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## Implementation Of The Laser PUD: Final Report

Raymond E. Giroux

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INSTITUTE FOR SIMULATION AND TRAINING

Contract Number N61339-94-C-0024  
CDRL A009  
STRICOM  
March 8, 1995

# Implementation of the Laser PDU

## Final Report

Institute for Simulation and Training  
3280 Progress Drive  
Orlando FL 32826

University of Central Florida  
Division of Sponsored Research



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**Prepared For:**  
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Contract Number N61339-94-C-0024  
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**Prepared by:**  
Raymond E. Giroux

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## 1. INTRODUCTION

This report presents the results of incorporating the Laser Protocol Data Unit (PDU) into the Institute for Simulation and Training (IST) personal computer (PC) based Distributed Interactive Simulation (DIS) Computer Generated Forces (CGF) Testbed.

The report describes:

- development and prototyping of the Laser PDU into the Testbed
- the behaviors added to use the Laser PDU
- test procedures
- recommendations for changes to the Laser PDU
- documented source code is included as Appendix A

This report is a deliverable item, CDRL A009, under subtask 3.2.1.1, "Implement Laser PDU," of the U.S. Army Simulation Training and Instrumentation Command (STRICOM) contract #N61339-94-C-0024, entitled "TRIDIS: A Testbed for Research in Distributed Interactive Simulation."

### 1.1 Abbreviations and Acronyms

ASCII	- American Standard Code for Information Interchange
CGF	- Computer Generated Forces
DIS	- Distributed Interactive Simulation
FSM	- Finite State Machine
GLLD	- Ground/Vehicular Laser Locator Designator
Hz	- Hertz
ID	- Vehicle Identification Number
IST	- Institute for Simulation and Training
I/ITSEC	- Interservice/Industry Training Systems and Education Conference
Km	- Kilometers
LD	- Laser Designator
LGM	- Laser Guided Missile
LGW	- Laser Guided Weapon
LOS	- Line of Sight
MULE	- Modular Universal Laser Equipment
NAWC-TSD	- Naval Air Warfare Center - Tactical Systems Division
OPFOR	- Opposition Forces
PC	- Personal Computer
PDU	- Protocol Data Unit
PEGASUS	- Programmable Environment: Ground, Air, Sea, Universal Simulator
PRF	- Pulse Repetition Frequency

STRICOM	- U.S. Army Simulation, Training and Instrumentation Command
SUT	- System Under Test
SWRI	- Southwest Research Institute
TADS	- Target Acquisition and Distancing System
TRIDIS	- Testbed for Research In DIS
WP	- Weapons Platform

## 2. General

The goal of this task was to incorporate the Laser PDU of the Standard for Distributed Interactive Simulation Application Protocols version 2.0 third draft into the IST's PC based DIS CGF Testbed. This was to include a minimal laser designation and laser tracking facility to be attached to helicopters simulated by the testbed. Modifications were made to the Data Logger and Scanner to permit testing of the Laser PDU.

A laser designator is an entity that can shine a laser onto another entity. A laser guided weapon (LGW) is a weapon that can track and hit a laser spot.

The laser PDU was used at 16th Interservice/Industry Training Systems and Education Conference (I/ITSEC 94) DIS demonstration. This was the first I/ITSEC where the laser PDU was used. The Laser PDU was used by IST, Southwest Research Institute (SWRI), Naval Air Warfare Center - Tactical Systems Division (NAWC-TSD), and CAE-LINK in the demonstrations that they participated in. NAWC-TSD's manned flight simulator (F14), and SWRI's manned AN/PAQ-3 Modular Universal Laser Equipment (MULE) laser designator simulator participated in a cross-platform laser PDU demonstration during rehearsal week. The target, a CGF tank, was successfully destroyed by a laser guided missile from the F14, using the laser spot provided by SWRI. SWRI did not participate in any other demonstrations due to difficulties they were having with some network traffic.

IST demonstrated the laser PDU in one mini demonstration at I/ITSEC 94, the "CGF" demonstration. The coordination for the demonstration was by Jon Williams of Loral and the participants were Loral, CAE-LINK, and IST. The scenario for the CGF Battle was a sequence of two engagements, a ground battle and an air battle, to demonstrate the capabilities of computer generated forces. IST did not participate in the air battle. The ground battle consisted of US tank forces attacking opposition forces (OPFOR) tanks supported by AH64 helicopters. IST provided four US AH64 helicopters and ten OPFOR T72 tanks (all CGF entities) in the demonstration using a single IST PC Based CGF on a 486-66 PC. The opposing forces moved toward each other and engaged when line of sight was obtained; no other "strategy" was used. The "free play" lasted until the scheduled completion time for the demonstration was reached, or the vehicles were all destroyed. The Laser PDU was

successfully used during the demonstration to designate targets. IST and CAE-LINK both used laser PDUs to self designate OPFOR tanks, which were then fired at with laser guided missiles.

Laser guided missile capability was given to the IST Programmable Environment: Ground, Air, Sea, Universal Simulator (PEGASUS). The simulator was demonstrated at I/ITSEC 94 to the conference attendees. The simulator could fire a laser guided missile (LGM) from its helicopter mode.

### **3. Behavior Implementation**

The behavior for the laser designator (LD), weapons platform (WP), and the LGM is implemented using finite state machines (FSM). For a complete discussion of the IST CGF mechanism for implementing finite state machines see "The IST Computer Generated Forces Testbed" [Smith 92b]. The FSMs have distinct states for each specific part of the behavior. When a specific part of the behavior (FSM state) is completed then the FSM transitions states to the next FSM state (next step of the behavior). Using FSMs allows behaviors to work pseudo concurrently.

#### **3.1 Behavior Implemented for the Laser Designator (LDTargetTracking)**

When the FSM "LDTargetTracking" is invoked the vehicle identification number (ID) of the target can be specified by the user on the command line, or the behavior model will pick the closest target to the LD. The LD will then route to within lasing range of the target if not already within lasing distance. The LD must have line of sight (LOS) with the target at all times in order to lase the target. If the LD does not have LOS then the LD will move perpendicular to the line from it to the target until it has LOS. The LD behavior can be given to any vehicle entity in the IST CGF Testbed.

##### **3.1.1 Laser Designator Behavior Details**

1. To invoke the LD behavior within the IST CGF, the operator will give a command to an entity to designate a target. The command specifies which entity will exhibit the LD behavior, the name of the laser designator equipment, and the code for the equipment to use. The target ID is optional.

Laser "ON" command format <id> DO <name> <code> [target id].

name - the name of the laser equipment (MULE or GLLD)

(Ground/Vehicular Laser Locator Designator)

code - the code (1-255) that the LD outputs

target id - (optional) the target's vehicle id

2. If no target ID is given, then the LD will select a target based on the distance of the potential target from the LD. The LD will pick the enemy target closest to itself.

3. The LD must route to within lasing distance (2Km) of the target. Once the LD is within lasing distance it must check the LOS to the target. If the target is not visible, the LD must route to new point within lasing distance and check the LOS again.

4. Once the LD is within range and has LOS it will designate the target and continue to designate the target by tracking it until either the target is destroyed, the LD is destroyed, or the "TERMINATE" command is given. During this time the Laser PDUs are being sent out at a rate of approximately 10 Hz. The tracking of the target requires maintaining LOS with the target, if LOS is lost repeat step 3. If the target was destroyed, restart at step 1. The LD PDUs communicate to the interested parties that the laser is on, and where the laser spot is located. The LD will keep the laser spot on an entity, and if the LD can not see the target entity for any reason then there will be no laser spot.

To see an American Standard Code for Information Interchange (ASCII) list of all of the Laser designators that are in the current exercise a "DUMP LD TO THE SCREEN" command was added to the CGF. This command will display on the PC screen in text format the Laser designator information contained in the Laser PDU.

To see a graphical representation of the local entities' lasers a "DISPLAY DESIGNATORS" command was added to the CGF. This command will display on the PC screen the line of the path that the laser must take from the designator to the target.

LD "TERMINATE" command format <id> DF

"DUMP LD TO THE SCREEN", press the asterisk key (\*).

"DISPLAY DESIGNATORS" command format <id> DD

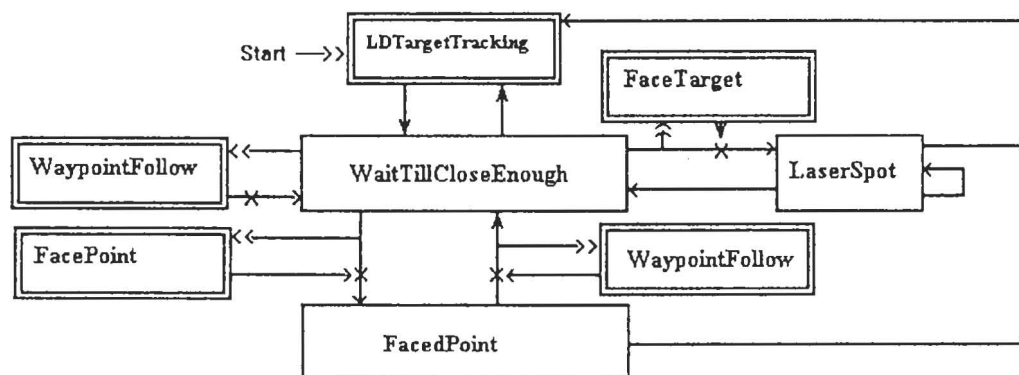


Figure 3.1 LDTargetTracking FSM



Figure 3.1 shows the state diagram for the LDTargetTracking FSM. For a complete discussion of the diagram notations see "Controlling Autonomous Behavior in Real-Time Simulation" [Smith 92a]. Each state has the ability to exit the behavior.

### 3.2 Behavior Implemented for the Weapons Platform (LGMissileFire)

When the FSM LG Missile Fire is invoked, the WP will select a target closest to the target location given with the correct laser code. The WP will then route to within LGM target acquisition range, and then will determine if it has LOS. If not, it will move until LOS is restored. Once the WP is within range and has LOS it will create a LGM entity in a dormant state. A LGM in a dormant state does not output any PDUs, and will not increase network traffic. Specific information passed to the LGM is the target area, the laser code, and the WP ID. Once the WP receives a **"LOCKED ON"** message from the LGM, the WP tells the LGM to **"LAUNCH"**. The WP behavior can be given to any vehicle entity in the IST CGF Testbed, though since the behavior only models Hellfire missiles it may not be realistic for other platforms. The only LGM implemented is the Hellfire LGM.

To implement the WP behavior it was necessary to communicate, or coordinate actions between entities. The IST CGF Testbed already had a system to send non-DIS messages. These messages conveyed information or commands from the CGF operator to a specific entity, and the response of the entity to the Console Manager. For the WP behavior to work it had to communicate with the LGM such information as where the laser spot was, and what laser code the spot had. Previous to this effort these messages were only used to transmit information between the operator interface and the entities. Now the messages are being used to transmit information between simulated entities. With this development, information, commands, and coordination of efforts can now be communicated between CGF entities. This could lead to more complicated automated behavior on the part of CGF entities.

#### 3.2.1 Weapons Platform Behavior Details (LGMissileFire)

1. A LGM open fire command must be given to the WP to begin the firing of LGM behavior.

**"FIRE A LGM"** command: <id> ( <x> <y> <LD code>

The WP then picks the closest laser spot with the correct code to the given [x, y]. After picking the closest laser spot, the WP checks if the spot is within the LGM acquisition distance (5000 meters). If the WP is outside this range it routes to a point within the range. The route point is chosen on a straight line from the WP to the target.

2. After arriving at the route point, the WP will stop and face the target. The WP now verifies LOS to the laser spot and that the WP is within the +/- 20 degrees from the LD to the target. If the WP can not see the laser spot for one or both of the above reasons then the WP will move in small (200 meter) increments until visible.

3. The WP will create a missile entity in the dormant state. The creation of the missile must give the missile the WP ID and return the missile's ID so that the two can communicate. The missile can receive and transmit messages in the dormant state to allow it to communicate with the WP. This allows us to create multiple missiles without bogging down the network with entity state PDUs.

4. Once the WP determines that the LGM has been created successfully it sends a message to the LGM to "TRACK" the laser spot with a specific laser code.

5. When the LGM responds with a "LOCKED ON" message the WP will send it a "LAUNCH" message.

6. After the "Launch" message the WP will restart its behavior at step 1. The firing of LGM behavior may also be stop with a "STOP" message.

"STOP" message: <WP id> DI.

The FSM diagram below shows all of the states that the WP goes through to fire a LGM.

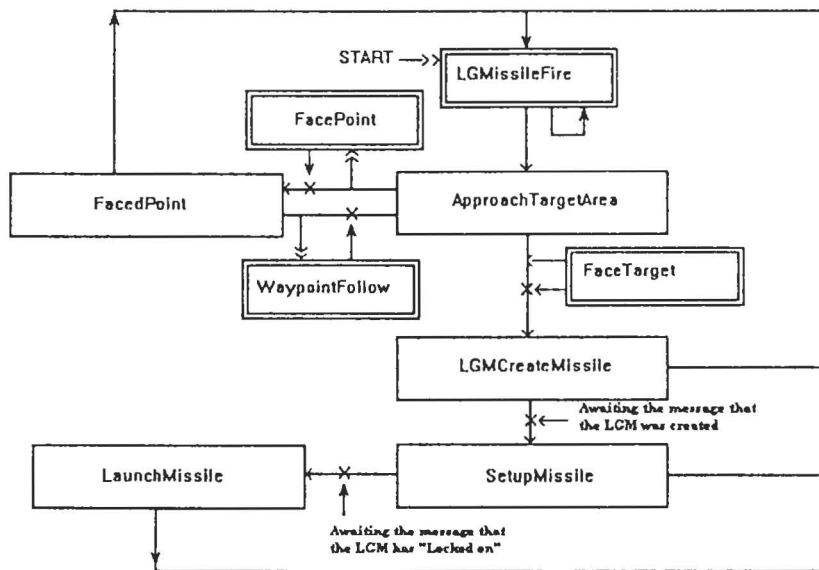


Figure 3.2 LGMissileFire FSM

Figure 3.2 shows the state diagram for the LGMissileFire FSM. For a complete discussion of the diagram notations see "Controlling Autonomous Behavior in Real-Time Simulation" [Smith 92a]. Each state has the ability to exit the behavior.

### 3.3 Behavior Implemented for the Laser Guided Missile (Hellfire)

While the LGM is dormant it updates its location and speed by synchronizing to those of the WP. The **"TRACK"** command gives the LGM the location of the target area, and the laser code. With this information the LGM looks for the closest target with the correct code to the target area. When it finds a target the LGM sends a **"LOCKED ON"** message to the WP. When it receives the **"LAUNCH"** command the LGM becomes non-dormant (it now sends out PDUs). Once launched the LGM dynamics are no longer tied to the WP so it will try to fly to the laser spot and detonate.

The LGM is created as an entity whereas other missiles in the IST PC based CGF testbed are not created as separate entities, but are created as FSMs attached to the launching entity. The other missiles are simulated as FSMs running under their parent WP. The problem with this is that a WP can only have a single missile in the air at a time, and if the parent WP is destroyed so is the missile. This is not realistic for independent flying missiles.

#### 3.3.1 LGM Behavior Details

1. Once the LGM is created in the dormant state it will not send out any PDUs until it is "Activated". The LGM updates its position information by copying that of its WP parent. The current position information is needed for it to determine LOS to a laser spot.
2. The LGM is given a **"TRACK"** command with the location, and code of the laser spot from the WP. If the missile can it begins to track the laser spot and then sends a message to the WP that it has **"LOCKED ON"**.
3. When the LGM receives the **"LAUNCH"** command from the WP it then accelerates away from the WP based on the speed and acceleration information in the entity configuration table. The direction of the missile is determined by the tracking routine and the ability of the missile to turn. At this point the LGM dynamics update routine is changed from just calculating an offset from the WP to actually flying the missile towards the laser spot.
4. If the missile loses its lock on the spot, the direction remains towards that of the last known location of the laser spot. If the missile regains a lock on the spot it can begin course corrections again.
5. At some point in time the missile will either hit the laser spot or, if the laser spot was lost, then hit some location where the laser spot had been. At this time the missile will have to determine what, if anything, it hit and then send out a detonation PDU. Once the missile is launched it has a life of its own and does not

depend on the WP for any information. This means that if the WP is destroyed it does not affect the LGM. Other missiles in the IST PC based CGF Testbed are destroyed if the WP is destroyed.

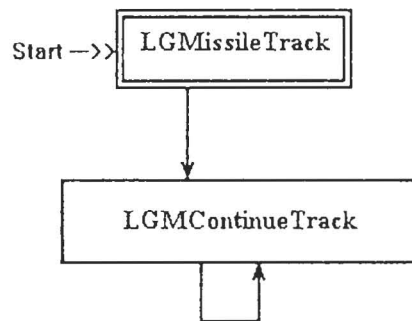


Figure 3.3 LGM laser spot tracking FSM

Figure 3.3 shows the state diagram for the LGMissileTrack FSM. For a complete discussion of the diagram notations see "Controlling Autonomous Behavior in Real-Time Simulation" [Smith 92a]. Each state has the ability to exit the behavior.

#### 4. Updates to the IST Test Tools

This section covers updates to the IST X Windows based SCANNER Management System, IST PC based LOGGER, and the IST DIS test procedures.

##### 4.1 IST SCANNER and the IST PC LOGGER

The IST SCANNER and IST PC based data LOGGER were updated to include the laser PDU. The scanner was updated to include validation of the laser PDU fields. The logger was updated to display the ASCII description of the laser PDUs contents on the PC screen, and save the laser PDU information to a log file.

##### 4.2 Laser PDU Test Procedure

The IST DIS test procedures document for compliance with DIS Protocol version 2.0 Draft 3 (IST-TR-94-03) was updated to include the laser PDU. The procedures now have a definition of what each field of the laser PDU should have in it. "Ideal" and "adverse" condition tests were added for both the reception and transmission of laser PDUs.

The "ideal test" tests the basic operation of the laser behavior. The test should determine if the system under test (SUT) can lase a target and if the SUT can hit a target being lased with a LGW.

The "adverse test" tests whether the SUT can handle some problems that might arise in the course of normal operation such as a situation in which the target is suddenly removed, or if the target is beamed (moved by means other than the normal driving) to a new location, or if the laser PDUs stop while the LGW is in flight.

## **5. Recommendations**

These sections cover suggested changes to the Laser PDU. These recommendations were forwarded in the form of a position paper to the 12th DIS Standards Workshop. This paper is included in Appendix A.

### **5.1 Recommended Laser PDU Enumerations**

The enumerations for the Laser PDU have not yet been determined in the 2.0.3 or the 2.0.4 DIS Standard enumerations documents. There are two sets of enumerations needed; System Enumerations and Code Enumerations. The lists of the suggested enumerations are in Appendix A.

### **5.2 PDU Fields**

The following are recommended changes to the laser code field and the laser spot field in the laser PDU. Section 5.4.6.3 of DIS Standard 2.0.3 and Section 5.4.7.2 of DIS Standard 2.0.4.

#### **5.2.1 Laser Code Field**

The laser code field is an 8-bit enumerated field, which does not allow for all of the possible laser codes. The modular universal laser equipment (MULE) for example can transmit 448 laser codes. The enumerated field can only represent 255 out of the 448 codes so if the MULE operator chooses an unrepresented code the simulator has to output either a default code or output zero (other). IST recommends that the field should be increased by 8 bits to become a 16 bit enumerated field to allow a complete representation of currently allowable codes. To do this IST recommends to use the padding field adjacent to the present laser code field. This would increase the size of the laser code field to 16 bits but would not increase the size of the laser PDU or move any of the other fields in the PDU. The impact of the suggested change would be to increase the accuracy of the laser simulation but not change the amount network traffic.

### 5.2.2 Laser Spot Field

The laser spot location field gives the location of the laser spot with respect to the designated entity. There is the possibility that a designated entity does not exist and that the spot is on a feature of the terrain. What to do with the laser spot field is not stated if there is not an entity ID in the entity ID field. The standard should state that this field will be all zeros if there is not a designated entity and that it is ignored by the receiver.

### 5.3 General PDU Requirements

The following section numbers apply to both the 2.0.3 and 2.0.4 DIS standards.

Section 4.4.7.3.2 states "The laser PDU shall be issued at a rate of 10 Hz", but there is no tolerance stated. IST recommends the phrase should be changed to "The laser PDU shall be issued at a rate within 10% of 10 Hz" since exactly 10 Hz is impossible to obtain.

Section 4.4.7.3.3 states "the firing entity shall output the designator spot world coordinate location information as part of the Detonation PDU"; this is only okay if the "firing entity" has complete control of the LGW. All of the LGW are self guided, i.e., they determine their own course and impact once released from the WP. IST recommends that this phrase and the one following it in that paragraph be changed from "firing entity" to "weapon", or "laser guided weapon".

### 6. References

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