free. For improvements, personnel time to develop.					
Range of Applicability	Human-system integration problems.					
Implementation Cost (H, M, L)	Low					
COTS/GOTS Availability	GOTS request form ARL					
Proprietary Status	Government owned. One commercial component.					
DoD Funding (RDT&E)	**1998**			**1999**	**2000**	**2001**
Exploratory (6.1)						
Basic (6.2)	3987			3997	5643	5942
Advanced (6.3)	Items other than IMPRINT included in program element					
Prototype (6.4)						
Production (6.5)						
Funding Profile	**1998 ($1000)**			**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD	3987			3997	5643	6942
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	**Minimal**			**Adequate**	**Oversubscribed**	
Past				NOT KNOWN		
Current				NOT KNOWN		
Future				NOT KNOWN		
Developer/User						
Developing Activity	Army Materiel Command, Air Force Office of Scientific Research					
Origin	Army Research Laboratory, Air Force Research Laboratory (as CART)					
User	Army, other services, other government, industry.					

	HOBM TECHNOLOGY METRICS	
Name of HOBM Technology:		
JWARS Commander Behavior Model		

Scientific Basis of Applicability	High	Medium	Low	Remarks
Physical Behavior (Physiology)			X	
Cognitive Behavior (Psychology)	X			
Organizational Behavior (Managerial)			X	

Technology Maturity		Remarks
Research Stage	YES	
Widely Published	NO	
Widely Reviewed	NO	
S/W Developed	YES	
S/W Tested	YES	
S/W Reviewed	NO	
Applied in Simulations	YES	Upon implementation in JWARS
Applied in Distributed Simulations	YES	
Applied in Models that have VV&A	YES	
Standards Approved	NO	

Technology Characterization	Red	Yellow	Green	Remarks
Availability	X			Must be JWARS user.
Community Acceptance			X	
Potential to Solve Real Problems			X	In operational Joint system.
Uniqueness of Problem Solving			X	One of few CBMs.
Potential to be Transitioned			X	
Potential to be Integrated			X	
Computing Resources Required		X		
Hardware		X		COTS hardware, software, and networking, NT workstations and UNIX servers.
Software		X		
Networks		X		

Direct Measures	Current SOTA	Target	Trends	
(# / sec)	NOT KNOWN			
(# entities)				
(Execution time)				
(...)				

Additional Technology Characterizations		Remarks
Cost Drivers	Personnel time for improvements.	
Range of Applicability	JWARS	
Implementation Cost (H, M, L)	Low	
COTS/GOTS Availability	GOTS	
Proprietary Status	Government owned	

DoD Funding (RDT&E)	1998	1999	2000	2001
Exploratory (6.1)				
Basic (6.2)	DMSO funded			
Advanced (6.3)				
Prototype (6.4)				
Production (6.5)				

Funding Profile	1998 ($1000)	1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD				
Government (Non-DoD)				
Academia				
Commercial				

Funding Adequacy	Minimal	Adequate	Oversubscribed	
Past		No data		
Current				
Future				

Developer/User				
Developing Activity	DMSO			
Origin	CACI, Inc.			
User	JWARS Program Office, analysts, all services, PA&E			

HOBM TECHNOLOGY METRICS						
Name of HOBM Technology:						
Marine Computer Generated Force						
Scientific Basis of Applicability	**High**	**Medium**	**Low**	**Remarks**		
Physical Behavior (Physiology)			X	Rule-based system for generation of infantry force route plans.		
Cognitive Behavior (Psychology)		X				
Organizational Behavior (Managerial)		X				
Technology Maturity				**Remarks**		
Research Stage		YES				
Widely Published		NO				
Widely Reviewed		SOMEWHAT		Review exists.		
S/W Developed		YES				
S/W Tested		YES				
S/W Reviewed		SOMEWHAT		Review exists.		
Applied in Simulations		YES				
Applied in Distributed Simulations		YES				
Applied in Models that have VV&A		YES				
Standards Approved		NO				
Technology Characterization	**Red**	**Yellow**	**Green**	**Remarks**		
Availability	X			Uncertain.		
Community Acceptance		X				
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving		X				
Potential to be Transitioned			X			
Potential to be Integrated			X	Utility for MODSAF demonstrated.		
Computing Resources Required		X				
Hardware		X				
Software		X				
Networks		X		Details not known.		
Direct Measures		**Current SOTA**		**Target**	**Trends**	
(# / sec)		NOT KNOWN				
(# entities)		NOT KNOWN				
(Execution time)		NOT KNOWN				
(...)						
Additional Technology Characterizations				**Remarks**		
Cost Drivers		Personnel time for improvements.				
Range of Applicability		Route planning				
Implementation Cost (H, M, L)		Low				
COTS/GOTS Availability		Uncertain				
Proprietary Status		Government owned.				
DoD Funding (RDT&E)		**1998**		**1999**	**2000**	**2001**
Exploratory (6.1)		NOT KNOWN				
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile		**1998 ($1000)**		**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD		NOT KNOWN				
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy		**Minimal**		**Adequate**	**Oversubscribed**	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity		Defense Advanced Research Projects Agency				
Origin		Hughes				
User		ModSAF				

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
Micro Saint						
Scientific Basis of Applicability	High	Medium	Low	**Remarks**		
Physical Behavior (Physiology)		X		Tool used for modeling individual and crew behavior. MS-HOS extension for man-machine interface...		
Cognitive Behavior (Psychology)	X					
Organizational Behavior (Managerial)		X				
Technology Maturity				**Remarks**		
Research Stage		YES				
Widely Published		SOMEWHAT		Publications exist.		
Widely Reviewed		SOMEWHAT				
S/W Developed		YES				
S/W Tested		YES				
S/W Reviewed		YES				
Applied in Simulations		YES				
Applied in Distributed Simulations		YES		Part of HLA compliant IMPRINT		
Applied in Models that have VV&A		YES		Used in several VV&Aed simulations.		
Standards Approved		NO				
Technology Characterization	Red	Yellow	Green	**Remarks**		
Availability			X	COTS		
Community Acceptance			X	Implemented in other M&S		
Potential to Solve Real Problems			X	Used on several programs.		
Uniqueness of Problem Solving		X				
Potential to be Transitioned			X	COTS product on several machines has been integrated into other M&S		
Potential to be Integrated			X			
Computing Resources Required			X			
Hardware			X	Windows		
Software			X	No special software		
Networks			X	Not required. Imported into HLA model.		
Direct Measures		**Current SOTA**		**Target**	**Trends**	
(# / sec)		NOT KNOWN				
(# entities)		NOT KNOWN				
(Execution time)		NOT KNOWN				
(...)						
Additional Technology Characterizations				**Remarks**		
Cost Drivers		Personnel time for improvements.				
Range of Applicability		Individual and crew behavior treated with network model.				
Implementation Cost (H, M, L)		Low?				
COTS/GOTS Availability		COTS				
Proprietary Status		Proprietary				
DoD Funding (RDT&E)		**1998**		**1999**	**2000**	**2001**
Exploratory (6.1)						
Basic (6.2)						
Advanced (6.3)	Micro Saint is commercial, but is used in DoD efforts.					
Prototype (6.4)						
Production (6.5)						
Funding Profile		**1998 ($1000)**		**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD						
Government (Non-DoD)						
Academia						
Commercial		X		X	X	X
Funding Adequacy		**Minimal**		**Adequate**	**Oversubscribed**	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity		Micro Analysis and Design				
Origin		See above.				
User	Commercial, all services.					

	HOBM TECHNOLOGY METRICS						
Name of HOBM Technology:							
MIDAS (Man -Machine Integration Design and Analysis System)							
Scientific Basis of Applicability	High	Medium	Low	Remarks			
Physical Behavior (Physiology)		X		Man machine interface modeling. Some crew and commander behavior available.			
Cognitive Behavior (Psychology)	X						
Organizational Behavior (Managerial)		X					
Technology Maturity				Remarks			
Research Stage		YES					
Widely Published		SOMEWHAT		Publications exist,			
Widely Reviewed		SOMEWHAT					
S/W Developed		YES					
S/W Tested		YES					
S/W Reviewed		YES					
Applied in Simulations		YES					
Applied in Distributed Simulations		NOT KNOWN					
Applied in Models that have VV&A		YES					
Standards Approved		YES					
Technology Characterization	Red	Yellow	Green	Remarks			
Availability		X		GOTS, must contactt developer.			
Community Acceptance			X	Used for several different problems.			
Potential to Solve Real Problems			X				
Uniqueness of Problem Solving		X		Similar to HOS V and MS HOS.			
Potential to be Transitioned		X		Used for several different problems. Engineering design tool No HLA effort.			
Potential to be Integrated	X						
Computing Resources Required			X				
Hardware			X	COTS hardware			
Software			X	GOTS model.			
Networks			X	No network required.			
Direct Measures		Current SOTA		Target	Trends		
(# / sec)		NOT KNOWN					
(# entities)		NOT KNOWN					
(Execution time)		NOT KNOWN					
(...)							
Additional Technology Characterizations				Remarks			
Cost Drivers		Personnel time for improvements.					
Range of Applicability		Man machine interface problems.					
Implementation Cost (H, M, L)		Low					
COTS/GOTS Availability		GOTS, COTS Hardware					
Proprietary Status		NASA/Army oroject		Has been used commercially.			
DoD Funding (RDT&E)		1998		1999	2000	2001	
Exploratory (6.1)							
Basic (6.2)		NOT KNOWN					
Advanced (6.3)							
Prototype (6.4)							
Production (6.5)							
Funding Profile		1998 ($1000)		1999 ($1000)	2000 ($1000)	2001 ($1000)	
DoD		X					
Government (Non-DoD)		X					
Academia							
Commercial		X					
Funding Adequacy		Minimal		Adequate	Oversubscribed		
Past				X			
Current				X			
Future				X			
Developer/User							
Developing Activity		NASA/Army Aviation					
Origin		NASA Anes Research Center					
User		Gocwenmwnr and commercial.					

HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:					
Natural Language Processing (Computational Linguistics)					
Scientific Basis of Applicability	High	Medium	Low	**Remarks**	
Physical Behavior (Physiology)			X	This is a discipline at the boundaries of linguistics and computer science concerned with the analysis of language.	
Cognitive Behavior (Psychology)			X		
Organizational Behavior (Managerial)			X		
Technology Maturity				**Remarks**	
Research Stage	YES				
Widely Published	YES				
Widely Reviewed	YES				
S/W Developed	YES				
S/W Tested	SOMEWHAT			No formal VVA.	
S/W Reviewed	YES				
Applied in Simulations	NO				
Applied in Distributed Simulations	NO				
Applied in Models that have VV&A	NO				
Standards Approved	NO				
Technology Characterization	Red	Yellow	Green	**Remarks**	
Availability		X		Contact developers for software. Registry exists. COTS product no longer exists.	
Community Acceptance		X			
Potential to Solve Real Problems	X			Little relevance to DoD M&S.	
Uniqueness of Problem Solving		X			
Potential to be Transitioned	X				
Potential to be Integrated	X				
Computing Resources Required			X		
Hardware			X	Entensive computational resouces not necessary. Mainly an academic endeavor.	
Software			X		
Networks			X		

Direct Measures	**Current SOTA**	**Target**	**Trends**	
(# / sec)	NOT KNOWN			
(# entities)	NOT KNOWN			
(Execution time)	NOT KNOWN			
(...)				
Additional Technology Characterizations		**Remarks**		
Cost Drivers	Personnel time.			
Range of Applicability	Study of the structure of language.			
Implementation Cost (H, M, L)	Low			
COTS/GOTS Availability	Contact developers.			
Proprietary Status	Product dependent.			
DoD Funding (RDT&E)	**1998**	**1999**	**2000**	**2001**
Exploratory (6.1)	Army SBIR funded in 1997. Company may be out of business.			
Basic (6.2)	May possibly be funded for intelligence purposes.			
Advanced (6.3)				
Prototype (6.4)				
Production (6.5)				
Funding Profile	**1998 ($1000)**	**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD				
Government (Non-DoD)	X	X	X	X
Academia	X	X	X	X
Commercial	X	X	X	X
Funding Adequacy	**Minimal**	**Adequate**	**Oversubscribed**	
Past		X		
Current		X		
Future		X		
Developer/User				
Developing Activity	NSF, European Union, Xerox, Microsoft			
Origin	Stanford, SRI, UMass, Microsoft, Xerox,Brown, U. Delaware, Europe, Japan,AT&T			
User	None identified.			

HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:					
Naval Simulation System (NSS) Behavior Model					
Scientific Basis of Applicability	High	Medium	Low	**Remarks**	
Physical Behavior (Physiology)			X	Rule based decision model in place. C2 capability. Expert system.	
Cognitive Behavior (Psychology)	X				
Organizational Behavior (Managerial)		X			
Technology Maturity				**Remarks**	
Research Stage	YES				
Widely Published	YES				
Widely Reviewed	YES				
S/W Developed	YES				
S/W Tested	YES				
S/W Reviewed	YES				
Applied in Simulations	YES				
Applied in Distributed Simulations	YES			Has been used in distributed form.	
Applied in Models that have VV&A	YES				
Standards Approved	NO			Operational simulation.	
Technology Characterization	Red	Yellow	Green	**Remarks**	
Availability	X			Must be approved user.	
Community Acceptance			X		
Potential to Solve Real Problems			X		
Uniqueness of Problem Solving			X		
Potential to be Transitioned			X		
Potential to be Integrated			X		
Computing Resources Required		X			
Hardware		X		Hardware, software and networks owned by government, not COTS. Supercomputer desirable for some purposes for full NSS.	
Software		X			
Networks		X			

Direct Measures	**Current SOTA**	**Target**	**Trends**	
(# / sec)	NOT KNOWN			
(# entities)	NOT KNOWN			
(Execution time)	NOT KNOWN			
(...)				
Additional Technology Characterizations		**Remarks**		
Cost Drivers	Personnel time for improvements and computer technology.			
Range of Applicability	Command and control			
Implementation Cost (H, M, L)	Medium			
COTS/GOTS Availability	GOTS			
Proprietary Status	Government owned.			
DoD Funding (RDT&E)	**1998**	**1999**	**2000**	**2001**
Exploratory (6.1)				
Basic (6.2)	NOT KNOWN			
Advanced (6.3)				
Prototype (6.4)				
Production (6.5)				
Funding Profile	**1998 ($1000)**	**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD	X	X	X	X
Government (Non-DoD)				
Academia				
Commercial				
Funding Adequacy	**Minimal**	**Adequate**	**Oversubscribed**	
Past		X		
Current		X		
Future		X		
Developer/User				
Developing Activity	Chief of Naval Operations N6 Directorate			
Origin	SPAWAR PMW 131			
User	Fleet Battle Experiments, Operating Forces.			

HOBM TECHNOLOGY METRICS						
Name of HOBM Technology:						
OMAR(Operator Model Architecture)						
Scientific Basis of Applicability	High	Medium	Low	**Remarks**		
Physical Behavior (Physiology)		X		Perceptual motor capability available		
Cognitive Behavior (Psychology)	X			Architecture for operator task modeling in complex systems.		
Organizational Behavior (Managerial)		X		Team capability.		
Technology Maturity				**Remarks**		
Research Stage		YES				
Widely Published		SOMEWHAT		Publications exist.		
Widely Reviewed		SOMEWHAT				
S/W Developed		YES				
S/W Tested		YES				
S/W Reviewed		YES				
Applied in Simulations		YES		A model architectur rather than a cognitive model.		
Applied in Distributed Simulations		YES		Distributed version available.(D-OMAR)		
Applied in Models that have VV&A		YES		ICARUS Federation		
Standards Approved		NO				
Technology Characterization	Red	Yellow	Green	**Remarks**		
Availability		X		GOTS, may not be in use		
Community Acceptance		X		Does not appear to be widely used.		
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving		X				
Potential to be Transitioned		X				
Potential to be Integrated		X				
Computing Resources Required			X			
Hardware			X	COTS, not Windows (port underway as of information)		
Software			X	Uses JAVA, C++, Common LISP		
Networks			X	Network not required.		
Direct Measures		**Current SOTA**		**Target**	**Trends**	
(# / sec)						
(# entities)		NOT KNOWN				
(Execution time)						
(...)						
Additional Technology Characterizations				**Remarks**		
Cost Drivers		Personnel time for improvements.				
Range of Applicability		Operator procedures in complex systems				
Implementation Cost (H, M, L)		Low				
COTS/GOTS Availability		GOTS				
Proprietary Status		Government owned.				
DoD Funding (RDT&E)		**1998**		**1999**	**2000**	**2001**
Exploratory (6.1)						
Basic (6.2)		X		NOT KNOWN	NOT KNOWN	NOT KNOWN
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile		**1998 ($1000)**		**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD		X				
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy		**Minimal**		**Adequate**	**Oversubscribed**	
Past				X		
Current				NOT KNOWN		
Future				NOT KNOWN		
Developer/User						
Developing Activity		Air Force Research Laboratory- AF Office of Scientific Research				
Origin		BBN, Inc.				
User		Air Force				

	HOBM TECHNOLOGY METRICS	
Name of HOBM Technology:		

SAMPLE(Situational Awareness Model for Pilot-in-the-Loop Evaluation)

Scientific Basis of Applicability	High	Medium	Low	Remarks
Physical Behavior (Physiology)		X		
Cognitive Behavior (Psychology)	X			Pilot situational awareness and response model.
Organizational Behavior (Managerial)			X	

Technology Maturity		Remarks
Research Stage	YES	
Widely Published	NO	One publication.
Widely Reviewed	SOMEWHAT	Reviews exist
S/W Developed	YES	
S/W Tested	YES	
S/W Reviewed	YES	
Applied in Simulations	NO	SBIR effort. No evidence of Phase II/
Applied in Distributed Simulations	NO	
Applied in Models that have VV&A	NO	
Standards Approved	NO	

Technology Characterization	Red	Yellow	Green	Remarks
Availability	X			SBIR effort. No evidence of Phase II/
Community Acceptance		X		Has been reviewed.
Potential to Solve Real Problems			X	
Uniqueness of Problem Solving		X		
Potential to be Transitioned	X			
Potential to be Integrated	X			
Computing Resources Required			X	
Hardware			X	Windows hardware
Software			X	Created with Windows compatible software.
Networks			X	No network required.

Direct Measures	Current SOTA	Target	Trends	
(# / sec)	NOT KNOWN			
(# entities)	NOT KNOWN			
(Execution time)	NOT KNOWN			
(...)				

Additional Technology Characterizations		Remarks
Cost Drivers	Adaptation to problem	
Range of Applicability	Air tactics and pilot response and actions.	
Implementation Cost (H, M, L)	Medium	
COTS/GOTS Availability	Probably needs tailoring	
Proprietary Status	SBIR product	

DoD Funding (RDT&E)	1998	1999	2000	2001
Exploratory (6.1)				
Basic (6.2)	NOT KNOWN			
Advanced (6.3)				
Prototype (6.4)				
Production (6.5)				

Funding Profile	1998 ($1000)	1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD	NOT KNOWN			
Government (Non-DoD)				
Academia				
Commercial				

Funding Adequacy	Minimal	Adequate	Oversubscribed	
Past	X			
Current	NOT KNOWN			
Future	NOT KNOWN			

Developer/User	
Developing Activity	Developmental Planning Directorate, Aeronautical Systems Center WPAFB
Origin	Charles River Analytics (SBIR)
User	Air Force

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
SOAR						
Scientific Basis of Applicability	High	Medium	Low	**Remarks**		
Physical Behavior (Physiology)			X	Models exist which account for these factors.		
Cognitive Behavior (Psychology)	X			Unified Theory of Cognition		
Organizational Behavior (Managerial)		X		Some aggregate behavior. Models organizations as cooperating ind.		
Technology Maturity				**Remarks**		
Research Stage	On Going Research					
Widely Published	Yes			Hundreds of Paper. Multiple Books.		
Widely Reviewed	YES					
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	YES			Used as underlying arch. for TAS A/C in JSAF		
Applied in Distributed Simulations	YES					
Applied in Models that have VV&A	Accredited, not v&V					
Standards Approved	NO					
Technology Characterization	Red	Yellow	Green	**Remarks**		
Availability			X	Public Domain,downloadable off website		
Community Acceptance			X	Worldwide user community		
Potential to Solve Real Problems			X	Applied for fielded military exercises		
Uniqueness of Problem Solving			X	Unified Theory of Cognition		
Potential to be Transitioned			X	Mulitple transitions and fielded systems		
Potential to be Integrated			X	Integrated with JSAF,STAGE, commercial game, and other environments		
Computing Resources Required						
Hardware			X	Runs on a wide range of hardware; most platforms that support C		
Software			X	Written entirely in C		
Networks			X	Network Support through IO links		
Direct Measures	**Current SOTA**			**Target**	**Trends**	
(# / sec)	3-20 decisions per sec			20 decisions per second	Maintain decision rate, increase entity counts	
(# entities)	1-20 plus JSAF on same platform			Increasing	Lower intensity sim. would increase entity count	
(Execution time)	7,000 Decision Rules			Increasing	Tested to 100,000 in research studies	
(...)						
Additional Technology Characterizations				**Remarks**		
Cost Drivers	Model Development Time					
Range of Applicability	Individual, real-time coginitive tasks					
Implementation Cost (H, M, L)	Medium					
COTS/GOTS Availability	Public Domain (Many GOTS models Developed)					
Proprietary Status	Public Domain (Models may be US government property.					
DoD Funding (RDT&E)	**1998**			**1999**	**2000**	**2001**
Exploratory (6.1)						
Basic (6.2)	250			525	605	625
Advanced (6.3)	1,200			1,300	550	650
Prototype (6.4)	200			450	500	750
Production (6.5)						
Funding Profile	**1998 ($1000)**			**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD						
Government (Non-DoD)						
Academia	1,300			1,600	600	300
Commercial	350			725	1,150	2,100
Funding Adequacy	**Minimal**			**Adequate**	**Oversubscribed**	
Past				X		
Current				X	(in relation to potential, underfunded)	
Future	X				(in relation to potential, underfunded)	
Developer/User						
Developing Activity	Fixed Wing, rotary wing and special operations forces behaviors; planning; models of emotions					
Origin	Carnegie Mellon Unviersity (Allen Newell, John Laird, Paul Rosenbloom)					
User	World Wide community for artificial intelligence and cognitive science research and applications.					

	HOBM TECHNOLOGY METRICS			
Name of HOBM Technology:				
EPIC SOAR				

Scientific Basis of Applicability	High	Medium	Low	Remarks
Physical Behavior (Physiology)		X		EPIC SOAR is a hybrid architecture that integrates the perceptual/motor processors of EPIC with SOAR. Together, they inherit each others HOBM Technology Metrics
Cognitive Behavior (Psychology)	X			
Organizational Behavior (Managerial)		X		

Technology Maturity		Remarks
Research Stage	On Going Research	
Widely Published	Limited	3-4 Pubs and a PhD dissertation
Widely Reviewed	NO	
S/W Developed	YES	
S/W Tested	YES	
S/W Reviewed	YES	
Applied in Simulations	YES	
Applied in Distributed Simulations	YES	Currently being applied to an HLA simulation environment.
Applied in Models that have VV&A	YES	Models are compared empirical human performance data.
Standards Approved	NO	

Technology Characterization	Red	Yellow	Green	Remarks
Availability			X	Public Domain
Community Acceptance			X	
Potential to Solve Real Problems		X		Unified theory of cognition
Uniqueness of Problem Solving			X	
Potential to be Transitioned		X		Has been integrated with an OMAR simulation
Potential to be Integrated			X	andwith an HLA simulation
Computing Resources Required			X	
Hardware			X	Runs on LINUX; can be adapted to run on other systems.
Software			X	LISP (EPIC) and C (SOAR)
Networks			X	Not required

Direct Measures	Current SOTA	Target	Trends
(# / sec)	3-20 decisions per sec		
(# entities)			
(Execution time)			
(...)			

Additional Technology Characterizations		Remarks
Cost Drivers	Model Dev. Time	
Range of Applicability	Modeling in perceptual, cognitive, and motor behavior of individuals	
Implementation Cost (H, M, L)	Medium	
COTS/GOTS Availability	GOTS	
Proprietary Status	SOAR (Public), EPIC (Research), (Models may be US Government proprietary)	

DoD Funding (RDT&E)	1998	1999	2000	2001
Exploratory (6.1)				
Basic (6.2)				
Advanced (6.3)		X	X	
Prototype (6.4)				
Production (6.5)				

Funding Profile	1998 ($1000)	1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD		153	85	X
Government (Non-DoD)				
Academia				
Commercial				

Funding Adequacy	Minimal	Adequate	Oversubscribed
Past			
Current		X	(in relation to potential, underfunded)
Future	X		(in relation to potential, underfunded)

Developer/User	
Developing Activity	Orignially developed for modeling acquisition of multiple-task knowledge; recently added memory to SOAR
Origin	University of Michigan (Integration performed by Ronald S. Chong, 1997)
User	The orignial developer

METRICS

Fundamental HOBM Technologies

		HOBM TECHNOLOGY METRICS				
Name of HOBM Technology:						
AGENT BASED SIMULATIONS						
Applicability to HOBM:	High	Medium	Low	**Remarks**		
Physical Behavior		X		Agents are objects with a set of associated states. These agents are situated		
Cognitive Behavior	X			within a computational environment within which they can sense and interact.		
Organizational Behavior	X			Transitions between states are specified through probalistic behavior networks.		
Technology Maturity				**Remarks**		
Research Stage	YES					
Widely Published	YES					
Widely Reviewed	YES					
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	YES					
Applied in Simulations	YES					
Applied in Distributed Simulations	YES					
Applied in Models that have VV&A	YES					
Standards Approved	PENDING					
Technology Characterization	Red	Yellow	Green	**Remarks**		
Availability			X	Wide Variety of Operational Applications in all DoD Regimes		
Community Acceptance			X			
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving			X	DMSO should support and leverage this technology		
Potential to be Transitioned			X		at every opportunity	
Potential to be Integrated			X			
Computing Resources Required			X			
Hardware			X			
Software			X			
Networks			X			
Direct Measures	**Current SOTA**			**Target**	**Trends**	
(# / sec)	N/A					
(# entities)	N/A					
(Execution time)	N/A					
(...)	N/A					
Additional Technology Characterizations				**Remarks**		
Cost Drivers	N/A					
Range of Applicability	N/A					
Implementation Cost (H, M, L)	N/A			Applications in all three functional DoD M&S Areas		
COTS/GOTS Availability	N/A					
Proprietary Status	N/A					
DoD Funding (RDT&E)	**1998**			**1999**	**2000**	**2001**
Exploratory (6.1)						
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	**1998 ($1000)**			**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD						
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	**Minimal**			**Adequate**	**Oversubscribed**	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity	VARIOUS			ALL DOD		
Origin				ALL DOD		
User				ALL DOD		

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
Swarm						
Applicability to HOBM:	High	Medium	Low	Remarks		
Physical Behavior	X			Swarm is a multiagent simulation language for modeling collections of con-		
Cognitive Behavior		X		currently interacting agents in a dynmaic environment. It is best utilized		
Organizational Behavior	X			to explore complex systems. It was developed in 1994 by Santa Fe Institute.		
Technology Maturity				Remarks		
Research Stage	MATURE					
Widely Published	YES					
Widely Reviewed	YES					
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	YES					
Applied in Simulations	YES					
Applied in Distributed Simulations	YES					
Applied in Models that have VV&A	YES					
Standards Approved	YES					
Technology Characterization	Red	Yellow	Green	Remarks		
Availability			X	Readily available for CGF and OPFOR modeling.		
Community Acceptance			X			
Potential to Solve Real Problems			X	High potential for adaptive behavior applications.		
Uniqueness of Problem Solving			X			
Potential to be Transitioned			X			
Potential to be Integrated			X			
Computing Resources Required			X			
Hardware		X				
Software		X				
Networks			X			
Direct Measures	Current SOTA			Target	Trends	
(# / sec)	N/A					
(# entities)	N/A					
(Execution time)	N/A					
(...)	N/A					
Additional Technology Characterizations				Remarks		
Cost Drivers	N/A					
Range of Applicability	N/A					
Implementation Cost (H, M, L)	N/A					
COTS/GOTS Availability	N/A					
Proprietary Status	N/A					
DoD Funding (RDT&E)	1998			1999	2000	2001
Exploratory (6.1)						
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	1998 ($1000)			1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD						
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	Minimal			Adequate	Oversubscribed	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity	SANTA FE INST					
Origin	SANTA FE INST					
User				ALL DOD		

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
Case Based Reasoning (CBR)						
Applicability to HOBM:	High	Medium	Low	Remarks		
Physical Behavior				CBR data base consists of stored memory of cases depicting prior episodes.		
Cognitive Behavior	X			New solutions are generated not by chaining these events, but by retrieving		
Organizational Behavior				the most relevant cases from memory and adapting to fit the new situation.		
Technology Maturity				Remarks		
Research Stage	YES			Highly useful in AI Programs (raises effectiveness)		
Widely Published	YES			Extensive bibliography available (141 References)		
Widely Reviewed	YES					
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	YES					
Applied in Simulations	YES			External data base and sophisticated retrieval system required.		
Applied in Distributed Simulations	YES			(Detailed KA package is critical to success)		
Applied in Models that have VV&A				(Knowledge maintenance is required)		
Standards Approved						
Technology Characterization	Red	Yellow	Green	Remarks		
Availability			X	Readily available for CGF and OPFOR modeling.		
Community Acceptance			X			
Potential to Solve Real Problems			X	High potential for adaptive behavior applications.		
Uniqueness of Problem Solving		X				
Potential to be Transitioned			X			
Potential to be Integrated			X			
Computing Resources Required			X			
Hardware			X			
Software			X			
Networks			X			
Direct Measures	Current SOTA			Target	Trends	
(# / sec)	N/A					
(# entities)	N/A					
(Execution time)	N/A					
(...)	N/A					
Additional Technology Characterizations				Remarks		
Cost Drivers	N/A					
Range of Applicability	Wide Range					
Implementation Cost (H, M, L)	N/A					
COTS/GOTS Availability	COTS					
Proprietary Status	Some					
DoD Funding (RDT&E)	1998			1999	2000	2001
Exploratory (6.1)						
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	1998 ($1000)			1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD						
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	Minimal			Adequate	Oversubscribed	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity	Numerous					
Origin	Numerous					
User	Numerous					

		HOBM TECHNOLOGY METRICS				
Name of HOBM Technology:						
Fuzzy Systems						
Applicability to HOBM:	High	Medium	Low	Remarks		
Physical Behavior				Fuzzy Systems is an alternative to traditional approaches for set theory and		
Cognitive Behavior		X		logic which had origins in Greek philosophy. It is characterized by the ability to		
Organizational Behavior		X		solve problems with incomplete. imprecise, vague and uncertain information.		
Technology Maturity				Remarks		
Research Stage	Adnvanced R&D					
Widely Published	YES					
Widely Reviewed	YES					
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	YES					
Applied in Simulations	Limited					
Applied in Distributed Simulations	Limited					
Applied in Models that have VV&A	Unknown					
Standards Approved	Pending					
Technology Characterization	Red	Yellow	Green	Remarks		
Availability			X			
Community Acceptance			X			
Potential to Solve Real Problems			X	Excellent potential for Decision Support System implementation		
Uniqueness of Problem Solving		X				
Potential to be Transitioned		X		Significant role in Control Theory technology		
Potential to be Integrated		X				
Computing Resources Required		X				
Hardware		X				
Software		X				
Networks		X				
Direct Measures	Current SOTA			Target	Trends	
(# / sec)	N/A					
(# entities)	N/A					
(Execution time)	N/A					
(...)	N/A					
Additional Technology Characterizations				Remarks		
Cost Drivers	N/A					
Range of Applicability	Wide Range					
Implementation Costs (H,M,L)	Low					
COTS/GOTS Availability	COTS					
Proprietary Status	Possible					
DoD Funding (RDT&E)	1998			1999	2000	2001
Exploratory (6.1)						
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	1998 ($1000)			1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD						
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	Minimal			Adequate	Oversubscribed	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity						
Origin	UC Berkeley			Dr. Lotfi Zadeh		
User	DoD					

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
Genetic computing						
Applicability to HOBM:	High	Medium	Low	Remarks		
Physical Behavior				Genetic Computing achieves automatic programming by genetically breeding		
Cognitive Behavior	X			a population of computer programs using the princilples of Darwinian natural		
Organizational Behavior			X	selection and biologically inspired operations.		
Technology Maturity				Remarks		
Research Stage		Basic				
Widely Published		No				
Widely Reviewed		No				
S/W Developed		Yes				
S/W Tested		Yes				
S/W Reviewed		Yes				
Applied in Simulations		Some				
Applied in Distributed Simulations		No				
Applied in Models that have VV&A		No				
Standards Approved		No				
Technology Characterization	Red	Yellow	Green	Remarks		
Availability		X				
Community Acceptance		X				
Potential to Solve Real Problems		X				
Uniqueness of Problem Solving			X	Wide range of use in AI and Fuzzy System algorithms		
Potential to be Transitioned			X			
Potential to be Integrated			X			
Computing Resources Required			X			
Hardware		X				
Software		X				
Networks		X				
Direct Measures		Current SOTA		Target	Trends	
(# / sec)		N/A				
(# entities)		N/A				
(Execution time)		N/A				
(...)		N/A				
Additional Technology Characterizations				Remarks		
Cost Drivers		N/A				
Range of Applicability		Wide range				
Implementation Cost (H, M, L)		Low				
COTS/GOTS Availability		COTS				
Proprietary Status		Some				
DoD Funding (RDT&E)		1998		1999	2000	2001
Exploratory (6.1)						
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile		1998 ($1000)		1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD						
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy		Minimal		Adequate	Oversubscribed	
Past		**X**				
Current		**X**				
Future		**X**				
Developer/User						
Developing Activity		Numerous				
Origin						
User						

HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:					
Machine Vision					
Applicability to HOBM:	High	Medium	Low	Remarks	
Physical Behavior			X	Machine vision is the technology that uses optical devices for non-contact	
Cognitive Behavior		X		sensing in order to automatically receive and interpret an image of a real scene	
Organizational Behavior			X	in order to obtain information and/or image acquisition.	
Technology Maturity				Remarks	
Research Stage	Advanced				
Widely Published	YES				
Widely Reviewed	YES				
S/W Developed	YES				
S/W Tested	YES				
S/W Reviewed	N/A				
Applied in Simulations	Some				
Applied in Distributed Simulations	YES				
Applied in Models that have VV&A	Unknown				
Standards Approved	Unknown				
Technology Characterization	Red	Yellow	Green	Remarks	
Availability			X		
Community Acceptance			X		
Potential to Solve Real Problems			X		
Uniqueness of Problem Solving			X	Applicable to advanced robotics design	
Potential to be Transitioned			X		
Potential to be Integrated			X	Significant role in control theory (autonomous operations)	
Computing Resources Required			X		
Hardware			X		
Software			X		
Networks			X		

Direct Measures	**Current SOTA**	**Target**	**Trends**	
(# / sec)	N/A			
(# entities)	N/A			
(Execution time)	N/A			
(...)	N/A			
Additional Technology Characterizations		**Remarks**		
Cost Drivers	Technical Development			
Range of Applicability	Wide			
Implementation Cost (H, M, L)	High			
COTS/GOTS Availability	Some			
Proprietary Status	Some			
DoD Funding (RDT&E)	**1998**	**1999**	**2000**	**2001**
Exploratory (6.1)				
Basic (6.2)				
Advanced (6.3)				
Prototype (6.4)				
Production (6.5)				
Funding Profile	**1998 ($1000)**	**1999 ($1000)**	**2000 ($1000)**	**2001 ($1000)**
DoD				
Government (Non-DoD)				
Academia				
Commercial				
Funding Adequacy	**Minimal**	**Adequate**	**Oversubscribed**	
Past		**X**		
Current		**X**		
Future		**X**		
Developer/User				
Developing Activity	Various			
Origin				
User		ALL DOD		

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
Neural Networks						
Applicability to HOBM:	High	Medium	Low	Remarks		
Physical Behavior			X	Neural Networks are based on the parallel architecture of animal brains. They		
Cognitive Behavior	X			can be very useful tools where one is unable to formulate an algorithmic		
Organizational Behavior			X	solution, or to pick out structure from existing data.		
Technology Maturity				Remarks		
Research Stage	In Production					
Widely Published	YES					
Widely Reviewed	YES					
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	YES					
Applied in Simulations	YES					
Applied in Distributed Simulations	YES					
Applied in Models that have VV&A	YES					
Standards Approved	YES					
Technology Characterization	Red	Yellow	Green	Remarks		
Availability			X			
Community Acceptance			X			
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving			X	Critical to AI development		
Potential to be Transitioned			X			
Potential to be Integrated			X	Parallel Computations Required		
Computing Resources Required			X			
Hardware		X				
Software		X				
Networks		X				
Direct Measures	Current SOTA			Target	Trends	
(# / sec)	N/A					
(# entities)	N/A					
(Execution time)	N/A					
(...)	N/A					
Additional Technology Characterizations				Remarks		
Cost Drivers	Development					
Range of Applicability	Wide			Wide use in AI programs (HOBM Potential)		
Implementation Cost (H, M, L)	High					
COTS/GOTS Availability	COTS					
Proprietary Status	Some					
DoD Funding (RDT&E)	1998			1999	2000	2001
Exploratory (6.1)						
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	1998 ($1000)			1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD						
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	Minimal			Adequate	Oversubscribed	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity	Various					
Origin	Various					
User				ALL DOD		

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
Pattern Recognition						
Applicability to HOBM:	High	Medium	Low	Remarks		
Physical Behavior				Pattern Recognition is the technology area that encompasses the development		
Cognitive Behavior		X		systems which recognize patterns in data. Important application areas are		
Organizational Behavior				character recognition, speed analysis, and person identification.		
Technology Maturity				Remarks		
Research Stage	Mature					
Widely Published	YES			Extensively used in autonomous missile targeting.		
Widely Reviewed	YES			Signal processing technology embedded in Pattern Recognition		
S/W Developed	YES					
S/W Tested	YES					
S/W Reviewed	YES					
Applied in Simulations	YES					
Applied in Distributed Simulations	YES					
Applied in Models that have VV&A	N/A					
Standards Approved	N/A					
Technology Characterization	Red	Yellow	Green	Remarks		
Availability			X			
Community Acceptance			X			
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving			X	Critical to AI development		
Potential to be Transitioned			X			
Potential to be Integrated			X	Parallel Computations Required		
Computing Resources Required			X			
Hardware		X				
Software			X			
Networks			X			
Direct Measures	Current SOTA			Target	Trends	
(# / sec)	N/A					
(# entities)	N/A					
(Execution time)	N/A					
(...)	N/A					
Additional Technology Characterizations				Remarks		
Cost Drivers	N/A					
Range of Applicability	N/A			Wide use in AI programs (HOBM Potential)		
Implementation Cost (H, M, L)	N/A					
COTS/GOTS Availability	N/A					
Proprietary Status	N/A					
DoD Funding (RDT&E)	1998			1999	2000	2001
Exploratory (6.1)						
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	1998 ($1000)			1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD						
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	Minimal			Adequate	Oversubscribed	
Past				X		
Current				X		
Future				X		
Developer/User						
Developing Activity	Numerous					
Origin	Numerous					
User				ALL DOD		

HOBM TECHNOLOGY METRICS

Name of HOBM Technology: **Robotics**

Applicability to HOBM:	High	Medium	Low	Remarks
Physical Behavior	X			Robotics: An automatic device that performs functions normally ascribed
Cognitive Behavior		X		to humans or a machine in the form of a human
Organizational Behavior				

Technology Maturity		Remarks
Research Stage	Extensive	DARPA foresees total autonomy by 2020
Widely Published	YES	
Widely Reviewed	YES	
S/W Developed	YES	Field encompasses all aspects of HOBM
S/W Tested	YES	
S/W Reviewed	YES	DMSO should monitor technology closely
Applied in Simulations	YES	
Applied in Distributed Simulations	YES	
Applied in Models that have VV&A	YES	
Standards Approved	Pending	

Technology Characterization	Red	Yellow	Green	Remarks
Availability		X		
Community Acceptance			X	
Potential to Solve Real Problems			X	
Uniqueness of Problem Solving			X	
Potential to be Transitioned			X	
Potential to be Integrated			X	
Computing Resources Required		X		
Hardware		X		
Software		X		
Networks		X		

Direct Measures	Current SOTA	Target	Trends	
(# / sec)	N/A			
(# entities)	N/A			
(Execution time)	N/A			
(...)	N/A			

Additional Technology Characterizations		Remarks
Cost Drivers	unlimited	
Range of Applicability	Wide	Wide use in AI programs (HOBM Potential)
Implementation Cost (H, M, L)	High	
COTS/GOTS Availability	Some	
Proprietary Status	Some	

DoD Funding (RDT&E)	1998	1999	2000	2001
Exploratory (6.1)				
Basic (6.2)				
Advanced (6.3)				
Prototype (6.4)				
Production (6.5)				

Funding Profile	1998 ($1000)	1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD				
Government (Non-DoD)				
Academia				
Commercial				

Funding Adequacy	Minimal	Adequate	Oversubscribed	
Past		X		
Current		X		
Future		X		

Developer/User				
Developing Activity	Numerous			
Origin	Numerous			
User		ALL DOD		

	HOBM TECHNOLOGY METRICS			
Name of HOBM Technology:				
Intelligent Tutoring Systems				

Applicability to HOBM:	High	Medium	Low	Remarks
Physical Behavior			X	Intelligent Tutoring Systems are computer-based training systems that
Cognitive Behavior	X			incorporate techniques for communicating and transferring knowleldge
Organizational Behavior			X	and skills to students.

Technology Maturity		Remarks
Research Stage	Mature	
Widely Published	YES	Excellent potential for military M&S training
Widely Reviewed	No	
S/W Developed	YES	Applicable to all military training
S/W Tested	YES	
S/W Reviewed	YES	
Applied in Simulations	No	
Applied in Distributed Simulations	No	
Applied in Models that have VV&A	NO	
Standards Approved	NO	

Technology Characterization	Red	Yellow	Green	Remarks
Availability		X		
Community Acceptance			X	
Potential to Solve Real Problems			X	
Uniqueness of Problem Solving		X		
Potential to be Transitioned			X	
Potential to be Integrated		X		
Computing Resources Required		X		
Hardware		X		
Software		X		
Networks		X		

Direct Measures	Current SOTA	Target	Trends	
(# / sec)	N/A			
(# entities)	N/A			
(Execution time)	N/A			
(...)	N/A			

Additional Technology Characterizations		Remarks		
Cost Drivers	S/W			
Range of Applicability	Wide			
Implementation Cost (H, M, L)	Low			
COTS/GOTS Availability	Yes			
Proprietary Status	N/A			

DoD Funding (RDT&E)	1998	1999	2000	2001
Exploratory (6.1)				
Basic (6.2)				
Advanced (6.3)				
Prototype (6.4)				
Production (6.5)				

Funding Profile	1998 ($1000)	1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD				
Government (Non-DoD)				
Academia				
Commercial				

Funding Adequacy	Minimal	Adequate	Oversubscribed	
Past		**X**		
Current		**X**		
Future		**X**		

Developer/User				
Developing Activity	Numerous			
Origin		All Dod		
User		ALL DOD		

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
Decision Support Systems						
Applicability to HOBM:	High	Medium	Low	Remarks		
Physical Behavior				The purpose of Decision Support Systems are to provide improved situational		
Cognitive Behavior	X			awareness, options generation, response selection, and recommendations		
Organizational Behavior		X		for resource allocation while reducing procedural mistakes.		
Technology Maturity				Remarks		
Research Stage	Basic				DTO Objective HS.21	
Widely Published	No			Decision Support Systems for Command andControl		
Widely Reviewed	No					
S/W Developed	Some					
S/W Tested	Some					
S/W Reviewed	No					
Applied in Simulations	Some					
Applied in Distributed Simulations	Some					
Applied in Models that have VV&A	NO					
Standards Approved	Pending					
Technology Characterization	Red	Yellow	Green	Remarks		
Availability		X				
Community Acceptance		X				
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving			X			
Potential to be Transitioned			X			
Potential to be Integrated			X			
Computing Resources Required			X			
Hardware		X				
Software		X				
Networks		X				
Direct Measures	Current SOTA			Target	Trends	
(# / sec)	N/A					
(# entities)	N/A					
(Execution time)	N/A					
(...)	N/A					
Additional Technology Characterizations				Remarks		
Cost Drivers	Basic Research					
Range of Applicability	Wide range					
Implementation Cost (H, M, L)	Medium					
COTS/GOTS Availability	CGOTS					
Proprietary Status	N/A					
DoD Funding (RDT&E)	1998			1999	2000	2001
Exploratory (6.1)						
Basic (6.2)					3.9M	4.1M
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	1998 ($1000)			1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD						
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	Minimal			Adequate	Oversubscribed	
Past	**X**					
Current	**X**					
Future	**X**					
Developer/User						
Developing Activity	USD (A&T)					
Origin	USD(A&T)					
User				ALL DOD		

	HOBM TECHNOLOGY METRICS					
Name of HOBM Technology:						
Advanced Distributed Learning						
Applicability to HOBM:	High	Medium	Low	Remarks		
Physical Behavior			X	The goal of Advanced Distributed Learning Systems is too pursue emerging		
Cognitive Behavior	X			network-based technologies; facilitate development of common standards;		
Organizational Behavior			X	and promote widespread collaboration to satisfy common needs.		
Technology Maturity				Remarks		
Research Stage	YES					
Widely Published	YES					
Widely Reviewed	YES					
S/W Developed	YES			DoD in extensive ADL development		
S/W Tested	YES			See "www.ADLnet.org"		
S/W Reviewed	YES					
Applied in Simulations	YES					
Applied in Distributed Simulations	YES					
Applied in Models that have VV&A	YES					
Standards Approved	Pending					
Technology Characterization	Red	Yellow	Green	Remarks		
Availability			X			
Community Acceptance			X			
Potential to Solve Real Problems			X			
Uniqueness of Problem Solving			X			
Potential to be Transitioned			X			
Potential to be Integrated			X			
Computing Resources Required			X			
Hardware			X			
Software			X			
Networks			X			
Direct Measures	Current SOTA			Target	Trends	
(# / sec)	N/A					
(# entities)	N/A					
(Execution time)	N/A					
(...)	N/A					
Additional Technology Characterizations				Remarks		
Cost Drivers	N/A					
Range of Applicability	N/A					
Implementation Cost (H, M, L)	N/A					
COTS/GOTS Availability	N/A					
Proprietary Status	N/A					
DoD Funding (RDT&E)	1998			1999	2000	2001
Exploratory (6.1)						
Basic (6.2)						
Advanced (6.3)						
Prototype (6.4)						
Production (6.5)						
Funding Profile	1998 ($1000)			1999 ($1000)	2000 ($1000)	2001 ($1000)
DoD						
Government (Non-DoD)						
Academia						
Commercial						
Funding Adequacy	Minimal			Adequate	Oversubscribed	
Past				**X**		
Current				**X**		
Future				**X**		
Developer/User						
Developing Activity				ALL DOD		
Origin				ALL DOD		
User				ALL DOD		

APPENDIX C

CROSS REFERENCE MATRIX

Cross Reference Matrix – Part 1

Broad HOBM, High Level HOBM, and Broad Computing Technologies vs. HOBM Needs

	High Performance Computing	Fundamental Computing Infrastructure	Human Computer Interactions	Architectures, Frameworks, Data Interchange Formats and Standards	Knowledge Engineering	Cognitive Modeling	Expert Systems	Natural Language Processing
CGF/SAF	X	X	X	X	X	X	X	
Organizational Decision Making		X		X	X	X	X	
COAA		X		X	X	X	X	
Decision Aids		X	X	X	X	X	X	X
Mission Rehearsal		X	X	X	X	X	X	
Situational Awareness		X	X	X	X	X	X	
IO/IW		X		X	X	X	X	
Simulation Design and Evaluation		X	X	X	X			X
Simulator Effectiveness		X	X	X				X
Simulation of C4I	X	X		X	X	X	X	
Weapons Effectiveness	X	X		X				
Complex Business Systems		X		X	X	X	X	

<u>Cross Reference Matrix - Part 2</u>

Fundamental HOBM Technologies vs. HOBM Needs

	Agent Based Sim.	SWARM	Case Based Reason-ing	Fuzzy Sys-tems	Genetic Com-puting	Machine Vision	Neural Net-works	Pattern Recog-nition	Robot -ics	Intel-ligent Tutor-ing	Decision Support	Advanced Distributed Learning
CGF/SAF	X	X	X	X			X		X		X	
Organizational Decision Making	X	X	X	X	X		X				X	
COAA	X		X	X	X		X	X			X	
Decision Aids	X		X	X	X		X	X			X	
Mission Rehearsal	X									X	X	X
Situational Awareness	X		X	X			X	X	X		X	
IO/IW	X		X	X			X	X			X	
Simulation Design and Evaluation			X	X								
Simulator Effectiveness			X					X				
Simulation of C4I	X	X	X	X			X		X			
Weapons Effectiveness	X	X		X	X							
Complex Business Systems	X	X	X	X	X		X				X	

APPENDIX D

HOBM WEB SITE LISTINGS

List of Web Links Related to Technology for HOBM

Artificial Intelligence

American Association for Artificial Intelligence:
http://www.aaai.org/

MIT Artificial Intelligence Laboratory Homepage:
http://www.ai.mit.edu/

Current MIT AI Lab Projects:
http://www.ai.mit.edu/projects/

MIT AI Lab Project MAC:
http://www.swiss.ai.mit.edu/projects/mac/index.html

List of Spinoff Companies from MIT AI Lab:
http://www.ai.mit.edu/research/spinoffs/spinoffs.shtml

SRI International Artificial Intelligence Center:
http://www.ai.sri.com/

Canadian National Research Council Institute for Information Technology List of AI Resources:
http://ai.iit.nrc.ca/ai_point.html

University of Arizona Artificial Intelligence Laboratory:
http://ai.bpa.arizona.edu/

Navy Center for Applied Research in Artificial Intelligence
http://www.aic.nrl.navy.mil/

Navy Center for Applied Research in Artificial Intelligence Project List
http://ai.bpa.arizona.edu/

Carnegie Mellon University AI FAQ
http://www.cs.cmu.edu/Web/Groups/AI/html/repository.html

UCLA AI FAQ – ftp site but updated more than CMU version
ftp://ftp.cs.ucla.edu/pub/AI/

Carnegie Mellon University Computer Science Department Research
http://www.cs.cmu.edu/research/areas.html

Stanford University Computer Science AI and Robotic Website
http://cs.stanford.edu/Research/ai.html

Guide to AI Resources on the Internet - British
http://www.ex.ac.uk/ESE/IT/ai.html

Guide to AI Resources of the Internet - US
http://www.cs.berkeley.edu/~russell/ai.html

Cognitive Modeling

First European Workshop n Cognitive Modeling
http://ki.cs.tu-berlin.de/EuroCog/eurocog.html

University of Michigan SOAR Home Page
http://bigfoot.eecs.umich.edu/~soar/

ACT-R Website
http://act.psy.cmu.edu/

CHI Systems COGNET/iGen/GINA Page
http://www.chiinc.com/ginahome.shtml

Fourth International Conference on Cognitive Modeling – July 2001
http://hfac.gmu.edu/iccm/

George Mason University Human Factors and Applied Cognition
http://www.hfac.gmu.edu/archlab/projectlisting.html

ACT-R Perceptual Motor Website
http://chil.rice.edu/byrne/RPM/project.html

ACT-R Book on the Internet
http://act.psy.cmu.edu/act/book/index.html

Psychological Online Documents for Cognitive and Experimental Psychology
http://www.psychologie.uni-bonn.de/online-documents/lit_cog.htm

SOAR FAQ from University of Nottingham
http://www.nottingham.ac.uk/pub/soar/nottingham/soar-lfaq.html#TableOfContents

Micro Analysis and Design Homepage
http://www.maad.com

OR/MS Today Simulation Software Survey
http://lionhrtpub.com/orms/surveys/Simulation/Simulation4.html

Human Activity Modeling Paper on the Internet at Georgia Tech
http://www.isye.gatech.edu/~cm/papers/model_requirement.10.96.html

List of Human Machine Interface Models
http://dticam.dtic.mil/htbin/allhsiquery?HSI

Early MIDAS Home Page at NASA
http://ccf.arc.nasa.gov/af/aff/midas/MIDAS_home_page.html

MIDAS Description
http://caffeine.arc.nasa.gov/midas/original-midas/Smith_Tyler_97.html

Later MIDAS Home Page at NASA
http://caffeine.arc.nasa.gov/midas

Electronic Community for Scholarly Research in Brain and Cognitive Sciences
http://cognet.mit.edu/

Iowa State University Software for Agent Based Computational Economics and Complex Adaptive Systems Page
http://www.econ.iastate.edu/tesfatsi/acecode.htm

Another CHI Systems Cognet Page
http://www.chiinc.com/cognethome.shtml

BBN OMAR Page
http://www.sover.net/~nichael/misc/omar/index.html

List of References to SAMPLE Model
http://citeseer.nj.nec.com/zacharias95sample.html

Air Force Research Laboratory AMBR Page
https://www.williams.af.mil/html/ambr.htm

University of Michigan EPIC Page
http://www.eecs.umich.edu/~kieras/epic.html

Overview of Artificial Intelligence
http://www.robotwisdom.com/ai/index.html

Computer Generated Forces

CGF-BR Conference Home Page
http://www.sisostds.org/cgf-br/index.htm

MaK Homepage
http://www.mak.com/technology.htm

List of Simulation Related References including CGF
http://www.bos.saic.com/Projects/ASTT_SNE/ref-a.html

CGF / SOAR Paper
http://ai.eecs.umich.edu/people/laird/papers/siw.html

OneSAF Home Page
http://www.onesaf.org/

Data Fusion

Drexel University Data Fusion Laboratory
http://dflwww.ece.drexel.edu/

IEEE Geoscience and Remote Sensing Society Data Fusion Committee Homepage
http://www.aris.sai.jrc.it/dfc/datafus.html

IEEE Geoscience and Remote Sensing Society Data Fusion Committee Library
http://www.aris.sai.jrc.it/dfc/library.html

NASA Ames Workshop on Data Fusion and Data Mining
http://ic-www.arc.nasa.gov/ic/data99-workshop/index.html

Computer Vision

Computer Vision Bibliography
http://iris.usc.edu/Vision-Notes/bibliography/contents.html

Expert Systems

Acquired Intelligence, Inc., Expert Systems Development Services and Products
http://www.aiinc.ca/

CLIPS Expert Systems Tool Page
http://www.ghgcorp.com/clips/CLIPS.html

Attar Software Limited, Software for capture and deployment of business rules
http://www.attar.com/home.htm

Granite Bear Development Expert Systems Shell for Windows
http://www.granitebear.com/esiewin.htm

JAGware Homepage, Expert systems developer
http://www.jagware.com/expert.html

Journal of IS Education Online Expert Systems Tutorial
http://gise.org/JISE/Vol1-5/EXPERTSY.htm

Fuzzy Systems

IEEE 2000 Fuzzy Systems Conference Page
http://fuzzieee2000.cs.tamu.edu/fuzz.html

IEEE Transactions on Fuzzy Systems
http://www.ieee.org/organizations/society/sp/tfs.html

The Math Works, Inc Fuzzy Logic Toolbox for use with MATLAB
http://www.mathworks.com/products/fuzzylogic/fuzzy.pdf

Fuzzy Logic Newsgroup
http://www.cs.cmu.edu/Groups/AI/html/faqs/ai/fuzzy/part1/faq.html

North American Fuzzy Information Processing Society Homepage
http://morden.csee.usf.edu/Nafipsf/

Fuzzy Systems Engineering Homepage
http://www.fuzzysys.com/

University of Macedonia Parallel and Distributed Processing Laboratory Resources on Fuzzy Systems Page
http://www.it.uom.gr/pdp/DigitalLib/fuzzy.htm

Tables of Contents for Advances in Fuzzy Systems Applications and Theory
http://www.wspc.com.sg/books/series/afsat_series.html

Human Computer Interaction

Carnegie Mellon University Human Computer Interaction Institute List of Research Projects
http://www.hcii.cmu.edu/Research/Projects.html

Human Computer Interaction Bibliography
http://www.hcibib.org/

Fomix Corporation Homepage - Company specializes in HCI
http://www.fonix.com/

University of Maryland Human Computer Interaction Lab
http://www.cs.umd.edu/projects/hcil/index.html

Montreal Center for Information Research HCI Page (Real name is in French page is in English)
http://www.crim.ca/hci/

University of California Berkeley Computer Science HCI Research Page
http://buffy.eecs.berkeley.edu/Research/CS/MIG/

Human Computer Interaction Journal Web Page
http://hci-journal.com/

History of HCI technology
http://www.cs.cmu.edu/~amulet/papers/uihistory.tr.html

National Science Foundation Information and Intelligent Systems Homepage
http://www.cise.nsf.gov/iis/index.html

List of Internet HCI resources
http://www.ida.liu.se/~miker/hci/index1.html

Intelligent Agents

Socially Intelligent Agents- The Human in the Loop - AAAI Symposium Proceedings
http://homepages.feis.herts.ac.uk/~comqkd/SIA-2000.html

Article describing Intelligent Agents
http://www.pulver.com/netwatch/topten/tt9.htm

AAAI Symposium on Intelligent Agents in Cyberspace
http://fistserv.macarthur.uws.edu.au/san/iac/

Bibliography on Intelligent Agents and Multi-agent Systems
http://liinwww.ira.uka.de/bibliography/Ai/agents.html

Internet site describing Bots
http://bots.internet.com/s-data.htm

IBM Research Intelligent Agents Activities
http://www.research.ibm.com/iagents/ibm_iagents.html

University of Maryland Baltimore County Agent Web – Internet resources and introductory material
http://agents.umbc.edu/

Survey of agent construction tools
http://www.agentbuilder.com/AgentTools/index.html

Review article on software agents
http://www.sce.carleton.ca/netmanage/docs/AgentsOverview/ao.html

Neural Networks

Attrasoft homepage – Company builds neural networks for various tasks
http://attrasoft.com/

NeuCo – Neural network consulting and technology company
http://www.neucollc.com/

Use of neural networks for information retrieval
http://cdsweb.u-strasbg.fr/misc/stiamurt.htx

NASA Computational Intelligence Group projects
http://ic-www.arc.nasa.gov/ic/projects/neuro/

Pacific Northwest National Laboratory Neural Network Research
http://www.emsl.pnl.gov:2080/proj/neuron/neural/neural.homepage.html

Pacific Northwest National Laboratory Neural Network Links
http://www.emsl.pnl.gov:2080/proj/neuron/neural/gateway/

Laboratory for Neural Network Modeling in Vision Research, Rostov State University Russia
\http://www.rybak-et-al.net/nisms.html

Adaptive Learning Technology for Internet Personalization
http://www.zsolutions.com/index.htm

NeuroDimension, Inc. Neural network software products
http://www.nd.com/

Pattern Recognition

Description of pattern recognition textbook
http://www.computer.org/cspress/catalog/bp07796.htm

Commercial image processing utility
http://www.mwlabs.de/

List of pattern recognition links
http://jeff.cs.mcgill.ca/~godfried/teaching/pr-web.html

Directory of pattern recognition information
http://www.ph.tn.tudelft.nl/PRInfo/index.html

Pattern recognition toolbox
http://www.inf.ufes.br/~thomas/home/tooldiag.html

Swarm (Agent) Technologies

Autonomous Ground Vehicle for Distributed Surveillance
http://www.ri.cmu.edu/pubs/pub_3217.html

Business Week Swarm Article
http://www.businessweek.com/chapter/kelly.htm

SWARM

Swarm Development Group Home Page
http://www.swarm.org/

Description of Swarm Simulation System
http://www.santafe.edu/projects/swarm/overview/overview.html

High Performance Computing

Silicon Graphics Inc Homepage
http://www.sgi.com/

Supercomputer information site
http://www.top500.org/

Additional detail from supercomputer information site.
http://www.top500.org/ORSC/

List of World's 500 Fastest Supercomputers during November 2000.
http://www.top500.org/list/2000/11/

IEEE Computer Society Listing of Parallel Computing Sites
http://computer.org/parascope/

DARPA Information Systems Office Homepage
http://dtsn.darpa.mil/iso/

High Performance Computing Modernization Program Homepage
http://www.hpcmo.hpc.mil/

Article comparing HPC performance to human brain function
http://www.transhumanist.com/volume1/moravec.htm

Article describing Raytheon Artificial Nervous System project
http://www5.compaq.com/rcfoc/981109.html

Natural Language Processing

University of Massachusetts Natural Language Processing Laboratory
http://www-nlp.cs.umass.edu/

Unsupervised Learning in Natural Language Processing Conference - 1999
http://www.ai.sri.com/~kehler/unsup-acl-99.html

Natural Language Processing Requirements for Voice Markup Languages
http://www.w3.org/TR/voice-nlu-reqs/

Japanese Natural Language Processing WWW Server List
http://galaga.jaist.ac.jp:8000/nlp/link/nlp_WWWserver.html

University of Delaware Natural Language Processing Lab
http://www.asel.udel.edu/natlang/nlp/nlp.html

Natural Language Software Registry (Maintained in Germany, in English)
http://registry.dfki.de/

Interviews with academic NLP experts. (Half are in Dutch, half in English)
http://coli.uni-sb.de/~mineur/Ta-speakers.html

"Survey of the State of the Art in Human Language Technology" Report on the Internet
http://cslu.cse.ogi.edu/HLTsurvey/HLTsurvey.html

List of NLP Resources on the Internet
http://www.asel.udel.edu/natlang/nlp/nlp_resources.html

List of NLP Links
http://www.cogsci.ed.ac.uk/~kversp/links.html

Association for Computational Linguistics Homepage
\http://www.aclweb.org/home.html

Microsoft NLP Research Page
http://www.research.microsoft.com/research/nlp/#people

Austrian Research Institute for Artificial Intelligence NLP Group
http://www.ai.univie.ac.at/oefai/nlu/

Microsoft NLP Links Page
http://research.microsoft.com/nlp/links.asp

Robotics

University of Massachusetts Robotics Internet Resources Page
http://www-robotics.cs.umass.edu/robotics.html

The Robotics Institute (Carnegie Mellon University) Homepage
http://www.ri.cmu.edu/home.html

Robotics Online Website
http://www.roboticsonline.com/

Stanford University Robotics laboratory

http://robotics.stanford.edu/

Machine Vision

Vision 1 Machine Vision Systems Manufacturer
http://www.vision1.com/

Robotic Vision Systems, Incorporated / Northeast Robotics – Machine vision lighting systems
http://www.nerlite.com/

Machine Vision Technology Transportation Engineering Cal Poly University Webpage
http://airship.ardfa.calpoly.edu/vips/machine.html

Cognex Corporation – Machine vision systems developer
http://www.cognex.com/

Cardiff University Wales Machine Vision Laboratory
http://bruce.cs.cf.ac.uk/bruce/index.html

Oak Ridge National laboratory Image Science and Machine Vision Group
http://www-ismv.ic.ornl.gov/

List of machine Vision Links - US
http://www.rdrop.com/~cary/html/machine_vision.html

Datacube, Inc. Image Processing Hardware and Software
http://www.datacube.com/

Directory of Machine Vision Resources – From Ireland
http://www.eeng.dcu.ie/~whelanp/resources/resources.html

Knowledge Representation

Knowledge Representation Meets Databases Homepage – Page for a series of workshops to facilitate interchange between these fields.
http://sunsite.informatik.rwth-aachen.de/Societies/KRDB/

British Knowledge Representation Links Page
http://www.cs.man.ac.uk/~franconi/kr.html

Knowledge Representation and Ontology Pages – University of Texas
http://www.cs.utexas.edu/users/mfkb/related.html

Knowledge Representation Book on the Internet
http://www.bestweb.net/~sowa/krbook/index.htm

Stanford University Knowledge Systems Laboratory http://www-ksl.stanford.edu/

Stanford University Knowledge Representation Related Links Page
http://www-ksl.stanford.edu/related.html

Introduction to Knowledge Representation
http://blackcat.brynmawr.edu/~dkumar/UGAI/kr.html

AT&T Research description of their Knowledge Representation system
http://www.research.att.com/sw/tools/classic/

Knowledge Representation and Data Engineering Laboratory Nara Institute of Science and Technology Japan
http://mimi.aist-nara.ac.jp/English/home-page.html

PARKA Scalable knowledge Representation System – University of Maryland
http://www.cs.umd.edu/projects/plus/Parka/parka-db.html

Genetic Computing

List of some genetic computing papers.
http://www.cs.bris.ac.uk/~brian/Research/genetic.html

Evolutionary Computation FAQ
http://www.cs.bham.ac.uk/Mirrors/ftp.de.uu.net/EC/clife/www/

List of Genetic Computing Links
http://www.aston.ac.uk/~dohertbs/resources.htm

Case-Based Reasoning

Case-Based Reasoning Information Resource
http://www.ai-cbr.org/theindex.html

University of Massachusetts Case-Based Reasoning Group
http://cbr-www.cs.umass.edu/

Case-Based Reasoning Repository
http://www-cia.mty.itesm.mx/~lgarrido/Repositories/CBR/reasoning.html

Introduction to Case-Based Reasoning
http://www.ils.nwu.edu/~e_for_e/nodes/NODE-23-pg.html

Case-Based Reasoning Product Experience Base – Decision Support System for CBR Development
http://demolab.iese.fhg.de:8080/

APPENDIX E

REFERENCES

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APPENDIX F

GLOSSARY

Algorithm – A set of well defined rules or procedures for solving a problem or providing an output for a specific set of inputs.

Cognition – A wide range of activities related to human information processing.

Expert System – A computer application that performs a task that would otherwise be performed by a human expert.

Fuzzy Expert System – An expert system that uses a collection of fuzzy membership functions and rules to analyze data.

GigaFlop – A billion floating point operations per second.

High Performance Computing (HPC) – A branch of computer science that concentrates on developing supercomputers and software to run on supercomputers.

Intelligent Tutoring System – A computer-based training system that incorporates techniques for communicating/transferring knowledge and skills to the student.

Knowledge Acquisition – The search, discovery, and collection of authoritative information or data to represent the real world in a system or a model.

Knowledge Engineering – The process from design through collection, pruning, and analysis that permits the domain or subject matter expert to represent information for the software developer.

Machine Vision – The act of acquiring an image via a lens/camera combination and then digitally processing that image to locate and act upon salient features.

Motor Behavior – Functions performed by the neuromuscular system to carry out physical activities.

Natural Language – A human language, such as English, French, or Japanese.

Natural Language Processing – Computer processing of spoken or written natural language.

Pattern Recognition – A process that identifies an object based on an analysis of its features.

Real Time Processing – The ability of a system to perform a complete signal analysis and take action on this data before the next data set arrives.

RHOBM – Robotic and Human Organizational Behavior Modeling. This is the field concerned with modeling the behavior and interactions of unmanned vehicles, robots, androids, and humans.

Robotics – The study and use of robots.

Sensing and Perception – The processes of transforming representations of external energy stimuli into internal representations that can be acted on by cognitive processes.

Supercomputer – A time dependent term which refers to the most powerful class of computer systems at the time of reference. As of June 2001, these are machines having speeds of 60 GigaFlops or greater.