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DIS Testbed Research And Development: Work Plan Report #1
CDRL A005

Brian Goldiez

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DIS Testbed Research and Development

Work Plan Report #1

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Division of Sponsored Research
DIS TESTBED RESEARCH AND DEVELOPMENT

NTSC TRADE Contract # N61339-91-C-0103
STRICOM Contract Monitor: Karen Danisas
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August 12, 1992

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1.0 INTRODUCTION

This plan describes IST's approach to accomplish the research tasks laid out in the contract entitled, "Investigation of OSI Protocols for Distributed Interactive Simulation" as modified by the Engineering Change Proposal (ECP) entitled, "DIS Testbed Research and Development" contract number N61339-91-C-0103. This research contract is funded through the NTSC Broad Agency Announcement 91-02. The basic contract, noted above, has been completed. This ECP is a logical addition to the project activities. The original contract was limited because a testbed was not available for implementing DIS using various communication mechanisms. This research project develops those capabilities by creating a testbed for implementing, testing, and evaluating DIS. The approach outlined in the ECP and this work plan ensures that an environment is available to fully evaluate DIS prior to any implementations in the public or private sectors.

1.1 PROJECT OBJECTIVES

IST's general objective for this project is to hasten the use of networking in real time simulation and to reduce the risk associated with the introduction. In particular, IST is interested in research involved with the performance, evaluation, and optimization of Distributed Interactive Simulation (DIS) data units and communications in actual real time simulation. A DIS testbed will be created to meet this general objective.

The DIS testbed will implement the DIS Standard on various communication stacks. The stacks will be aligned to match activities from the DIS standards and related communications efforts. Included will be the various sets of PDUs as they evolve as well as the communication system, data bases, etc. IST's intention will be to provide a rapid prototyping environment for DIS ideas, strategies, standards, etc. This approach will allow
the DIS community to evaluate alternatives based on data, not conjecture. Specific tests could be conducted by sponsoring organizations with support from IST. All test methods and results will be available for reproduction.

This testbed will contain one of the many protocol translators currently under development. The protocol translator will allow access to STRICOM's SIMNET hardware at IST for a more complete DIS environment than currently available. Connectivity to the Terrestrial Wide Band (TWB) network will be through facilities at STRICOM via a commercial off the shelf microwave (or other similar type) device.

The specific objectives IST hopes to meet as a result of this research project are as follows:

- Development of a DIS testbed. A minimal DIS testbed should be implemented in a short period of time to support the demonstration and evaluation needs of the DIS community. A full DIS testbed is necessary in the long term.

- Creation of an approach to testing DIS. This objective involves developing methods and procedures to evaluate the syntax and semantics of DIS. The entire structure of DIS should be subject to evaluation.

- Development of an easy to reach DIS network. If DIS is going to be useful, organizations should have access to a DIS network. Such a network can be used as a learning tool, as an experimental tool, or as a mechanism to evaluate individual DIS strategies.

- Generate and document DIS data and test concepts. Many organizations are experimenting with simulator networks. Data must be collected, catalogued, and documented so that others can analyze DIS for their own needs prior to
building hardware and software.

- Evaluate DIS concepts. Standards can be evaluated and tested prior to acceptance. Ideas can be evaluated in a test environment prior to financial or contractual commitments.

1.2 PROJECT TASKS

The technical approach taken to meet the objectives of this project will consist of three primary tasks: 1) testbed development and implementation, 2) interface support, and 3) testing/testbed operations. These tasks are further explained along with subtask definition in the paragraphs which follow. These task descriptions, therefore, form the bridge between the proposal and the equivalent of a specification, as it will guide the conduct of the research activities of this project.

TASK 1: Testbed Development and Implementation

This task includes the design, development, and implementation of a DIS testbed. The design of the testbed will support a wide range of user needs. It will provide verification of the DIS standards process, provide a tool for DIS implementers, and function as a standing demonstration mechanism which facilitates the promulgation and expanded use of DIS. The design must therefore be flexible with respect to configuration and architecture.

The testbed will be developed using modular designs. Modularity is extremely important for several reasons. First, the testbed is to be designed to grow with DIS. This requires that the testbed be able to accommodate protocol data units, protocols, and communication services that are known, as well as those that may be envisioned. This modularity could result in a reduction in performance, however. Well defined interfaces will be established.
and testbed performance will always be evaluated as a trade off against modularity. These trade offs and the resulting designs will be available to internal and external scrutiny.

The second reason modularity is important is due to schedule. Task 3 (to be described in subsequent sections) has a requirement for a minimal testbed to support the I/ITSC Conference in November, 1992. There are also subsequent capabilities required to accommodate DIS 1.0 and the various communications architectures under consideration in the Communication Architecture and Security Subgroup of the DIS Standards effort. Cost as well as schedule dictate retaining as much commonality as possible through modularity.

The testbed will be designed to use off the shelf components to the maximum extent practical. The reasons for this decision are the same as those for modularity. In addition, though, interfaces to off the shelf components are well documented and available to the general public. Parallel development efforts will also be enhanced by using off the shelf components.

**TASK 2: Interface Support**

An important aspect of a testbed is assisting those who may wish to use it. This task defines a mechanism to implement such support. There are three aspects of this support which will be provided by IST. The first is to support those who may wish to use DIS software and hardware designs developed by IST. The second is to demonstrate integration of non-DIS systems into the testbed (DIS systems should interface and integrate more easily than non-DIS systems. DIS systems will be integrated into the testbed as part of Task 1). The third aspect is to support organizations wishing to implement DIS. IST expects to learn a lot about DIS in the process of implementing this testbed. This knowledge will be transferred to those wishing to use DIS.

**TASK 3: Testing/Testbed Operations**

This task includes developing and conducting simulator networking tests, integrating new technologies and methodologies
into testing, and sustaining the testbed's day to day operations. Four types of tests will be conducted. Two types of tests are at the subsystem level; the other two are system level tests. All tests will use SIMNET 6.6.1 as a baseline. New technologies appropriate to DIS will be pursued. In particular, IST will continue to pursue integrating Open Systems Interconnection (OSI) into DIS. Also, test methods will be developed which track product development and provide for early verification of interoperability. Finally, the testbed will be demonstrated and operated on a continual basis. Effort must be expended for routine operations and planned for special operations.

Testing will cover hardware, software, and paper products (e.g., the DIS Standard). The testing methodology will use a bottom up approach. Discrete tests will be developed for communications, protocols, data, applications, and systems. The Item Under Test (IUT) can be a simulator, a new PDU, a different communications architecture, etc. The IUT will be integrated into an existing simulator, if necessary, and a DIS network to perform quantitative and qualitative tests. Downward compatibility with older versions will be ensured.

New technologies and test methods will be studied and integrated into the testbed. The purpose of these integrations will be to hasten the introduction of new technology into DIS, to influence the development of standards, and to enhance the ability to verify and validate interoperability early in the development cycle. In particular, OSI has been suggested as an architecture for supporting DIS. Effort will be expended to continue this research. Also, techniques will be developed to assess interoperability early in an item's development cycle.

The testbed operation must be consistent with the development and use of the testbed. Personnel must be available to operate and administer the testbed. In addition, several demonstrations are planned and will require staff support to assure success.

2.0 DETAILED DESCRIPTION OF TASKS

A detailed description of the three major tasks and their
subtasks is presented below. The following paragraphs describe the goals, subtasks and deliverables for each of the three primary tasks comprising this project.

Each of the subtasks will be described in the following manner. First, there will be a description of the subtask as described in the ECP. Second will be an optional section which further explains the subtask. Third will be a description of the product which results from the effort expended in the subtask.

2.1 TASK 1: Testbed Development and Implementation

One design report will be used to document all phases of Task 1. The report will be structured in a manner which tracks the subtask descriptions which follows.

2.1.1 Subtask 1.1 Systems Design

Proposal: A design will be developed by IST which supports STRICOM's needs, is consistent with IST's other research efforts, and meets the needs of the DIS community. IST will coordinate with Loral to ensure the testbed is consistent with the DIS architecture and the needs of BDS-D.

The testbed will initially include the SIMNET equipment (2 M-1 Simulators, MCC, Stealth, PVD, Data Logger, and BBN SAFOR) on loan to IST, and the IST developed SAFOR. The configuration of this equipment at IST necessitates that either two M-1 simulators are used without the Stealth or that one M-1 simulator be available simultaneously with the Stealth. This restriction is due to the availability of only two SIMNET image generators at IST. Computing resources acquired under N61339-89-C-0045 (Aviation Technology) will be integrated into the testbed to support data logging and to provide hardware for an operator control station. Additional hardware and software envisioned in the baseline testbed includes procurement of a DIS/SIMNET protocol translator, connectivity to outside communication services, and computing and communication
resources appropriate to the development and demonstration of a DIS network (minimally envisioned to include 4 Intel 486 PC or Motorola VME based computing resources, hard disc capacity, printers, peripheral equipment, TCP-UDP/IP software, Ethernet (IEEE 802.3), FDDI, and other hardware and software necessary to interface computing and simulator resources in a cost effective manner, such as serial interfaces, parallel interfaces, etc.). The additional hardware is necessary to develop a DIS network and to minimize disruption of other on-going research efforts at IST.

Additional Description: STRICOM's needs are further defined to include the requirement to create a testbed design which supports evaluation of the DIS Standard, satisfies the maximum number of BDS-D exit criteria as defined in various STRICOM documents, and takes advantage of existing designs and procurements made by Loral under the ADST contract. If feasible, the design should also support integration of other government simulation assets, such as those which may be identified by NTSC or Armstrong Laboratories.

IST will use the computing hardware from the Aviation Trainer Technology Program to rehost a PC based data logger. Additional computing resources (i.e., 486 computers) will be used to build a flexible interface to the DIS network where one computer could be used to pull information off the network and send it on to a simulator and another computer could take the data from a simulator and send it on to the network. Other arrangements are acceptable as long as flexibility is maximized and adverse performance impacts are minimized. Flexibility should be provided for several network interfaces, for a variety of protocol stacks, and for interfacing to a simulator. For example, an alternate arrangement could have one computer serve as a network interface (bi-directional) and the other computer serve as a simulator interface. Providing a high performance interface (e.g., IEEE 488) between these computers also meets the general flexibility requirements.

As a goal, the design of the testbed should support the following communication protocols and external linkages:

- IEEE 802.3 (Carrier Sense Multiple Access with Collision
Detection

- ETHERNET
- Fiber Distributed Data Interface (FDDI)
- Transmission Control Protocol (TCP)
- User Datagram Protocol (UDP)
- Internet Protocol (IP)
- SIMNET ASSOCIATION Protocol
- DIS Protocols as developed
- Connection to T-1 or the Terr. WideBand Network (TWB)
- Connection to the Loral installed 56 kbs service at IST
- 1-800 service using commercial circuits

**Deliverables:** See the explanation provided in Section 2.1, above.

### 2.1.2 Subtask 1.2 Interface with SIMNET Equipment

**Proposal:** Interface with IST's existing SIMNET equipment and laboratory efforts which use SIMNET or develop in a SIMNET environment. This will provide a robust and heterogeneous environment for DIS test and evaluation.

**Additional Description:** IST will implement this subtask by procuring a protocol translator from TSI. This translator will have limited capability. For example, only four PDUs (those necessary for the I/ITSC demonstration) will be available. Please see the Statement of Work to TSI for further details.

After the I/ITSC demonstration, IST will have gained knowledge in the operation and performance of the TSI protocol translator. At that time, IST will assess four alternatives for expanding the protocol translator's capability. One alternative will be to modify the TSI protocol translator at IST to provide translation to all ten DIS 1.0 PDUs. A second alternative will be to contract with TSI to modify the translator to accommodate the remaining 6 PDUs, not provided in the original TSI protocol translator. The third alternative will be to procure or use a translator from another vendor (Loral is purported to be developing a translator
for the CSRDF to AIRNET program). The fourth alternative is to use the TSI translator, as originally delivered, because enhancement is not cost effective. The analysis and resulting decision must be documented.

This subtask will also support the initial effort necessary to modify IST's developed systems to be compatible with the four DIS 1.0 PDU's identified as necessary for the I/ITSC demonstration (subtask 3.5). The four PDUs are Entity State, Fire, Detonation, and Collision. Compatibility with UDP/IP will also be required. Modification to IST developed software includes the IST developed PC based Computer Generated Forces and data logger software. IST will attempt to modularize the above software items to make future changes easy to effect. The changes made to IST software will be documented by revising existing documentation and in-line documentation within the software. The IST developed software is undergoing constant change. This effort will only work on the most recent change in effect when this subtask commences.

**Deliverables:** See the explanation provided in Section 2.1, above.

### 2.1.3 Subtask 1.3 Long Haul Connectivity

**Proposal:** Interface with a T1 phone line and the TWB network to be located at STRICOM/NTSC. Line of sight microwave, or other similar approaches, are acceptable.

**Additional Description:** T1 phone service has limited appeal (due to cost) outside of DoD. However connectivity to the Terrestrial Wide Band Network (TWBNet)/ Defense Simulation Internet (DSI), 56 kbs from Loral ADST, and (800) service is desirable for several reasons. First is the ability to conduct remote testing and collaboration with other government, academic, or industrial organizations. Second is the appeal of a high performance network and the ability to study a heterogeneous mix of simulations. Third is the possibility of providing an access point to organizations
who may not have access to a simulation network. Fourth is the ability to provide a low cost connection point for DIS to almost anyone.

Before connectivity to these networks can be designed, the interfaces, performance, access points, access methods, and rules of usage must be determined and documented and presented to STRICOM for approval. Once the above matters have been determined, a connectivity design must be developed. IST must also determine how its network can cost effectively link to the TWBNNet/DSI located at STRICOM. Microwave, Laser, or Infrared linkages are available. However, trade-off analyses must be conducted to determine which method is most cost effective within the budget allocated in IST's proposal. The results of this analysis must be documented.

**Deliverables:** See the explanation provided in Section 2.1, above.

### 2.1.4 Subtask 1.4 New PDUs

**Proposal:** The ability to accommodate new PDUs will be developed and provided. This accommodation will be based upon our understanding of new PDUs which have been suggested at all standards meetings up through the March, 1992 standards meeting. Additional PDUs which may be proposed in the future will be implemented to the extent feasible (subject to cost, technical, and
programmatic considerations of this and related projects).

Additional Description: IST is currently implementing four PDUs in conjunction with an interoperability demonstration for I/ITSC. The four PDUs are Entity State, Fire, Detonation, and Collision. DIS versions and test procedures for these PDUs are also being developed. There are six other PDUs in DIS Version 1.0. These PDUs are Service Request, Resupply Offer, Resupply Received, Resupply Cancel, Repair Complete, and Repair Cancel. These six additional PDUs will be implemented in months 7 through 12. IST's proposal reflects implementing the ten PDUs in the DIS 1.0 standard and two new PDUs, an emitter PDU and a PDU which may be needed to
support interfacing with wargames, such as an aggregation/disaggregation PDU. Any effort required to accommodate the PDUs into the testbed is included in this subtask. Such effort will include modification to IST systems developed as part of other projects (e.g., CGF) as well as software and systems developed as part of this project (test drivers). Because the extent of modification is not known, a list will be created which identifies the system to be modified, the extent of modification necessary, and the effort necessary to implement the modification. This list will be prioritized and coordinated internally and with STRICOM prior to any modifications taking place.

This subtask will also support the effort necessary to modify systems developed by IST to be fully compatible with DIS 1.0 (May 10, 1992 version of the DIS standard). Included will be the IST developed Computer Generated Forces software and data logger software. IST will attempt to modularize the above software items to make future changes easy to effect. The changes made to IST software will be documented by changing existing documentation and in-line documentation with the software. The IST developed software is undergoing constant change. This subtask, therefore, will only apply to the most recent change in effect when this subtask commences.

DIS 2.0 PDUs will be evaluated for compatibility with the testbed design. These PDUs could be very fluid in their definition. Therefore, where possible, plans will be made to accommodate the DIS 2.0 PDUs although no actual implementation into the testbed is included in this effort.

Deliverables: See the explanation provided in Section 2.1, above. In addition, this subtask will modify existing documentation on the systems modified by IST. In-line documentation of software code will also be developed.

2.1.5 Subtask 1.5 New Protocols

Proposal: The ability to accommodate a variety of protocols will be provided. This accommodation will be based upon our
understanding of new protocols which may be contemplated for DIS based upon all standards meetings up through March 1992. Additional protocols (especially lower layer implementations) which may be proposed in the future will be implemented to the extent feasible (subject to cost, technical, and programmatic considerations of this and related projects).

**Additional Description:** The ability to accommodate a variety of protocols is also included in IST's proposal. This accommodation can only extend within the IST testbed's Local Area Network. There are some limitations which are noteworthy. First, the ability to accommodate FDDI will be limited to certain portions of the testbed. IST's Computer Generated Forces System, which is a key component of the testbed, is currently being reconfigured to support a variety of network protocols, including FDDI. However, with this increased flexibility comes a decrease in performance. The performance decrement is currently unknown, but will be evaluated using UDP/IP and Ethernet. The performance impact of interfacing to FDDI will be evaluated during the conduct of the research effort.

The ability to accommodate FDDI will be restricted to the IST development network. The protocol translator from TSI does not support FDDI, nor do the SIMNET units. It is unknown if the Aviation Situation/Awareness Trainers (ASATs) at IST can be designed to accommodate FDDI. IST will investigate the feasibility of implementing FDDI on the ASATs and proceed after discussing programmatic impact with STRICOM. Therefore, new network architectures will have a limited range of testing due to hardware limitations. IST will attempt to work with vendors to expand the range of hardware systems capabilities on the network. IST's attempts will be limited to discussions with vendors in general. In the case of Loral, IST will attempt to work collaboratively to achieve testbed flexibility through periodic design meetings with Loral staff.

This task will also include the effort necessary to modify IST developed products to be compatible with a variety of communications protocols. As noted in task 1.4, above, a list of
IST developed products on the testbed will be compiled. The benefits resulting from accommodating new communications protocols will be assessed. The effort required to make the accommodation will also be assessed. The resulting list will prioritized and coordinated internally and with STRICOM prior to implementing alternate communication protocols.

Deliverables: See the explanation provided in Section 2.1, above. In addition, this subtask will modify existing documentation on the systems modified by IST. In-line documentation of software code will also be developed.

2.1.6 Subtask 1.6 DIS Simulator Interfaces

Proposal: Interface with new DIS compatible simulators. This interface hardware and software will add further definition to the term "Cell Interface Unit" in the DIS architecture.

Additional Description: IST will coordinate with Loral on the development of their Cell Interface Unit (CIU). IST will attempt to borrow a CIU to interface with the testbed network. IST will connect its DIS version of CGF to the CIU. Tests will be developed (see subtask 3.3) which evaluate the performance and operation of the CIU.

Deliverables: See the explanation provided in Section 2.1, above. In addition any tests will be documented in the appropriate testing document.

2.1.7 Subtask 1.7 non-DIS Simulator Interfaces

Proposal: Interface with non-DIS compatible simulators. This interface hardware and software will add further definition to the term "Cell Adapter Unit" in the DIS architecture.

Additional Description: IST will coordinate with Loral on the development of their Cell Adapter Unit (CAU). IST will attempt to
borrow a CAU to interface with the testbed network. IST will modify and connect its Aviation Situational Awareness Trainers (ASAT) to the CAU. Tests will be developed (see subtask 3.3) which evaluate the performance and operation of the CAU.

**Deliverables:** See the explanation provided in Section 2.1, above. In addition any tests will be documented in the appropriate testing document.

### 2.2 TASK 2: INTERFACE SUPPORT

#### 2.2.1 Subtask 2.1 Support to DIS Sites

**Proposal:** Support to organizations wishing to implement any IST developed testbed hardware or software. This activity will include telephonic support for any organization approved by STRICOM, installation of testbed software (subject to hardware and software commonality) at ADST sites at Ft. Knox and Ft. Rucker, and installation (subject to hardware and software commonality) at the IDA simulation facility in suburban Washington, D.C. Two installations per site per year are envisioned. IST will seek support from the ADST contractor to ensure minimal down time.

**Additional Description:** IST will need to determine the configuration of hardware and software at each of the sites noted above. If hardware is different from the configuration at IST, an assessment will be made as to the level of rehosting effort. IST will then coordinate with STRICOM to ensure that the labor and travel budgeted in the proposal is appropriately applied to the sites most critical to STRICOM's needs.

**Deliverables:** IST will maintain a log of queries and installation experience (by using trip reports).

#### 2.2.2 Subtask 2.2 non-DIS Installations
Proposal: Integration and installation of non-DIS systems at the IST testbed. These activities are distinguished from task 1, above, by consideration of specific installations at IST which may be desired by the government. Two installations per year are envisioned at this time. The first installation would be the integration of UPAS with the testbed and the second would be installation of the ASAT units into the testbed. Other installations are at the discretion of the government and are limited to IST defining testbed capabilities, descriptions of hardware and software, and labor support. Modifications to the testbed are not envisioned by IST to accommodate one time or infrequent use of testbed capabilities.

Additional Description: IST will reverse the order of installations (ASATs will be installed first, followed by UPAS). The reason for the change is that further enhancements are being planned to UPAS. Until the UPAS baseline stabilizes, incorporation into the testbed is not advised. After UPAS is stable, an assessment will be made to determine the best method to interface with the testbed (i.e., modification of UPAS internal software, the use of a translator, or the use of a CAU).

The ASATs will be incorporated into the testbed; however, the current configuration of the ASATs does not provide for additional software to be added. In addition, the existing system is tightly coupled. IST will identify the timing and memory requirements necessary to put ASAT onto the testbed network. IST will study the source code to determine specific areas of code which can be deleted to provide space for a software interface to a CAU. The performance of the ASAT will be evaluated to assure minimal adverse impact results from the software deletion.

One additional installation is discussed in the proposal. Based on recent discussions with STRICOM it appears that NTSC may be a candidate for providing a non-DIS entity onto the network. Any device in this task should be located at IST for convenience of access and testing. IST will continue to refine installation approaches by first pursuing the NTSC system.
Deliverables: IST will maintain a log of queries and installation experience (by using trip reports).

2.2.3 Subtask 2.3 Organizational Support

Proposal: Support to organizations wishing to implement DIS. IST envisions the testbed will be used for first time implementations of DIS or the evaluation of competing DIS concepts which may arise from the standards process. The knowledge gained from these implementations will be documented (identified elsewhere in this proposal). However, this sub-task also provides telephonic support (to the extent provided by labor estimates) to organizations which may require consultation for their individual DIS implementations. Consultation will be limited to STRICOM designated organizations (envisioned at this time to be the Army activities at NASA Ames and Ft. Leavenworth). Other support will be provided to no more than 10 government or industrial organizations on a first come first served basis at no more than 8 labor hours per organization.

Additional Description: IST will get approval from STRICOM prior to expending effort on this project consulting to organizations wishing to implement DIS.

Deliverables: Written log of consultation and approving official.

2.3 TASK 3: TESTING/THEORY OF OPERATION

This task includes the development, execution, recording, and analysis of interoperability tests. Testing will use a bottom up approach. Such an approach aids isolation of problems. In addition, deductive testing will be the preferred testing method. Inductive testing will be used if deductive testing is not practical. In deductive testing, one sets up acceptance criteria ahead of time, conducts a tests, records observations, and deduces
acceptable performance from the data. In inductive testing, one does not develop rigorous tests, but instead lets a system operate and infers acceptable performance from observing the operation.

IST will attempt to obtain all test data from the network. This approach avoids intrusion into the simulator and problems associated with proprietary data. However, there may be instances where test data is not available on the network (e.g., visual system correlation). In these cases IST will identify the data needed, notify the DIS Standards efforts of the data requirements along with a method to obtain the data, and attempt to obtain the data (on an interim basis) directly from the system under test.

Four types of tests will be conducted. Two types of tests are at the subsystem level; the other two types of tests are system level tests. All tests will use SIMNET 6.6.1 as a baseline.

At the subsystem level IST will conduct Application Layer Tests or Protocol/Network Level tests. Specific tests will be dictated by the particular DIS requirement. For example, the development of new PDUs will be evaluated compared to a mathematically rigorous and physically based datum (Application Layer Test) along with an evaluation of network impact (Protocol/Network Level Test). DIS requirements which only impact network performance will only be evaluated using a Protocol/Network Level Test.

System level tests will consist of quantitative and qualitative evaluations. The purpose of system level tests is to evaluate the impact of individual DIS changes or enhancements on system level performance. IST will develop criteria for these tests based upon on-going research efforts in the DIS standards project and previous research at IST in networking and aviation technology.

2.3.1 Subtask 3.1 Applications/Application Layer Tests

Proposal: Application Layer Tests will be developed based on mathematically rigorous and physically based principles. IST will use a methodology previously developed under contract to Loral for rotor modeling. We will extend this methodology to other domains.
of interest to the DIS community, specifically modeling of environmental conditions created from a radar environment, dead reckoning, and a complete vehicle dynamics model of a helicopter.

The methodology developed under contract to Loral consists of developing rigorous mathematical routines to model a particular system or physical phenomenon. The algorithms are completely decoupled to allow evaluation of specific phenomena. IST has worked with such models for helicopter dynamics (limited) and dead reckoning. We will ask for government support in acquiring baseline models for analysis. If government support is not available, IST will obtain models through public domain sources. However, such models are often less complete than government supplied models.

IST will analyze the particular model implementations proposed for the DIS implementation. Specifically, IST will evaluate CSRDF/AIRNET, the proposed radar/emitter PDUs, and the dead reckoning models in the DIS standard. The analysis will identify areas missing or not fully covered in the specific DIS implementation as compared to the rigorous baseline model. Other systems can also be compared to the rigorous model. Performance differences are then always compared against a known baseline (i.e., the rigorous model) and an assessment can be made of interoperability between different modeling methods.

The approach described above will be compared to the qualitative system tests (described below). This approach will provide corroborating data points for acceptable system performance.

Additional Description: The use of a mathematical or physical datum is a technique to compare the fidelity of electronic or mechanical simulations. The technique involves establishing an ideal set of criteria which are used to evaluate other simulation model implementations. The criteria must be valid and must be measurable using consistent methods across the environments of interest.

An example can best illustrate this technique. Consider the case of helicopter dynamics. Ideally one would use a full fidelity
model of a helicopter as a datum. Such a model would contain the fully coupled equations of motion of the helicopter; a computational fluid dynamics model of the rotor, tail rotor, and body; an ICAO atmosphere model, and a full weather model. Each of these models would have been separately validated against actual data (flight test, whirl stand, or weather). The models would also have been validated as an integrated system against an actual air vehicle flight test.

A standard set of maneuvers is used for comparison. The idealized model is maneuvered and time histories are generated (maneuver types can be obtained from the Naval Air Test Center Test Pilot School documentation which is used by the Army for helicopter flight testing). These time histories should be consistent (through reformatting) with the DIS PDU standard. DIS simulators are also put through the same maneuvers. The time histories are compared (or in the case of an electronic system, appropriate parameters are accumulated and compared). An analysis of the models (with all other parameters held constant, such as the visual system characteristics) can then estimate if interoperability will be a problem based on the one parameter (i.e., the mathematical model) of interest. The estimate can then be cross checked against actual network experience obtained during subjective evaluations.

IST realizes that several sources may be available for the so-called "Idealized Model". IST prefers the models to be validated using (from highest to lowest priority) operational test data, development test data, engineering simulation data, or training simulation data. We realize that a mixture of data sources may be necessary to achieve our goals.

Certainly the first order of business will be to identify the models to be evaluated. IST will conduct a survey of the available radar and helicopter simulation models as early as possible. The survey will be based on government sources of models. Industry models tend to be proprietary or too expensive to procure an entire data package.

In the case of radar models, IST will identify and establish contact (with support from STRICOM) with appropriate Army agencies involved with Radar R&D. IST will use its contacts to identify
operational radar simulators appropriate and/or available that can be considered for evaluation. In the case of helicopter models, contact has been initiated with Mr. Richard McFarland of NASA Ames. Mr. McFarland is a Research Engineer in the Flight Systems and Simulation Research Division at NASA Ames. He has been working on a high fidelity simulation model of the Blackhawk helicopter for about two decades. This model will head the list of the models IST would like to have. NASA Ames also has a simulation program of Apache helicopter.

Since it is desired to use many of these radar and helicopter models in a larger simulation environment, a performance criterion (i.e. fidelity measure, timing, etc.) for models will be established so that analysis using the DIS network can be assessed. In order to evaluate those radar and helicopter models, data compatible with the DIS interoperability standards must be generated. The DIS data will be derived from a standard set of scenario driven input parameters ("input drivers") is to be used to test each "radar and helicopter model". These tests will form an error-variance envelope (random and systematic errors) of each radar and helicopter output data set against the reference output data set. (reference data input and output sets established from either a "master radar or helicopter simulator" or from an actual position attitude and/or velocity data set). This input parameter set will be broad enough to stress the radar and helicopter model to find its domain of applicability.

Based on the method described above, fidelity measures (error variance values) and timing properties (minimum supporting data rates) will be determined. Each measure of a radar and/or helicopter model tested will be compared to the reference model values and hence, to each other, yielding a procedure to select those radar and/or helicopter models which may be sufficiently compatible to interoperate on the DIS network. This test procedure remains objective in that models are evaluated based on performance criteria; they do not depend on the source of the models. The list of models subjected to evaluation and the associated rating process for establishing a baseline benchmark will be defined and entered into the DIS guidelines document.
Other Application Layer tests are envisioned using the DIS 1.0 Standard. Test procedures will be developed to demonstrate compliance for each of the ten Protocol Data Units. Other aspects of the standard which support data units will also be tested and evaluated. These include, but are not limited to coordinate systems, byte ordering, units of measure, and appendices.

Deliverables: A separate math model report will be developed for each of the mathematical applications described, above. The report will describe the methodology used to evaluate the math models, describe all models, and provide results from the analysis. The Other Application Layer tests described above will be reflected in a Test Procedures/Results Report.

2.3.2 Subtask 3.2 Protocol/Network Layer Tests

Proposal: Protocol/Network Layer tests will be developed and conducted for the DIS recommended protocols as they evolve. Initial tests will be developed to baseline UDP/IP performance in a DIS environment using Ethernet. Three other protocol tests are envisioned: one using UDP/IP with wireless ethernet (if compatible with testbed hardware); a loopback test using UDP/IP with FDDI; and a test of an OSI based stack (selected by IST) using FDDI.

Additional Description: Wireless Ethernet (Motorola) will be evaluated if a system can be obtained on loan from Motorola. The OSI tests should be amended to use IEEE 802.3. IEEE 802.3 is the baseline configuration used in SIMNET and minimizes interfacing requirements to the rest of the testbed. Two additional tests will be run. One test will involve the SIMNET Association and IEEE 802.3. An additional test will include DIS and Ethernet.

This task will also require the accumulation of data. IST anticipates a small contract award to Grumman to support data collection. Grumman has developed a Lotus based program which assists in the analysis of network loading. Additional network assessment methods can be developed by IST.
Deliverables: Appropriate sections will be added to the Test Procedures/Results to document testing methods and results.

2.3.3 Subtask 3.3 Quantitative System Tests

Proposal: Quantitative System Tests will be developed. IST will develop system level tests for an integrated network. We will extend the local area network tests in subtask 3.2, above, to a long haul network to be implemented between IST and STRICOM. The long haul linkage will be through a line of sight linkage between IST and STRICOM. The line of sight communications will link into a T-1 telephone line and TWB located in STRICOM's facility. We will develop tests which investigate the nominal and peak performance of this long haul network.

Other system level performance tests will be developed which measure throughput, overload control, syntax, and semantics of the network. Through system level tests, IST will also identify system bottlenecks and develop approaches to overcome those bottlenecks. For example, current network to simulator interfaces are often a cause of local area network bottlenecks. As more interfaces are added to create a long haul network, different bottlenecks are quite likely. Developing the testbed in the systematic manner described in this proposal will allow a full exploration of the DIS environment as it matures.

Additional Description: System level tests are intended to evaluate a component in a system setting. As such, quantitative system tests will be developed for each PDU, and each protocol/communication component. Tests must be designed to allow results to be partitioned and organized in a way in which they can be related to other tests. The purpose is to assess relative performance differences between different implementations and interpretations of DIS. Additional testing needs and necessary development efforts should be identified in this subtask regarding peripheral aspects of the DIS Standard. The list should include, but not be limited to, evaluation of entity type hierarchical
arrangements noted in Appendix H2 of the DIS Standard, the quantity of coordinate transformations required by DIS, the use of various representations of the Earth's shape in DIS, and the general treatment of the operation of mixed fidelity environments in DIS.

The DIS Architecture proposed by Loral will also be evaluated. In particular, the functionality and performance of CAUs and CIUs will be evaluated. Arrangements, through STRICOM, will be made with Loral to either borrow these items or to simulate their performance and functionality in one of the testbed computers (subject to performance limits of the testbed hardware).

Deliverables: Appropriate sections will be added to the Test Procedures/Results to document testing methods and results.

2.3.4 Subtask 3.4 Qualitative Tests

Proposal: Qualitative tests will be conducted by subject matter experts. Two types of tests are envisioned. One test will be made to assess the utility of the network implementation to training, test and evaluation, analysis, etc. These tests will be in accordance with soldier-in-loop criteria developed by the requesting organization. Other qualitative tests may be conducted to determine whether certain DIS tools are useful. Initial evaluations will be oriented to correlation metrics for visual systems.

Additional Description: IST will provide test design and support for this subtask. Actual conduct and interpretation of results is the responsibility of the requesting organization.

Deliverables: Appropriate sections will be added to the Test Procedures/Results to document testing methods and results.

2.3.5 Subtask 3.5 Testing and Demonstrations

Proposal: Testing and demonstrations will be conducted by
IST. The initial testbed capability will be demonstrated as part of the I/ITSC Conference in San Antonio, Texas in early November, 1992. Coincident with the demonstration will be production of documentation on the testbed performance in accordance with 3.2 through 3.4, above. Similar tests will also be conducted on the SIMNET hardware at IST to form a set of baseline values for system performance.

Formalization of the IITSC demonstration is currently underway at IST. IST has received approval from the IITSC Steering Committee to conduct this demonstration. A meeting held at IST on 10 April 1992 had attendees from 19 different organizations (to include IST) and discussed the feasibility of having such a demonstration with respect to testbed capabilities, DIS, and Project 2851 interoperability. It is likely that a good portion of the participants will take part in the I/ITSC demonstration.

The scope of the demonstration will be as follows. Project 2851 will provide a terrain data base in SIF. The data base will represent a specific area of Ft. Hunter Liggett, CA. Only four PDUs will be used; Entity State, Fire, Detonation, and Collision. IST's Semi-Automated Forces will be modified to transmit and receive the above mentioned DIS packets. The underlying communications support will be determined and be implemented by IST. Several alternatives are available. The risk to IST of implementing the alternatives to be used in decreasing preference are:

a) convert the IST testbed to DIS PDUs encapsulated in IEEE 802.3 (Ethernet) frames,
b) convert the testbed as in a, above, but encapsulate the DIS PDUs in the BBN's Association Protocol (AP) which in turn would be encapsulated in IEEE 802.3 frames or,
c) convert the IST testbed to DIS PDUs encapsulated in a minimal implementation of UDP/IP, encapsulated in IEEE 802.3 frames.

The desirability of the above options from networking and technical points of view are in an opposite direction to the risk assumed. Therefore, IST will implement option c, above, for the
I/ITSC demonstration. Support from IST to other I/ITSC participants will be extremely limited until such time that IST becomes familiar and implements option c.

Additional tests will be prepared and conducted using the testbed as new ideas related to DIS emerge. In the spring of 1993, IST will demonstrate and test the full set of DIS PDUs. Additional tests envisioned include evaluation of correlation metrics, performance measures PDUs, and electronic warfare. IST will also support the BDS-D ATTD by endeavoring to work with Loral to integrate and evaluate the CSRDF to AIRNET demonstration. IST will plan on providing four demonstration/tests per year after the first year of operation.

**Additional Description:** This topic is further described in an IST report informally titled Decisions/Actions. This document outlines the network design to support I/ITSC. Also a set of test procedures and scenario descriptions will be developed.

A critical aspect of interoperability relates to differences in fidelity between the simulators on the network. Currently, the most important area of fidelity differences is in the visual system and the accompanying representation of terrain, culture, and models in the simulation. IST's approach to testing will address measuring these differences in fidelity. The testbed will be used to support these studies (which result from other contractual efforts). However, effort will need to be expended to develop data bases for the testbed which support these studies in visual system and terrain data base fidelity.

Differences in simulator network capacity is another area of interoperability which the testbed will address. Methods will be developed (using the software provided by Grumman) to identify compatibility criteria based upon individual simulator network capacities and the tasks performed by the network of simulators.

**Deliverables:** Test related items will be documented in Test Procedures/Results Report.

2.3. **Subtask 3.6 Assimilation of OSI into DIS**
Proposal: The assimilation of OSI into the DIS architecture and testbed will require OSI operational guideline documents to be developed. First, an OSI implementors handbook will be produced. This will describe architectural concepts and implementation strategies for developers and users of the OSI communication services. The integration of OSI protocols into public data networks and the TWB/DSI will also be covered. The results from this task will be provided to the DIS CASS for incorporation into the DIS communication architecture standard.

Secondly, a guidelines document for DIS applications in a multipeer (in this context, multipeer represents multicast, broadcast, and unicast transmissions) environment will be developed. This document will be based on the OSI extended application layer structure (XALS) and will detail the process through which real-time simulation environments can access Transport services using null Presentation and Session services. The guidelines will be designed with maximum flexibility for growth of the DIS Application Layer structure. The DIS application layer will be required to support a variety of simulated and real entities. To make efficient use of the lower-level services, a mechanism which permits these entities to be multiplexed on (or share) a single lower-level connection should be developed. Using XALS, the structure will identify DIS application entities as generic application service elements and application service objects. This structure will provide a stream-lined interface to multipeer services at the Transport layer. This document will complement on-going work with the multipeer addendum to the OSI Reference Model.

Additional Description: IST will prepare Statements of Work for Open Network Solutions (ONS) and OPUS ONE to continue their work in Multipeer Multicast (MPMC) Standards. Mr. James Moulton of ONS has been instrumental in writing and promoting connectionless oriented MPMC under contract to IST as part of the current contract with STRICOM. Mr. Joel Snyder of OPUS ONE has performed research similar to Mr. Moulton, but oriented to connection oriented MPMC. Margaret Loper will manage their efforts via Section 3.6 of IST's
ECP. IST will also coordinate with the Center for Standards. The scope of coordination will be determined with STRICOM in early 1993.

**Deliverables:** Multicast service definitions and protocol specifications will be developed which support DIS requirements. These reports will be submitted to appropriate ANSI working groups for consideration. They will also be included in Bi-Monthly Status and Management Reports for STRICOM review. A final report will be generated at the end of the contract documenting the results of the second year's work.

3.0 SCHEDULES AND DELIVERABLES

Appendix A is a Work Flow Diagram interrelating tasks, subtasks, deliverables, and milestones.

4.0 ORGANIZATIONAL STRUCTURE AND MANAGEMENT RELATIONSHIPS

This project will be controlled by standard project management principles. At IST these principles include the management of staff, technical direction of the project, fiscal matters, purchasing, and document control. Mr. Brian Goldiez, Director Research and Development, will be the Principal Investigator/Program Manager for this project. Mr. Goldiez will ensure that sufficient resources are applied to this project. The pressing schedule constraints early in this project requires borrowing resources from other projects. Mr. Goldiez will provide a careful review of the requirements of this project to minimize the impact on projects which loan personnel to this effort. IST expects to fill additional positions to meet the long term needs of this type of research effort. Mr. Goldiez will utilize IST's existing infrastructure of administrative support to assist him in the execution of his duties.

Mr. Scott Smith will be the lead technical individual (i.e., Project Engineer) for this research effort. He will be responsible
for the day to day technical content of this research project. Mr. Smith will also be responsible for the execution of Tasks 1 and 2, described above. Ms. Margaret Loper will be responsible for the execution of Task 3 as well as the Systems Engineering aspects of the research.
APPENDIX A

PROJECT FLOW DIAGRAM
SCHEDULE/DELIVERABLES

<table>
<thead>
<tr>
<th>TASKS</th>
<th>Months After Contract Award</th>
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</table>

- **1.1 Systems Design**
  - 1.1A Design Report

- **1.2 I/F W SIMNET**
  - 1.2A Design Report

- **1.3 External Linkage**
  - 1.2A Design Report

- **1.4 New PDU's**
  - 1.4A Design Report

- **1.5 New Protocols**
  - 1.5A Design Report

- **1.6 Interface DIS SIMS**
  - 1.6A Design Report

- **1.7 I/F Non-DIS SIMS**
  - 1.7A Design Report

- **2.1 Off Site Install/Sup**
  - Ft. Knox
  - Ft. Rucker
  - IDA

- **2.1A Site/Query Report**

- **2.2 I/F Non-DIS Systems**
  - UPAS
  - ASAT

- **2.2A Design Report**

- **2.3 DIS Implementation Support**

- **2.3A Activity Report** As Req'd
SCHEDULE/DELIVERABLES

<table>
<thead>
<tr>
<th>TASKS</th>
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<tbody>
<tr>
<td>3.1 Application Tests</td>
</tr>
<tr>
<td>- Obtain Model</td>
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<tr>
<td>- Math Models Analyses</td>
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<tr>
<td>- Helicopter</td>
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<tr>
<td>- Dead Reckoning</td>
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<tr>
<td>- Radar</td>
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<tr>
<td>3.1A Math Model Report</td>
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<tr>
<td>3.2 Protocol Tests</td>
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<tr>
<td>- Dev. Tests</td>
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<tr>
<td>- Conduct Test (3)</td>
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<tr>
<td>3.2A Test Procedures/Results Report</td>
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<tr>
<td>3.3 System Tests</td>
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<tr>
<td>(Quantitative)</td>
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<tr>
<td>- Dev. Tests</td>
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<tr>
<td>- Conduct Tests</td>
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<tr>
<td>3.3A Test Procedures/Results Report 2</td>
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<tr>
<td>3.4 Systems Tests</td>
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<tr>
<td>(Qualitative)</td>
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<td>3.4A Test Procedures/Results Report 2</td>
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<td>3.5 Tests/Demos</td>
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<tr>
<td>- IITSC</td>
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<td>- All PDU's</td>
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<tr>
<td>- Other (EW, CSRDF, Cor. Metrics, PERF)</td>
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<tr>
<td>3.6 OSI</td>
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<tr>
<td>3.6A Implementation HDBK</td>
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<tr>
<td>3.6B DIS Guideline</td>
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### SCHEDULE/DELIVERABLES

#### TASKS

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#### MINIMAL ACTIVITY

- Minimal activity periods are indicated with **--**.

#### Schedule/Contract Award

- **Month 0**: 0792
- **Month 1**: 0892
- **Month 2**: 0992
- **Month 3**: 1092
- **Month 4**: 1192
- **Month 5**: 1292
- **Month 6**: 0193
- **Month 7**: 0293
- **Month 8**: 0393
- **Month 9**: 0493
- **Month 10**: 0593
- **Month 11**: 0693
- **Month 12**: 0793
- **Month 13**: 0893
- **Month 14**: 0993
- **Month 15**: 1093
- **Month 16**: 1193
- **Month 17**: 1293

#### Notes

- 1,2 Reports Will be Consolidated With Sections Appropriate to Taskings.
- As Req'd

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