Beyond DoD: Non-Defense Training and Education Applications of DIS

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Invited Paper

Networked simulation for education and training is discussed as a functional capability though which Distributed Interactive Simulation (DIS) may find application in the non-Defense world. Effectiveness of networked simulation in Defense education and training applications has yet to be conclusively demonstrated, but studies completed thus far have yielded positive results. Results from non-Defense applications are also likely to be positive. The characteristics of networked simulation that are relevant to its transfer to non-Defense applications include a focus on group performance, physical dispersion of participants, requirements for real-time response, emergent task environments, visual task environments, accessible performance data, provisions for practice, immersive realism, and interactions with many entities. These characteristics are matched with potential, non-Defense applications of networked simulation such as training for crews, teams, and units, edutainment, education, training, school-to-work transitions, and lifelong learning. Remaining issues include further development of technical standards, legal standards, research and development, fiscal and regulatory policies, and development of the communications infrastructure.

I. INTRODUCTION

In this paper we view Distributed Interactive Simulation (DIS) as a Defense-developed capability that has made networked simulation technically feasible and practically attainable. In Defense applications, networked simulation allows physically dispersed participants to engage each other directly in real-time combat operations on shared, electronic terrain through the use of simulation technologies and computer networking. The focus in this paper is on the functional capabilities of networked simulation which are made possible by DIS.

As discussed by Shiflett and Lunceford [1] among others, the promise of networked simulation for enhancing Defense preparedness is substantial. Among other things, networked simulation provides manned, force-on-force environments in which individuals and military units can prepare for warfighting across a wide spectrum of activities required to attain readiness. These activities include design, development, test, and evaluation in the acquisition of military systems, training for individuals and units, development of tactics and doctrine, and rehearsal for specific missions. Networked simulation environments avoid many untested assumptions about human behavior that are incorporated in traditional or static computer-based combat models. They also avoid the artificial constraints that must be imposed on field exercises by environmental, economic, and safety considerations. On the other hand, they miss the elemental stresses imposed on combatants by conditions encountered in the field, sea, and air. The value of networked simulation is likely to decrease to the degree that these stresses influence objectives and outcomes—and increase to the degree that they do not.

Networked simulation preserves all the usual benefits of simulation. These include safety, economy, controlled visibility, and reproducibility [2]. Lives can be hazarded, materiel destroyed, viewpoints and perspective changed, and events played and replayed in ways that range from impracticable to unthinkable in the "real world" using real equipment. On the other hand, networked simulation provides only representations of real devices or situations. To a significant extent, its value keys on its ability to represent realistically those aspects of the real world that are relevant to the objectives of the exercise. In education and training, its value depends on its representation of those aspects of the task environment that affect accomplishment of the instructional objectives.

Despite the range of its current applications, the roots of networked simulation as well as DIS are in training. They were originally developed to improve the warfighting performance of crews, teams, and units [3]. The essential ingredient that networked simulation brings to the preparation of these groups is an opportunity for accessible, frequent, and realistic practice with substantive, understandable, and relevant feedback. As its principal architect, Jack Thorpe, stated [4, p. 493]: "This [concern with practice] emphasizes what we already know about how a team achieves mastery

Manuscript received December 15, 1994; revised May 9, 1995.

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IEEE Log Number 9412979.

of its art, be it a sports team, an orchestra, an operating room team, or a combat team: Massive amounts of practice are demanded. There is no substitute." Investment by the DoD in simulation technologies of all sorts has been sizable and long standing. Annual DoD research and development expenditures for simulation and training devices ranged from \$200–300 million from the mid-1970's to the mid-1980's, when they fell to about \$100 million, where they have continued to the present [5]. These figures do not include research and development investments made by the Army and the Advanced Research Projects Agency in SIMNET (Simulator Networking) and DIS. These investments totaled about \$350 million across the period 1983–1989. Aside from research and development, the DoD spends about \$1.5 billion each year to acquire and maintain the simulators it needs to meet its training requirements [6].

II. DOES NETWORKED SIMULATION WORK?

The DoD investment in simulation has yielded significant technological opportunities. For instance, Orlansky and String [7] reviewed 22 studies that, in aggregate, suggest that about 30 min of flight time is saved for every hour spent in an aircraft simulator. At one-tenth the cost of operating military aircraft, simulators may then improve the cost-effectiveness of training by a factor of five when they can be used to train tasks that would otherwise be taught using operating aircraft. Networking these simulators, which in Defense applications substantially depends on DIS, should demonstrate similar cost and effectiveness improvements in training.

However, networked simulation is a new technology and conclusive findings concerning its training impact remain to be established. The studies that have been completed thus far suffer from small sample sizes, lack of baseline controls, and inadequate test designs. Still, it is notable that no known study of networked simulation applied to training has produced negative results, as Orlansky *et al.* [5] point out. Evaluation studies of networked simulation have produced the following positive results:

- Kraemer and Bessemer [8] found that more battle runs in networked simulation produced higher scores in international armor competition.
- Gound and Schwab [9] found no differences in performance of 55 field tasks by platoons trained using networked simulation and those trained in the field.
- In a reanalysis of the Gound and Schwab data, Brown, Pishel, and Southard [10] concluded that networked simulation had actually produced superior results in 10 of the field tasks.
- Bessemer [11] compared results from 714 platoons that received conventional training in the Armor Officer Basic Course with 39 platoons that received networked simulation and found that networked simulation both improved field performance ratings by 25% and saved 20% of time in the course.
- Kelly *et al.* [12] found that the German version of networked simulation reduced navigation errors of British crews by 60%.

These findings have not escaped notice in the international community. Several nations other than the United States are now establishing plans and funding programs for applications of networked simulation. In non-Defense applications, it seems reasonable to expect networked simulation to yield similarly positive results and attract similarly favorable notice.

III. CHARACTERISTICS OF NETWORKED SIMULATION

One way to assess the applicability of networked simulation in non-Defense activities is to list its characteristics and match them with potential applications. A list of these characteristics might include the following.

1) Focus on Groups: Networked simulation is intended to improve the performance of groups, i.e., crews, teams, and units. Individual members of the groups are expected to have attained an appropriate level of proficiency in their skill specialties before they begin—they should know how to operate equipment (drive tanks), use job aids (read maps), understand objectives (carry out orders), manage subordinate groups and individuals (command and control), and so on. Both individual and group proficiency will increase with exposure to networked simulation, but the primary focus of this experience is on collaboration, coordination, and the performance of crews, teams, and units.

2) Physical Dispersion of Participants: Networked simulation allows participants who are geographically dispersed to engage and exercise with one another—without the expense and administrative complication required to bring them into physical proximity. Their dispersion is constrained only by the physical limits of the communication network they use.

3) Real-Time Responses: The DIS technology that underlies networked simulation is optimized for real-time responsiveness. It is particularly useful in simulating environments that demand responses to time-sensitive challenges that must be prioritized and met as rapidly as possible.

4) Emergent Task Environments: Networked simulation based on DIS was originally designed for tasks and activities that cannot be prespecified in any deterministic fashion. These tasks evolve rapidly over time and in response to actions taken in the simulated environment. Communication and coordination within and between individuals, crews, teams, units, and commanders are free and uncontrolled. Dynamic, nondeterministic task environments such as these are generally described as emergent [13]. More needs to be done to improve the dynamic, real-time responsiveness and the fidelity of networked simulation, but its capacities for supporting emergent task environments exceed those of many alternatives in terms of both cost and effectiveness.

5) Visual Task Environments: Networked simulation and its underlying DIS technology have been designed for environments in which the actions to be taken depend largely on visual cues. The image system is the core of networked simulation.

6) Accessibility of Performance Data: Networked simulation allows massive amounts of performance data to be

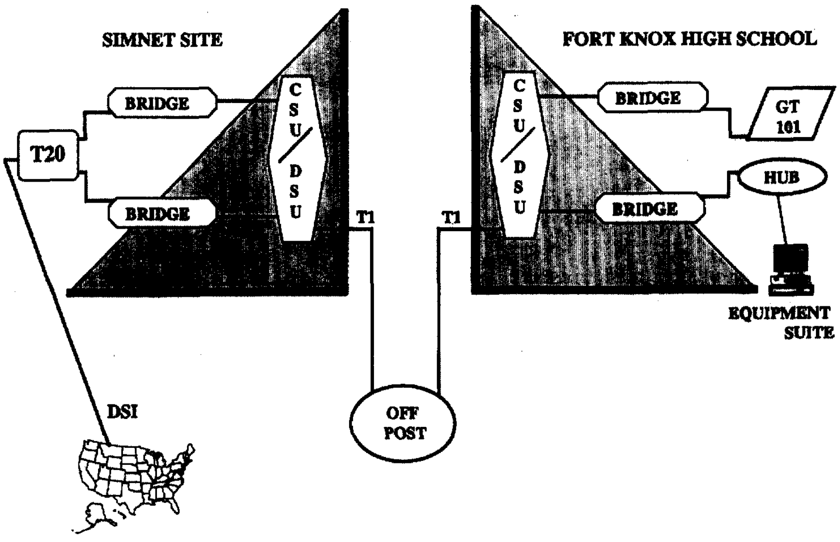

Fig. 1. Fort Knox configuration.

recorded and then easily retrieved, viewed, and assessed. Because all DIS network packets may be recorded, performance archives can all be played and replayed using the same visual, simulated environment in which they were recorded but viewed from any vantage point desired. This capability for visual and highly detailed replay provides after-action review in which actuality—rather than rhetoric or uncertain observation—drives feedback and adjudicates assessment.

On the other hand, work remains to be done to improve the capabilities of networked simulation to support analytical studies—specifically, the quantity and quality of analysis tools should be improved. Some work to achieve this objective is proceeding. More is needed and the work that is proceeding needs to be better coordinated. Nonetheless, it seems reasonable to expect that performance data from networked simulation will become more usable and accessible for analyses in the future.

7) Provisions for Practice: As discussed earlier, networked simulation is intended to provide massive amounts of accessible, affordable practice. Practice without the benefits of simulation and networking must rely on actual equipment, expertise, resources, and collaborating group members to be affordable and locally available.

8) Provisions for Realism: Ironically, the environments supported by networked simulation increase some dimensions of realism by allowing human performance to become an integrated determinate of outcomes, placing fewer constraints on force-on-force operations, reducing the quantity and impact of artificial conditions imposed by field activities, and increasing the freedom to undertake operations that would otherwise be too dangerous or costly.

9) Interaction with Many Entities: Networked simulation allows its participants to interact with a large number of entities that must respond in a realistic fashion to their actions. These entities may be either manned, computer generated but human controlled, or completely computer generated and controlled. The capabilities for computer generation and control allows the number of entities involved in the simulation to become sufficiently large to meet objectives that would otherwise be unaffordable and unattainable.

IV. BEYOND DoD—APPLICATIONS FOR NETWORKED SIMULATION

What functional requirements beyond Defense might be served by these functional characteristics? Where might the simulated environments based on DIS and the networked simulation it provides find application in the non-Defense world? The following are some suggested areas.

A. Training for Crews, Teams, and Units

Most human activity is performed by individuals working within groups such as crews, teams, and organizational units. Activities performed by these groups have substantial commercial and social value. In their review of crews, teams, and units in business and industry, Cannon-Bowers *et al.* [14, p. 355] reported a clear "consensus among those who study industrial and organizational behavior that work groups are the cornerstone of modern American industry."

The salaries commanded by professional athletes, as well as the general cessation of useful activity during major athletic events such as the World Series, World Cup, and the Super Bowl testify to the social value placed on the performance of crews, teams, and units.

Cannon–Bowers *et al.* [14] documented the requirement to train crews, teams, and units in non-Defense settings by citing examples of 21 such groups commonly found outside the military. These include quality circles, management teams, maintenance crews, product development teams, cockpit crews, surgery teams, negotiating teams, instructor teams, and athletic teams. This list could easily be augmented by the inclusion of fire fighting teams, well-drilling

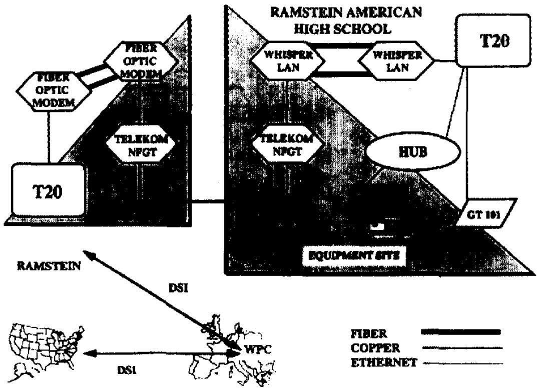

Fig. 2. Patch American High School configuration.

crews, police SWAT teams, ship crews, disaster emergency teams, and ground-air control teams. Nearly all of these noncombat crews, teams, and units must exercise group coordination and communication skills to meet emergent situations with time sensitive demands.

B. Edutainment

The sensory-immersing, motivating character of networked simulation exercises has not escaped the notice of the entertainment industry. Shopping malls, airports, waiting rooms, and other locations where video games are now found might well include simulators waiting to engage in continuous, simulated operations. Participants could join virtual or live crews to form units that perform challenging missions with or against participants who could be found at any time operating on the electronic battlefield, but who could be positioned anywhere in the physical world. The value of DIS protocols in allowing video game developers to build devices that are capable of networked connectivity and that successfully communicate with each other in real-time seems inescapable for these applications.

The challenge here is to make the missions performed by participants educationally relevant, while retaining their entertainment value. Participants might assume the role of emergency team members in civilian activities such as fire-fighting, anti-terrorism missions, or disaster relief. Realistic rules of the physical world could be brought into play—computer-generated entities would not be able to exceed their performance (in the case of machines) or ergonomic (in the case of people) limits; climatic forces would have to be understood, predicted, and managed; chemical properties of hazardous materials could be included; etc. Participants might also operate in exotic locations such as the surface of Venus, the bottom of the ocean, or inside the human body. Edutainment value would key on an individual's opportunity to engage in cooperative and/or antagonistic operations with others physically located anywhere, at any time of day, from any location supplied with a simulator, across many language and cultural barriers. The edutainment community has begun to experiment with networked simulation, but, with one or two notable exceptions, it appears to be unaware of DIS protocols.

C. Education

Students in formal educational settings are seldom required to engage in real-time, collaborative interaction as members of problem-solving teams despite the instructional value of these experiences. Teachers depend on "chalk and talk" to convey information, and students are viewed more as passive recipients of learning than as active participants in a teaching-learning process. Classrooms continue to operate as isolated entities that provide few opportunities for networking or communication with the outside world. Educational applications for networked simulation are hard to find in practice, although they are not difficult to imagine. Despite this state of affairs, today's educators increasingly emphasize the value of collaborative problem solving, project-based learning, and learning by doing. New applications of technology in education, especially networked simulation, can support the inclusion of instructional approaches that are more group-oriented, concrete, and motivating.

The most promising of these applications require students to collaborate in solving problems. The students do not learn for abstract benefits to be obtained in the indefinite future but for more practically obvious and immediately motivating rewards. Students may collaborate with others in geographically dispersed locations, satisfy real-time constraints for coordination and response, access specialized information in remote digital libraries, perform experiments using virtual laboratories and laboratory equipment that outstrip locally available resources, and interrogate subject matter experts whose specialized knowledge they need to solve the problems.

The capabilities of DIS technology and networked simulation to support these instructional applications were investigated in Fall 1993, and demonstrated to plenary sessions of the 15th InterService/Industry Training Systems and Education Conference (I/ITSEC) held in Orlando in November. Three demonstrations—Wright Flyer, World Band, and GalaxSee—were undertaken. The demonstrations involved collaborative instructional activity among four Department of Defense Dependent Schools (DoDDS): Fort Knox High School (FKHS) in Kentucky; Patch American High School (PAHS) in Germany; Ramstein American High School (RAHS) in Germany; and Seoul American High School (SAHS) in Korea [15] (Figs. 1–4). Wright Flyer and World Band activities were demonstrated in real-time, "live" presentations by DoDDS students in all four schools to plenary sessions of I/ITSEC. GalaxSee activities were shown on videotape during the same sessions. All three demonstrations at I/ITSEC were moderated by the Secretary of the US Department of Education and were intended to demonstrate the applicability and promise of military-developed networked simulation, DIS protocols, and the Defense Simulation Internet (DSI) to augment educational activities.

In the Wright Flyer project, students designed airplanes with the technology available in 1903 and then flew them over visual terrain using networked simulation software

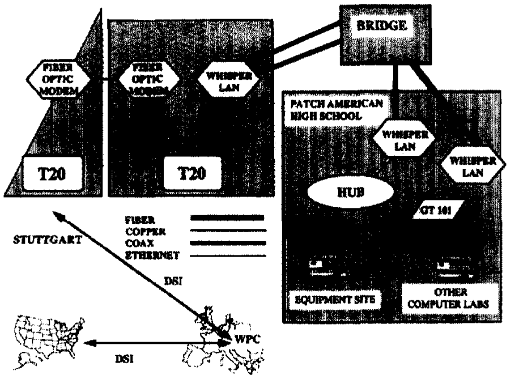

Fig. 3. Ramstein American High School configuration.

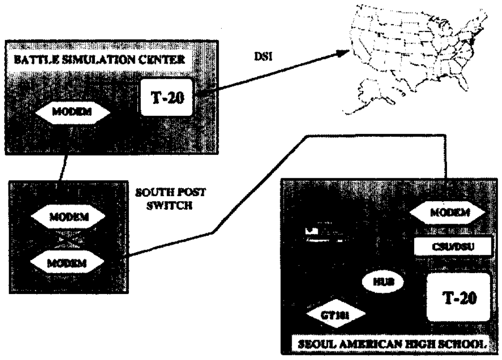

Fig. 4. Seoul American High School configuration.

that was originally designed for military training exercises. They learned about the physics of flight, the mathematics of navigation, the history of technology, and the features, both planned and unplanned, of networked computer communications. Students, teachers, project staff, and NASA experts all used DIS and the DSI to collaborate on the design of aircraft and then to demonstrate the capabilities of their aircraft to I/ITSEC attendees.

In the World Band demonstration, students at the DoD Schools performed in concert a musical composition they had arranged and orchestrated via the DIS/DSI network. To do so they used computers, synthesizers, the MIDI musical instrument digital interface, and digital effects generator. Prerecorded background music was initiated in one location and blended with accompanying music from the four school sites to the I/ITSEC audience. To accomplish this, the students had to solve the problems associated with synchronous, real-time musical performance over a network circling half of the world.

GalaxSee was fundamentally an Internet activity in which the DSI was used to provide connectivity. GalaxSee is an interactive scientific inquiry tool using a supercomputer located at the National Center for Supercomputer Applications to investigate issues of galaxy formation. The DoDDS students experimented with different numbers, masses, and velocities of stars and the supercomputer provided views of galaxies formed under these assumptions.

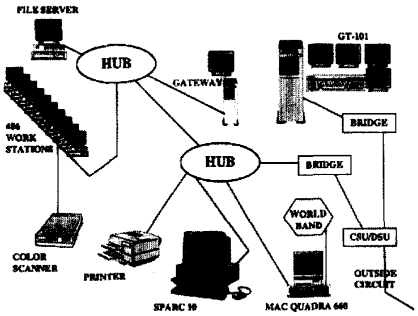

Fig. 5. Computer laboratory.

A computer laboratory to support these activities was installed at each school (Fig. 5). Among other things, the laboratory included ten 486DX-33 PC systems to use as work stations, one 486DX-50 PC system to use as a file server, a Hewlett-Packard Laserjet printer, a GT-101 display package for the Wright Flyer application, an Apple Mac Quadra 650 used both for GalaxSee and for the World Band application and its equipment (synthesizers, MIDI interface, and digital effects generators), and a SPARC station 10 to facilitate Internet access. The GT-101 package included a color image generator, three 19-in monitors to provide an out-of-cockpit panoramic view, a spaceball for controlling the aircraft, and a Silicon Graphics Indigo computer to provide a map display of aircraft locations.

To accommodate all equipment on the LAN, two 12-port, 10 Base-T ethernet concentrator hubs were installed.[1] The PC work stations, the PC file server, and a specialized gateway were connected to one hub, and the printer, SPARC station 10, and Mac Quadra 650 with its World Band equipment were connected to the other [15]. The hubs were interconnected, and one of the hubs was connected either to a bridge or directly to a T-20 gateway depending on local requirements. All equipment except for the GT-101 display package used Internet Protocol (IP) for communication. The GT-101 package used Stream 2 (ST2) protocol and was bridged directly to the outside—it was not connected to either hub.

The DSI provided long distance connectivity for the four schools. However, each site was different and connections between the DSI gateway and each school needed different accommodations to meet local requirements. With the exception of FKHS in Kentucky, temporary tail circuits were established at each school by connecting a temporary (usually borrowed) T-20 to a permanent T-20 at the nearest DSI gateway. At FKHS connectivity was made from the CONUS (Continental United States) DSI backbone to a T-20 gateway at the Blackhorse DIS site. FKHS is located off-post. The T-20 gateway, with an additional board to accommodate DSI connectivity to the high school, was connected to two parallel Gandalf bridges, a CSU/DSU

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[1] The authors are grateful to AB Technologies Inc. for their after-the-fact retrieval of technical documentation and general assistance in preparing these descriptions of the network support established for the demonstrations.

(channel service unit/data service unit), and a T-1 line leased from the local telephone company. Connectivity returned to the T-20 on a CSU/DSU and two parallel Gandalf bridges at FKHS. One bridge was connected to an ethernet hub linked to the computer laboratory package, while the other was connected separately to the GT-101 to support the ST2 protocol used by the Wright Flyer application. This bridge and modem configuration eliminated the need for a T-20 at the school.

PAHS in Germany was connected to the DSI via the T-20 gateway at European Command (EUCOM). A second T-20 borrowed from the Warrior Preparation Center in Ramstein was installed at the high school along with fiber optic modems to achieve connectivity on two separate parallel circuits. As at Fort Knox, one circuit supported the computer laboratory package on a LAN and one supported the Wright Flyer. The high school was connected via a 1000 ft fiber optic cable to the EUCOM T-20.

DSI connectivity at RAHS in Germany was similar to that at PAHS. However, in this case the link between the Warrior Preparation Center and PAHS was provided by a leased Deutsche Bundespost line that connected the T-20 at the Warrior Preparation Center to a borrowed T-20 at PAHS. As before, one circuit coming directly from the T-20 was connected to support the computer laboratory package on a LAN and the other was connected to support the Wright Flyer application.

DSI connectivity at SAHS in Germany was accomplished by connecting the T-20 at the Battle Simulation Center to a borrowed T-20 at SAHS. An initial attempt to use an aging commercial cable between the BSC and SAHS failed. Instead a tactical cable was used with four modems to establish connectivity—one at each end and two back-to-back at the cable midpoint. The tactical cable was connected at SAHS to a CSU/DSU and then to yet another borrowed T-20. The Wright Flyer was connected on one circuit from this router and the computer laboratory equipment was connected on another. Time and resources did not permit establishing a LAN at SAHS. Only the Wright Flyer GT-101, SPARC Station 10, and World Band Mac Quadra 650 were installed at SAHS.

The demonstrations at I/ITSEC were presented using large-screen displays connected to the CONUS DSI backbone via a tail circuit from the US Army Simulation Training and Instrumentation Command (STRICOM) to the I/ITSEC hotel. After the demonstrations were shown, students at the DoDDS schools were interviewed in real-time by the United States Secretary of Education who was connected to I/ITSEC displays via satellite from Washington, DC.

In December 1993, 48 students and 11 teachers involved in the Wright Flyer, World Band, and GalaxSee instructional activities completed a questionnaire concerning their experiences. Among the students, 85% or more reported that they "extremely or very much" preferred this type of learning experience to more conventional classroom instruction, enjoyed networking with other students, were motivated to work on this project, and overall, enjoyed the project. Among the teachers, 85% or more reported that they "extremely or very much" support expansion of the curriculum to take advantage of networking technologies, support expansion of the curriculum to take advantage of synthetic environment technologies, are interested in continuing the project, and overall found the project to be educationally valuable. The difficulties with the three projects noted by students and teachers in written comments exclusively concerned time pressures, need for better planning and organization, and delays in equipment delivery. They did not note problems with the content nor educational value of the three projects.

1) Training: In the commercial marketplace, major foreign competitors place much greater emphasis on developing and maintaining workforce skills than does the United States. Experienced production workers in Japanese automobile assembly plants, for example, receive three times as much formal training each year as their American counterparts. Research in the United States has shown that workers who receive formal job training are 30% more productive than those who do not [16]. Networked simulation may be key to making the training needed in our workplaces accessible and affordable. This need is especially great in small-to medium-sized firms, which have few resources of their own to devote to producing and implementing the training and lifelong learning their workers need. This need is also strongly felt by workers who, on their own, are attempting to improve their skills or transfer their skills to new areas of work. Teamwork, collaboration to solve motivating and job relevant problems, access to subject matter experts and monitors, and, perhaps most importantly, development of learning communities in our workplaces can evolve from applications of networked simulation used to meet workforce training requirements.

2) School-to-Work: Transitions from school to work and occupational choices are often haphazard and uninformed. Students need to understand and experience directly both the responsibilities and the rewards of the workplace and the "look and feel" of activity in specific occupations. Through networked simulation, students can enter into realistic workplace environments with their fellow students or with workers who have accumulated lifelong experience in these environments. They can experience in the virtual world the demands and workday challenges of entry-level positions along with the eventual satisfactions and rewards of many different occupations before committing to the training and other preparation they require for real-world participation. The school-to-work transitions that have been the target of much recent study [17] and legislation will be considerably eased if students can readily access realistic experience with the variety of workplaces to which they might aspire.

3) Lifelong Learning: All the capabilities of networked simulation should be as accessible from the work bench or kitchen table as they are from schools and learning centers. If networked simulation is a routine and fully accepted application for the National Information Infrastructure (NII), the functions listed above such as virtual laboratories, Wright Flyer, the World Band, workplace simulations, team, crew, and unit training, and collaborative, project-oriented problem solving involving dispersed participants should become as accessible as the Internet. How DSI will be used to reach kitchen tables and work benches remains to be determined, but the DIS protocols could prove essential in supporting networked simulation over the NII. If this level of accessibility can be achieved, it will make substantial progress toward creating a nationwide community of lifelong learners whose capacities for high-wage, high-skill work are developed, sustained, and updated through participation in simulated environments supported by networked simulation.

V. WHAT ARE THE NEXT STEPS?

There is, then, both a vision for ready access to high-quality, networked simulation and the challenge to bring the vision about. What is needed to meet this challenge? The following comprise a partial list:

1) Technical Standards: A market for education and training software now exists, but it is fragmented and riven by competing interests that are striving for proprietary advantage. As many have noted, competitors must decide if they want a bigger slice of the current pie, or a bigger pie. DIS technical standards for networked simulation are being developed [18], but they must be accommodated to non-Defense applications and become established and routinely observed before the stakes in this market will be large enough to attract substantial and sustained market investment. DIS standards may allow Defense industries that are knowledgeable in networked simulation to identify and establish a broader market base for their products, services, and expertise. These efforts may serve as a launching pad for these industries to enter non-Defense, civilian markets.

2) Legal Standards: Procedures for dealing with intellectual property rights must also become established before significant incentives can exist for vigorous research and development investment in non-Defense applications of networked simulation. These standards must be developed and established before the potential market for networked simulation—as well as other forms of technology-based instruction—will begin to receive the commercial attention and investment that it is capable of sustaining.

3) Research and Development: Research and development is needed to improve the technical capabilities of networked simulation itself—it is far from a mature technology. Additionally, improvements are needed in the analytical capabilities that are available for reviewing the great amount of detailed performance data available from networked simulation and in the ease with which networked simulation can be used in non-Defense applications. This is to say nothing of the need to develop the applications themselves—applications that are sustainable, scalable, and effective for use in non-Defense settings. However, support for all research and development in education and training is limited.

Overall, research and development account for about 2.5% of US Gross National Product [19]. Business invests about 2% of its sales each year in research and development. This investment pales beside the 7–23% of sales invested in research and development by high technology firms, which may better serve as models for current-day education and training. Whatever the case, the amount now invested by all sources in education and training research and development as a proportion of the national enterprise is less than 0.1%. A significant impediment to the integration of networked simulation technologies into the mainstream is lack of investment funding. The appropriate level of support for education and training research and development is difficult to determine, but the current investment is low relative to that found in other areas of national importance and should probably be increased.

4) Fiscal and Regulatory Policies: Commercial venture capitalists want to see a quick return on their investments, and changing a basic infrastructure is not in line with those expectations. The government is no different. With cutbacks in federal spending on many fronts, there is little opportunity to secure funds for large-scale projects. Nevertheless, we need fiscal and regulatory policies that either directly or indirectly reward effective and demonstrable applications of networked simulation. For instance, universal access for kindergarten through high school (K–12) education is being discussed by the Federal Communications Commission and the Congress. The issues raised in these discussions will affect the ease with which all networked applications, including networked simulation, find their way into our schools. These issues will continue to receive attention as the Congress addresses upcoming telecommunications legislation.

5) Communications Infrastructure: State governments face common issues in establishing networks to support the information infrastructure. Developing a broad-based communications architecture is a high priority issue. Several states have embarked on large scale projects to ensure interoperability at both the state and federal levels. Notable among these projects are the Iowa Communications Network (ICN) and North Carolina's "Vision Carolina."

The state of Iowa has invested about $97 million to install its comprehensive fiber optic ICN to 125 "points of presence" throughout 99 counties [20]. Iowa is expanding ICN to an additional 500 sites, which are intended to link every college and high school in the state. Iowa supports its investment by offering services to commercial enterprises, although its revenues do not yet cover the true costs of its operations. Effectively, Iowa has established a testbed for network and simulation projects. Although distance education is the main focus and service of the ICN, it is also used for computer data and Internet links, telemedicine, and telephone communications for hospitals and clinics, Iowa Public Television, and the Iowa National Guard. The Iowa Legislature recently approved federal government traffic on the ICN, facilitating the demonstration, evaluation, and transfer of networked simulation technology to state education and training uses.

The state of North Carolina is using T3 (45 Mb/s) leased telephone lines to connect 106 sites in an effort to link educational, medical, economic development, and public safety organizations statewide [20]. The total investment by the 28 sponsoring local phone companies will reach about $160 million over the next three years. The costs for both Iowa's and North Carolina's networks are exclusive of programming costs and in North Carolina sites will have to purchase the equipment they need for the applications they want.

Although these two states have been among the leaders in building communication infrastructures that are capable of supporting networked simulation, they are by no means unique. For instance, 12 of the 15 states that participate in the Southern Regional Education Board have made some investment in a communication infrastructure applied to education and training [21].

A physical layer for supporting networked simulation is, then, gradually evolving. What is missing are agreements on technical approaches for meeting the states' applications requirements in ways that help them leverage their investments. DIS protocols, architectural considerations, and functional capabilities for meeting real-time multicast communication requirements should be brought to the attention of these state-based telecommunication initiatives. Outreach from the Defense community would help accomplish this objective.

VI. FINAL WORD

Networked simulation will give teachers, students, workers, and instructors access to a great variety of instructional resources and to each other. Steps have already been taken to effect the transfer of this technology to civilian applications. Some have been technical, such as the effort to develop DIS technical standards [18] and standards for developing portable courseware now documented in Military Standard 1379D [22]. Others have been promotional, such as the "Wright Flyer" and "World Band" demonstrations. Still others have been less direct, but no less significant, such as the creation of the cross agency Committee on Education and Training which reports to the National Science and Technology Council and of the cross-association National Coordinating Council on Technology in Education and Training. More needs to be done, but with outreach achieved through the cooperation and support of the DIS community the transfer should succeed and enhance the productivity of learning across many non-Defense applications.

REFERENCES

[1] J. Shiflett and D. Lunceford, "DoD applications of DIS," *Proc. IEEE,* this issue.

[2] J. R. Raser, *Simulation and Society: An Exploration of Scientific Gaming.* Boston: Allyn and Bacon, 1969.

[3] E. A. Alluisi, "The development of technology for collective training: SIMNET, a case history," *Human Factors,* vol. 33, pp. 343–362, 1991.

[4] J. A. Thorpe, "The new technology of large scale simulator networking: Implications for mastering the art of warfighting," in *Proc. 9th InterService/Ind. Train. Syst. Conf.,* Amer. Defense Preparedness Assoc., Arlington, VA, 1987, pp. 492–501.

[5] J. Orlansky *et al.,* "The value of simulation for training," IDA Paper P-2982, Inst. for Defense Analyses, Alexandria, VA, 1994.

[6] *US Military Trainers and Simulators Markets.* New York: Frost and Sullivan, 1993.

[7] J. Orlansky and J. String, "Cost-effectiveness of flight simulators for military training," IDA Paper P-1275, Institute for Defense Analyses, Alexandria, VA, 1977.

[8] R. E. Kraemer and D. W. Bessemer, "US tank platoon training for the 1987 Canadian Army Trophy (CAT) using a simulation networking (SIMNET) system," ARI Rep. 1457, US Army Res. Inst., Alexandria, VA, 1987.

[9] D. Gound and J. Schwab, "Concept evaluation program of simulation networking (SIMNET) final report," TRADOC TRMS 86-CEP-0345, ACN 862299, US Army Armor School, Fort Knox, KY, 1988.

[10] R. E. Brown, R. E. Pishel, and L. D. Southard, "Simulation networking (SIMNET) preliminary training developments study (PTDS)," TRAC-WSMR-TEA 8-88, US Army Armor School, Fort Knox, KY, 1988.

[11] D. W. Bessemer, "Transfer of SIMNET training in the armor officer basic course," ARI Tech. Rep. 920, US Army Res. Inst., Alexandria, VA, 1991.

[12] M. Kelly *et al.* "Combined arms tactical trainer (SR(L)4060) LSOR2 trials: Overview report on AGPT and SIMNET phases," APRE Rep. 94R026, Army Personnel Res. Establish., Farnborough, Hampshire, UK, 1994.

[13] H. Wagner, N. Hibbits, R. D. Rosenblatt, and R. Schulz, "Team training and evaluation strategies: State-of-the-art," HumRRO TR-77-1, Human Resources Res. Org., (DTIC/NTIS No. ADA 038 505), Alexandria, VA, 1977.

[14] J. A. Cannon-Bowers, R. Oser, and D. L. Flanagan, "Work teams in industry: A selected review and proposed framework," in R. W. Swezey and E. Salas, Eds., *Teams: Their Training and Performance.* Norwood, NJ: Ablex, 1992.

[15] Annu. Rep., "DoDDS project," AB Technologies, Alexandria, VA, 1994.

[16] US Congress, Office of Tech. Assess., *Worker Training: Competing in the New International Economy,* OTA-ITE-457, US Govt. Printing Office, Washington, DC, 1990.

[17] US Dept. Labor, *What Work Requires of Schools: A SCANS Report for America 2000.* Washington, DC: US Govt. Printing Office, 1991.

[18] R. Hofer and M. Loper, "DIS today," *Proc. IEEE,* this issue.

[19] L. J. Perelman, "Closing education's technology gap," Briefing Paper No. 111, Hudson Instit., Indianapolis, IN, 1989.

[20] NIST, "A transformation of learning: Use of the NII for education and lifelong learning," in *Putting the Information Infrastructure to Work,* Rep. of Information Infrastructure Task Force Comm. on Applications and Tech., NIST Special Publication 857, Gaithersburg, MD, 1994.

[21] S. E. Jones, "Educational technology: K–12 planning and investments in the SREB states," Southern Regional Education Board, Atlanta, GA, 1994.

[22] US Dept. Defense, *Military Standard, Military Training Programs, MIL-STD-1379D.* Washington, DC: US Govt. Printing Office, 1990.

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