Advanced Distributed Simulation: Decade in Review and Future Challenges

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ABSTRACT

As networking technologies and computer hardware performance advanced in the late 1980s, distributed simulation became a feasible way to provide military training at distant, sometimes remote locations. Efforts were made to advance the technologies surrounding distributed simulation, from networking protocols to the representation of the battlespace and its entities. The following SSC San Diego efforts supported advances in distributed-simulation-related areas throughout the 1990s and continue to support the next generation of 21st century simulation systems.

INTRODUCTION

The 1990s saw SSC San Diego continue to be the leader in Advanced Distributed Simulation (ADS) technologies for the U.S. Navy. SSC San Diego simulations supported worldwide users in training, assessment, analysis, testing, experimentation, and technology research. SSC San Diego supported network-centric simulations and joint-service objectives. The Center defined and advanced two major simulation protocol threads: the Distributed Interactive Simulation (DIS) protocol and the Aggregate-Level Simulation Protocol (ALSP). These protocols were the genesis of the latest and current Defense Modeling and Simulation Office's (DMSO's) standard: the High-Level Architecture (HLA) Run-Time Infrastructure (RTI).

SSC San Diego's simulation efforts supported a variety of venues that tested and experimented with the protocols over large distributed networks, and developed capabilities that supported the trend from service-specific to joint-service exercises. The major advanced distributed simulation efforts during the decade were provided by the following SSC San Diego simulation systems: the Research, Evaluation, and System Analysis (RESA) Simulation; the Marine Corps' Marine Air Ground Task Force (MAGTF) Tactical Warfare Simulation (MTWS); the Synthetic Theater of War (STOW) Advanced Concepts Technology Demonstration (ACTD); and the Joint Simulation System–Maritime (JSIMS–M). These simulations supported venues that included the construction of Joint Federation training exercises supported by RESA and MTWS through their development of ALSP interfaces. The support included the advent of ACTDs, with STOW emerging as the first ACTD, and further support was provided to a variety of subsequent ACTDs (e.g., Joint Countermine Operational Simulation (JCOS), Extending the Littoral Battlespace (ELB), and Joint Medical Operations–Telemedicine (JMO–T)) using DIS and eventually RTI protocols. Additional support has continued through experimentation in Fleet Battle Experiments (FBEs) and Joint Experimentation (JE) events. SSC San Diego simulations will continue to support these venues by improving existing simulations and by developing next-generation advanced distributed simulation systems that support joint-service operations, such as JSIMS–M.

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14. ABSTRACT
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The following section will briefly describe support provided by these SSC San Diego simulations, including some specific events, followed by the final section on future potential.

ADVANCED DISTRIBUTED SIMULATION (1990s)

As networking technologies and computer hardware performance advanced in the late 1980s, distributed simulation became a feasible way to provide military training at distant, sometimes remote locations. Efforts were made to advance the technologies surrounding distributed simulation, from networking protocols to the representation of the battlespace and its entities. The following SSC San Diego efforts supported advances in distributed-simulation-related areas throughout the 1990s and continue to support the next generation of 21st century simulation systems.

Research, Evaluation, and System Analysis (RESA)

The RESA simulation system has a 23-year history and has evolved to meet the Navy's ever-expanding needs for a constructive simulation system that focuses on theater-level naval operations. The capabilities of RESA to realistically simulate the naval warfare environment, generate streams of realistic scenario-driven data to C^4I support systems, and to interface with other models/analysis tools have led to its application in a wide variety of projects.

Throughout the 1990s and continuing today, the RESA system has provided the Navy with a stand-alone system to support a wide variety of applications, including systems analysis, concept of operations development, advanced technology assessment, and C^4I system simulation. In the early 1990s, the reliability of the system and its flexibility in adapting to the Navy's changing needs, led to its evolution into today's RESA system, fulfilling dual missions in the areas of joint-forces training and joint and naval research, development, test, and evaluation (RDT&E).

To fulfill the Navy's need for a naval training system within the U.S. Joint Forces Command (JFCOM) Joint Training Confederation (JTC), the RESA team aided in the design of the ALSP. Developed specifically for the JTC, the ALSP interface allowed the sharing of simulation information with other service constructive simulations including the Army's Corps Battle Simulation (CBS) and the Air Force's Air Warfare Simulation System (AWSIMS). Today, the ALSP JTC integrates a wide variety of models and simulations supporting joint forces and allied training at the command level, worldwide, in exercises such as Unified Endeavor at the U.S. Atlantic Command (USACOM) and Ulchi Focus Lens at the Combined Forces command in South Korea. In the mid-1990s, the Marine Corps MAGTF MTWS system, developed and supported by SSC San Diego, was integrated into the JTC, thus completing the inclusion of all joint-service warfare areas.

Concurrent with providing the Navy's system in the JTC, SSC San Diego was selected to participate in the design and development of the DIS protocols for the integration of joint-service constructive simulations, virtual models, and live-range entities. This task was accomplished in support of joint-service assessment, analysis, testing, experimentation, and technology research. The RESA system became one of the Navy's first DIS-compliant simulations, and it has been used in a variety of joint-service and allied studies sponsored by DMSO, the Defense Advanced Research Projects

Agency (DARPA), the Ballistic Missile Defense Office (BMDO), the Office of the Secretary of Defense (OSD), and the Office of the Chief of Naval Operations (OPNAV). As the naval component in joint-service distributed projects, the RESA system has contributed to developing and testing command and control structures, operational plans, concepts of operation, and analyses. Areas of study include analyses of the Cooperative Engagement Capability (CEC), the next-generation aircraft carrier (CVNX), the Zumwalt-class 21st century destroyer (DD 21), and Joint Theater Missile Defense Attack Operations.

The extensive simulation capabilities of RESA, coupled with its record of reliable operations and transportability, have not only resulted in its use at a number of facilities for a variety of applications but have also led to its use in providing the core simulation infrastructure for other simulation developments such as the CounterMeasures Analysis Simulator (CMAS), Space and Electronic Warfare Simulation (SEWSIM), the Air Warfare Simulation System (AWSIMS), and the Battleforce Electro-Magnetic Imagery (EMI) Evaluation System (BEES).

The history of the RESA system not only lends merit to SSC San Diego's current reputation as a prominent leader in the design and development of distributed simulation systems, but also attests to SSC San Diego's status as a true pioneer in the world of modeling and simulation (M&S).

Marine Air Ground Task Force (MAGTF) Tactical Warfare Simulation (MTWS)

The MAGTF MTWS system, developed and supported by SSC San Diego, is a constructive simulation that provides exercise control services and tactical combat simulation capabilities to support tactical training exercises. Development of MTWS began in 1989. In 1995, the system was formally accepted by the Marine Corps as the replacement for the Tactical Warfare Simulation, Evaluation, and Analysis System (TWSEAS). MTWS supports all aspects of MAGTF combat operations, including air, ground, maritime, and amphibious operations, in a multisided environment to permit creation of the widest possible range of tactical conditions to challenge staff decision-making. The MTWS Analysis Review System (MARS) component provides the training audience with exercise review, analysis, and replay capabilities.

In the mid-1990s, the MAGTF MTWS system was integrated into the JTC via an ALSP interface. The MTWS ALSP interface supports a wide variety of air, ground, and surface interactions with other ALSP confederates. In a confederation with multiple MTWS actors, the interface supports ground-to-ground interactions; this is unique within the ALSP confederation. Besides the ALSP interface for supporting interoperation with the JTC, a DIS interface was developed to support real-time simulation interoperability with other DIS simulations, such as the Joint Semi-Automated Forces (JSAF) simulation. MTWS was used in conjunction with JSAF to support modeling and simulation for the ELB ACTD in 1999. MTWS also interfaces to C4I systems such as the Global Command and Control System (GCCS), providing scenario-based track update information via over-the-horizon (OTH)-GOLD messages, and a variety of Intel-related U.S. Message Text Format (USMTF) messages.

In its original configuration, MTWS operated as a set of simulation applications distributed across a networked suite of TAC-4 HP processors, connected via a central hub to a second network of TAC-3/4 user stations.

The simulation applications—ground combat, air operations, ship-to-shore, logistics, etc.—can be distributed over as many as six host processors, or all can run on a single host processor, at the user's option, depending on the size, scope, and intensity of the scenario. The user stations provide a tactical map display supporting both vector and raster map images, as well as various exercise definition, control, and reporting functions. In early 2001, the TAC-3/4 user stations were replaced by PC/Win32 workstations, which provide enhanced functionality with increased performance.

As the TAC-4 hardware is phased out, and the functionality and capacity of the system continue to increase, MTWS is evaluating the benefits of migrating the remainder of the system to another platform(s). This includes migration to more platform-independent development tools (e.g., compiler, etc.). Also, MTWS expects to introduce a Web-based After-Action Review (AAR) system this year, which will significantly enhance the potential to support remote training.

Synthetic Theater of War (STOW)/Joint Semi-Automated Forces (JSAF)

STOW, developed in the mid-1990s, was based on the culmination of several advanced research projects sponsored by DARPA in the early 1990s. These projects spearheaded efforts to advance technologies for the next generation of computer-generated forces and distributed simulation; specifically in areas of aggregation/deaggregation, high vs. engineering fidelity, scalability (handling large numbers of distributed objects), and DIS protocols. STOW Europe (STOW-E) exploited these technologies by integrating constructive, virtual, and live simulation in a major joint exercise in 1994 called Unified Endeavor (Reforger). The exercise was held primarily in Germany but was distributed to sites in England and the U.S. In 1995, STOW transitioned to an ACTD.

STOW evolved from Simulation Networking (SIMNET) protocols to DIS protocols to DMSO's standard HLA RTI protocols. In 1997, STOW became the largest federation ever to use the newly mandated HLA RTI protocols. The main product that the STOW ACTD transitioned was a joint distributed simulation capability called Joint Semi-Automated Forces (JSAF).

Currently, JSAF primarily supports the JE events for JFCOM at the Joint Training and Analysis Simulation Center (JTASC) in Suffolk, VA. The JFCOM Experimentation Directorate, J9, is now the operational sponsor and makes extensive use of JSAF for Human-in-the-Loop (HITL), virtual experiments. The U.S. Navy's Maritime Battle Center uses JSAF as the core simulation for its Fleet Battle Experiments (FBEs). JSAF is also supporting the Joint Medical Operations–Telemedicine ACTD. A JSAF User's Group has recently been created to represent a broadening group of agencies making use of HLA-compliant JSAF technologies.

Joint Experimentation Using JSAF

Joint Experimentation 9901 (JE9901)

The JE9901 Experiment explored new approaches to JE in the context of investigating how future systems, especially sensor systems, can be used to defeat critical mobile targets in the form of theater ballistic missiles before they are fired. The Critical Mobile Target Cell (CMTC) was used to provide real-time tasking authority for the sensors, and then Automated Target Recognition was used to continuously track targets.

Attack Operations 2000 (AO 00)

The AO 00 Experiment used a war-game scenario with Sensor and Shooter Concept of Operations (CONOPS) for the 2007 timeframe. The experiment dealt with HITL acting as a black-box surrogate, deciding on which platforms and weapons systems/munitions were to be used in a synthetic environment. The AAR system logged the Experiment/Simulation in real-time for playback, thread analysis, and battle damage assessment. (See Figure 1 for sample synthetic environment.)

FIGURE 1. Realistic environments and dynamic terrain features have become a reality in simulation. A simulated vehicle crosses a bridge (left), and then the bridge is bombed and destroyed (right), making the bridge impassable by other vehicles. Bridging assets now exist that could build a simulated temporary bridge for forging the river.

ACTD Using JSAF

Joint Countermine Operational Simulation (JCOS)

The objective of the Joint Countermine (JCM) ACTD was to demonstrate the capability to conduct seamless mine countermeasure (MCM) operations from sea to land. The ultimate goal was to develop improved MCM equipment, operational concepts, and doctrine to support amphibious and other operations involving Operational Maneuver from the Sea (OMFTS), and to support the follow-on land operations.

Modeling and simulation played a key role in the JCM ACTD. JCOS was used to evaluate the operational use of countermine systems, to evaluate plans developed to accomplish exercise objectives, and to evaluate doctrine and tactics in a variety of scenarios and tactical situations.

The JCOS goal was to provide an end-to-end simulation capability for joint MCM operations. JCOS used and leveraged existing Advanced Distributed Simulation JSAF capabilities to meet this goal. With this approach, JCOS was able to simulate and rehearse joint warfighting operations in a mined environment across the operational continuum from deep water, through littoral, to inland objectives.

JCOS was used during the planning phases of two amphibious assault exercises that required extensive MCM operations. JCOS was also used during exercises to simulate a much more robust MCM component.

Joint Medical Semi-Automated Forces (JMedSAF)

The objective of the Joint Medical Operations–Telemedicine (JMO–T) ACTD was to provide a near-term capability to defeat time, distance, and organizational obstacles to effective Joint Health Service Support in austere and nonlinear operational environments.

The plan developed by SSC San Diego to provide M&S support for the ACTD was similar to that followed for the JCM ACTD, in which JSAF capabilities were enhanced in the specific domain area required. A comprehensive representation of Army, Air Force, Marine, and Navy medical treatment behaviors was developed to provide medical mission planning and rehearsal at a Joint Task Force/Commander in Chief (CINC) level that would be on a par with those employed by the combat branches. (See Figure 2.)

Specific capabilities developed include:

- Medical entities: hospital ships, medical treatment facilities, ambulances, helicopters, and individuals capable of being wounded or sick.
- Medical behaviors: combat injuries based on weapon/casualty type pairings and defined medical patient codes, disease and nonbattle injuries determined on percentage of population at risk, medical facilities with staff, equipment, holding capacities, and evacuation assets.
- Medical C^2 reporting: a medical C^2 message interface to the Medical Equipment Workstation (MEWS) that will provide Annex Q (medical reports section of an OP Order) reporting as well as information on individual patient encounters.

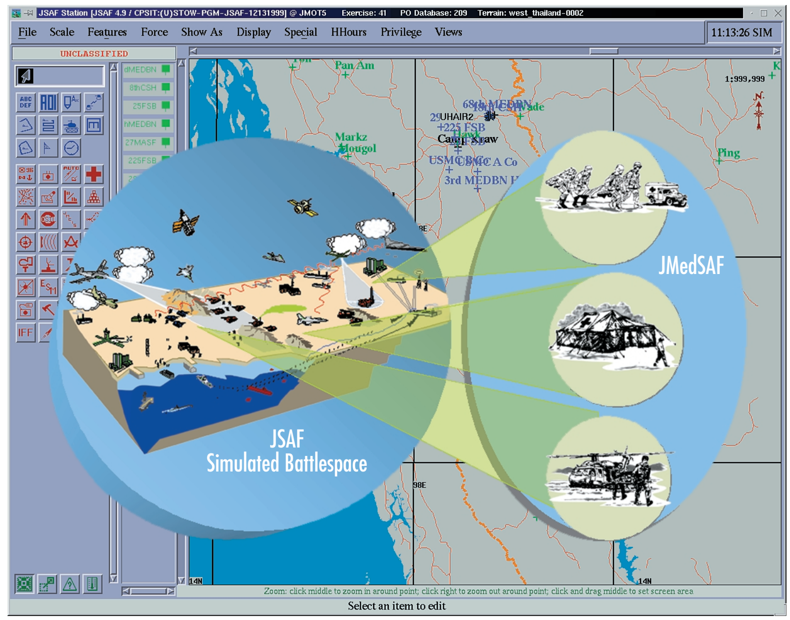

FIGURE 2. JMedSAF is a medical extension of JSAF, providing the ability to simulate medical play in the simulated tactical battlespace. Medical play includes combat injuries, disease-related illnesses, and nonbattle injuries; medical treatment facilities, their staffs, and supplies; the evacuation of injured or sick, or subsequent return-to-duty; and interfaces to medical C^2 workstations.

JMedSAF has been demonstrated at Kernel Blitz '99 in conjunction with ELB ACTD (April 1999), in the Pacific Warrior Exercise CPX (November 1999), and in Cobra Gold 2000 (May 2000). Participation in Cobra Gold 2001 is also planned. JMedSAF will also be used (in conjunction with a distributed simulation from the Army's Training and Doctrine Command) to assess the effects of varying levels of medical support for future Objective Forces.

Extending the Littoral Battlefield

The main objectives of the ELB ACTD were to (1) expand battlespace connectivity in the littoral regions by using wireless network technologies and hand-held computing devices, and (2) further flatten the command and control structure for executing missions in austere and nonlinear operational environments.

The plan developed by SSC San Diego provided M&S support to the ELB ACTD Major System Demonstration (MSD) #1 in order to (a) accomplish greater realism for the common tactical picture, (b) enhance situational awareness of the battlespace, (c) increase the density of message traffic to C^4I systems, and (d) provide a mechanism to support testing events when limited resources were available. The simulation objectives were to:

- "Round out the battlespace" by using simulated entities as required for testing and demonstration (e.g., Supplemental Blue and Opposing Force Units, Ships, End User Terminals [EUTs], P3C, etc.)
- Provide certain simulated sensor message feeds (e.g., Joint Surveillance Target Attack Radar System [JSTARS], Tactical Remote Sensor System [TRSS], Guardrail, and unmanned aerial vehicle [UAV])

- Stimulate the ELB Watch Officer Workstation with OTGold and USMTF messages
- Stimulate the RMTP network with simulated EUT message traffic (JUnit and SALUTE POSREPs)

ELB employed two war-gaming simulation systems to accomplish these objectives: MTWS and JSAF. The simulations used their specialized strengths to provide the required functionality. JSAF was primarily used for higher fidelity amphibious, mine, and special operations, while MTWS was primarily used for its higher echelon battlespace representation, including rear area force and other massed troops with fewer computing resources necessary.

Joint Simulation System–Maritime (JSIMS–M)

JSIMS–M began development in the late 1990s and promises to be the next generation of advanced distributed simulation. JSIMS–M is being developed as a state-of-the-art simulation system in conjunction with the overall JSIMS Alliance. The development environment is based on object-oriented principles that use automated-code generation tools for overall reduced costs in the development and maintenance phases. In 2000, JSIMS–M became responsible for developing the Simulation Engine for the JSIMS Alliance. The Simulation Engine is based on a Government off-the-Shelf (GOTS) parallel discrete event simulation called Synchronous Parallel Environment for Emulation and Discrete Event Simulation (SPEEDES). This high-tech simulation can support faster-than-real-time operations, multi-processor systems, and simulation repeatability. SPEEDES is a simulation framework that supports simulation interoperability across a variety of parallel and distributed platforms (see Figure 3.)

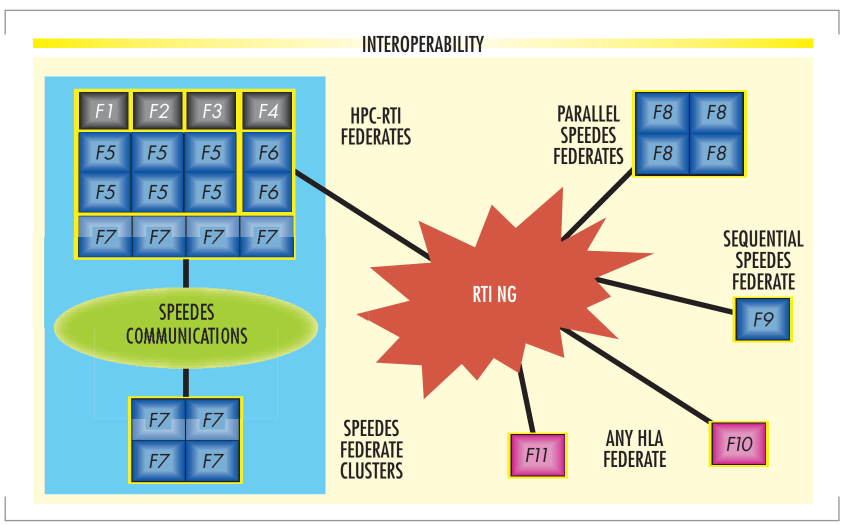

FIGURE 3. SPEEDES is a parallel discrete event simulation engine. The flexibility of the SPEEDES environment is depicted above and provides the capability of executing on one or many processors. The interoperability is maintained between SPEEDES nodes and any other HLA RTI federates.

SPEEDES development was initiated in 1990 by the National Aeronautics and Space Administration (NASA) at the Jet Propulsion Laboratory and was one of a number of simulation infrastructure projects initiated in the early 1990s that explored simulation interoperability over different computing platforms. The primary goal of SPEEDES was to provide interoperability between objects distributed across large numbers of processors while using a common simulation engine. A key feature of SPEEDES is its ability to preserve causally correct event processing in a repeatable manner without sacrificing parallel performance or constraining object interaction.

Currently, several Department of Defense simulation projects use SPEEDES to provide all or part of their core infrastructure. Besides JSIMS, there is the Joint Modeling and Simulation System (JMASS), the Extended Air Defense Test Bed (EADTB), the Joint National Test

Facility's (JNTF's) Wargame 2000, the High Performance Computing and Modernization Office (HPCMO) infrastructure, and the Defense Modeling and Simulation Office (DMSO) project in support of a Human Behavioral Representation Test Bed.

The JSIMS program will provide a simulation environment capable of meeting a broad set of requirements for training and mission rehearsal. JSIMS is a single, distributed, seamlessly integrated modeling and simulation environment. The system provides the software and hardware infrastructure necessary to support multiple training, planning-and-analysis rehearsal, education, and doctrine development events in a variety of composable configurations. JSIMS–M is the component of JSIMS necessary to satisfy Navy training needs. JSIMS–M provides the capability to JSIMS to represent all aspects and elements of the maritime operational environment needed to support the execution of joint and service scenarios, and to train JTF and JTF component staffs. JSIMS–M will ultimately replace RESA and the Enhanced Naval Wargaming System (ENWGS) in joint and Navy training environments.

The overall development of JSIMS is the responsibility of an executive structure called the JSIMS Alliance, which relies on software development from multiple Domains. The Domain Agent (DA) for the maritime component of JSIMS is the Space and Naval Warfare Systems Command (SPAWAR) (PMW 153).

As a result of Alliance-wide reorganization occurring at the end of 1999, the Maritime domain has been identified as the development domain responsible for both Maritime objects in simulation (such as naval vessels, weapons), the ocean acoustic propagation loss data, and the development of certain common components that will provide data and software services to all components of the Joint Simulation. JSIMS Maritime common components' products include the Common Components Simulation Engine (CCSE), the Common Algorithms Support Services (CASS), and the Model Driver Database Diagnostic Interface (MDDI).

JSIMS is a multi-domain, cross-service military simulation system built on HLA. The HLA enables simulation objects modeled in multiple domains to be brought together into an application-specific joint simulation known as a federation. Within the HLA Architecture, multiple Simulation Object Models (SOMs) and supporting libraries can be accessed to provide various objects and services to compose a Federation Object Model (FOM). The coordination of object models is achieved through an RTI, which operates at the federate level. Services to the RTI are provided through the CCSE directly or provided through a specialized interface, depending on the architecture of the participating federate.

High Performance Computing (HPC)

High Performance Computing (HPC) initiatives were supported throughout the decade and have focused on the ability to use distributed, extremely high performance parallel-processing systems. SSC San Diego receives funding from the HPC Modernization Program (HPCMP) through its Common HPC Software Support Initiative (CHSSI). The CHSSI Force Modeling and Simulation (FMS)/C4I FMS Computational Technology Area supports the development of a simulation run-time infrastructure for HPC (HPC-RTI). Its immediate purpose is to greatly enhance computing capabilities for HLA distributed simulations. The HPC-RTI allows parallel computers to manage multiple HLA federates on a single machine while partaking in a distributed HLA simulation (Federation). The engine for the HPC-RTI is SPEEDES, which provides time management, data distribution management, object management, etc. SPEEDES, is currently the simulation engine for JSIMS and the BMDO Wargame 2000 system, and is currently being integrated into JMASS. The HPC-RTI then provides an HLA structure for SPEEDES.

ADVANCED DISTRIBUTED SIMULATION 2000+

As we move forward into the 21st century, JSAF and HPC will continue to support advanced distributed simulation efforts, and JSIMS–M will become part of the next generation of simulations.

JSAF will continue JE support with Unified Vision 2001 (UV01), Millennium Challenge 2002, and Olympic Challenge 2004. The mission of UV01 is to support the JFCOM Campaign Plan 2001. The Joint Experimentation Directorate (J9) is conducting a concept refinement experiment integrating Rapid Decisive Operations and its supporting functional concepts, as well as preparing for Millennium Challenge 2002 and Olympic Challenge 2004.

The HPC-RTI goal is to integrate into the GCCS as part of the Defense Information Infrastructure Common Operating Environment (DII COE) in order to provide a modeling and simulation capability to the Warrior in support of C^4I. HPC will also investigate further enhancements to SPEEDES, including an integration of a Common Reasoning Engine (CORE) along with other behavior-capture mechanisms and near-optimal decision-making mechanisms to provide commander objects in a distributed parallel environment through the HPC-RTI. The HPC-RTI will provide scalability of simulation size (large numbers of objects, large numbers of decision mechanisms, and large numbers of human-like behaviors) and reliable performance with real and faster-than-real time.

JSIMS–M will continue to investigate performance enhancements to SPEEDES and critical functionality improvements. The fundamental challenge for this parallel discrete-event simulation is to efficiently process events concurrently on multiple processors while preserving the overall causality of the system as it advances in simulated time. While JSIMS–M is currently being developed as the next generation of advanced distributed simulation based largely on the simulation engine (SPEEDES) and its future direction, the generation-after-next should also evolve with the advance of simulation technologies. Enhancements in performance and affordability of parallel systems, and automation of development and interface frameworks will lead to robust, high-speed, quickly reconfigured simulations to support a plethora of military and commercial uses. The simulations will cross domains from training, to analysis, to concept exploration, to test and evaluation and more. The simulation will simplify the support of training venues that include training at multiple echelons simultaneously. For example, the medic will be trained in triage or on a patient simulator by using virtual simulators, while another medic is in the field in a live exercise entering patient encounters using a Palm-top. The encounters are fed into the overall simulation and provide medical situational awareness to the medical commander and his staff. While using the same simulation, the staff will be able to take the "real" C^4I picture off-line, and run faster-than-real-time to evaluate and analyze various courses of action. These courses of action will be interactive and allow different inputs and constraints to be imposed. The ability to accomplish most of this exists, but the ability to do it with ease, and at reasonable cost, is still difficult.

Some challenges still facing future simulation include:

Scalability/Adaptability: Can a simulation be effectively tailored to support the task at hand both in size (footprint) and functionality? For instance, can the simulation be run on a laptop to train an individual or small group while in transit to an operational area? Can it be scaled to support large task forces over multiple operational areas, including coalition forces?

Network Capacities/Load Balancing: Can the simulation be distributed via various network capacities to the sites and/or platforms involved? For instance, can the simulation be used over limited bandwidth connections to a platform or perhaps limited because of security requirements? Do nodes on multiprocessing platforms have the approximate same workload?

Multi-Echelon Training: Can modeling and simulation be cost-effective for supporting integrations of constructive, virtual, and live simulations? Can these integrated simulation solutions support multi-echelon training at the appropriate fidelity for each echelon? Can interface frameworks be developed that make interoperability between these domains affordable?

Multiple Domains: Can a single simulation architecture have the flexibility to extend through domain areas (training, analysis, research, experimentation, etc.)?

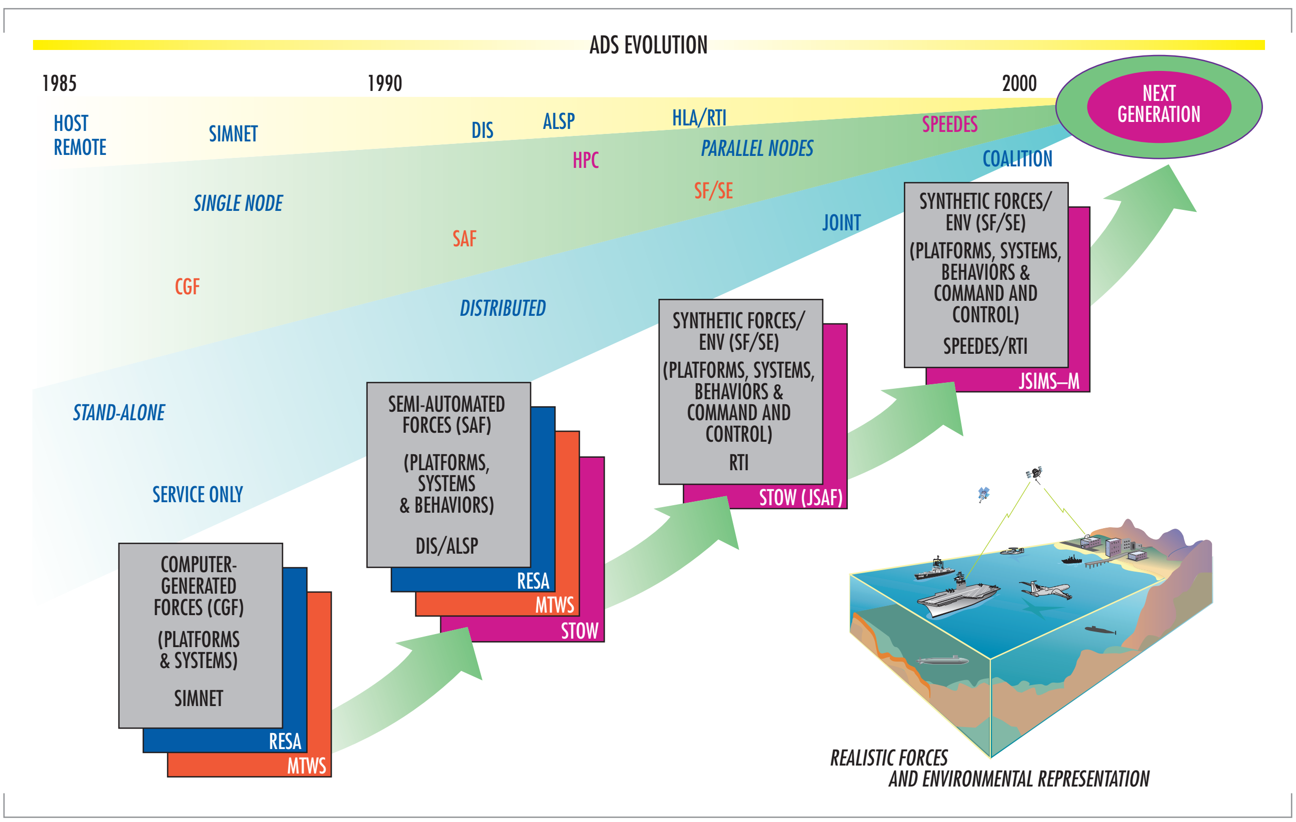

FIGURE 4. Advanced distributed simulation evolution through the 1990s and into the 21st century. Leading the way are advancements in network technologies and protocols, computer technologies, modeling representations of forces and environments, and the requirements of a more complex, diverse user community.

Modeling and simulation exposed and evolved these challenges in the 1990s. However, these are just a few of the challenges facing advanced distributed simulation in the 21st century. Next-generation and generation-after-next simulations need to address these questions, and SSC San Diego, with its simulation arsenal, will continue in the forefront of this investigation. (See Figure 4.)

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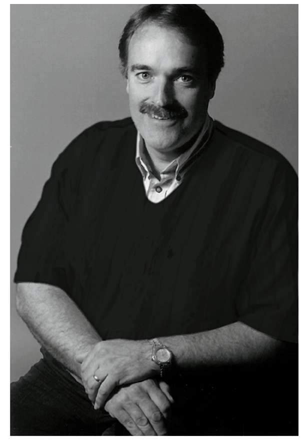

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