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13. ABSTRACT *(Maximum 200 Words)*

This Feasibility Analysis Study Describes the results of a small study effort to examine the feasibility of a Generic Instructor Operator Station (GIOS) for use on US Army engagement simulators. It is focused on three specific programs: AGTS, CCTT, and AVCATT, with emphasis on the first two because of lack of hard requirements for AVCATT. The approach has been to re-engineer the AGTS IOS such that it could be added to CCTT or AGTS as a DIS compatible device to support structured gunnery training. It also addressed the inclusion of semi-automated Instructor Operator (IO) functions to give each IO a greater span of control, with the goal of reducing IO manpower requirements significantly.

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Table of Contents

1. Introduction

This Feasibility Analysis Study report describes the results of a small ADST II study effort to examine the feasibility of a Generic Instructor Operator Station (GIOS) for use on US Army engagement simulators. We have focused on three specific STRICOM programs: AGTS, CCTT, and AVCATT, with emphasis on the first two because of a lack of hard requirements for AVCATT. Our approach has been to re-engineer the AGTS IOS such that it could be added to CCTT or AGTS as a DIS compatible device to support structured gunnery training. Further, we have addressed the inclusion of semi-automated Instructor Operator (IO) functions to give each IO a greater span of control, with the goal of reducing IO manpower requirements significantly.

The main benefit of this concept, if implemented, would be the ability to add a structured, precision gunnery capability to the inherent tactical training capability of the CCTT program. We see no reason why this concept should not extend to future CATT devices as well, with the appropriate tailoring. Another benefit is the reduction in manpower required to perform the IO functions. Currently AGTS can require as many as five Instructors and four Operators to support platoon gunnery exercises; our goal is to reduce this to a single IO.

The impact of adding a GIOS to the target systems is addressed. We point out that a GIOS by itself is necessary but not sufficient to allow CCTT to support precision gunnery; other issues such as scene update rate and training data requirements also come into play.

The FAS report is organized as follows: Background (Section 2), Objectives (Section 3), Approach (Section 4), Data Collection (Section 5), System Design (Section 6), Potential Follow-On Activities (Section 7), Summary (Section 8), and References (Section 9). Figure 1-1 illustrates the overall development process.

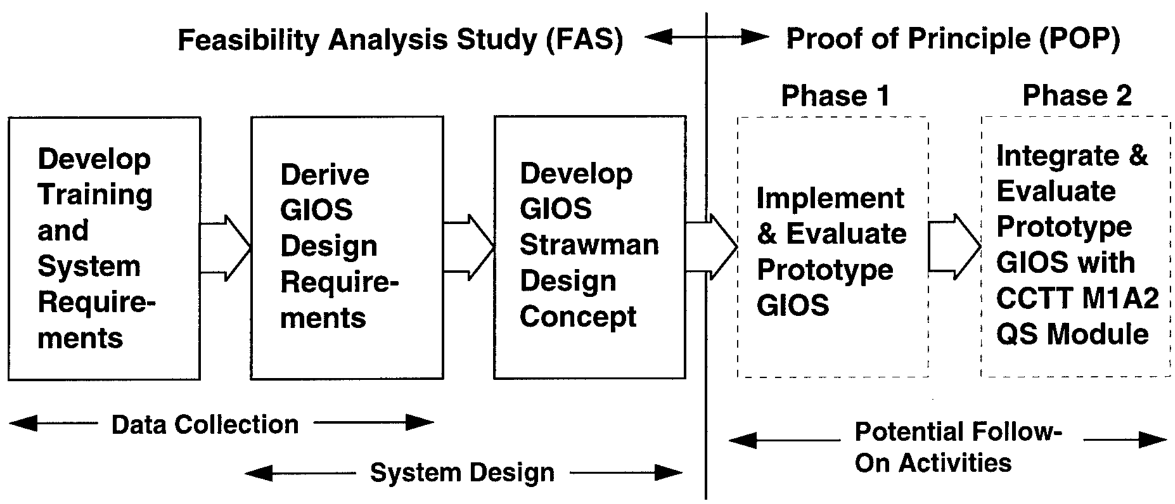

Figure 1-1: Overall Approach

The follow-on activities, if implemented, would logically fall into two phases, as shown: a stand-alone prototype implementation first phase to prove the concept from an engineering standpoint, followed by a user oriented evaluation phase via integration and test of a prototype GIOS with a CCTT M1A2 Quick Start module in the OSF.

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We also acknowledge the contributions of Thurman Autrey and John Schlott to this report.

2. Background

Individual and crew training systems for DoD have traditionally employed dedicated Instructor Operator Stations. For many years the prevailing wisdom has been that one Instructor Operator and one IOS per crew station is required to achieve effective training. Precision gunnery trainers from COFT (Conduct of Fire Trainer) to PGT (Platoon Gunnery Trainer) and now AGTS (Advanced Gunnery Training System) have required dedicated instructors and dedicated IOS's [ref 1]. Whereas these systems extend to platoon level, the training emphasis is at the individual and crew level.

SIMNET introduced large scale collective training capabilities into DoD. SIMNET and its successor CCTT are aimed at force-on-force free play exercises at the platoon, company, and battalion levels, in contrast to the AGTS highly structured individual and crew gunnery trainers [ref 2]. These systems do not require 1 on 1 instruction, nor do they utilize Instructor Operator Stations. Rather, a single battlemaster working at a Master Control Console (MCC) oversees one or more exercises, which are typically comprised of a number of crew stations, SAF stations and other assets networked together.

AGTS capitalized on the requirement for dedicated IOS's by embedding the IOS with the host computer system. This design approach was taken to minimize recurring costs to the overall program. In addition to servicing the IOS, the host computer also serves as the interface to the crew station and to the DIS network.

It has been argued by some that the AGTS IOS should have been broken out from the crew station as a separable DIS asset in order to be compliant to DIS standards. The counter-argument is that since an IOS is required for every crew trainer, there is no reason to add cost to the system just to make it a stand-alone DIS device. There is no DIS architectural construct we are aware of that requires a stand-alone IOS.

However, there are other reasons to evolve the AGTS IOS into a networkable asset. For one, STRICOM has expressed an interest in adding a structured gunnery training capability to CCTT and subsequent CATT devices. Another reason is to reduce the manpower required to support the training systems; for example, if an AGTS IOS could be designed stand-alone such that one instructor could oversee two or more crew stations, then fewer IOS devices and fewer IO's would be needed. It is noteworthy that this requirement for stand-alone, networkable IOS devices for gunnery trainers has already appeared in RFP's issued by overseas users.

From a CCTT perspective, a modular, networkable IOS would offer the potential to add a structured gunnery training capability to CCTT systems. It should also be possible to extend this training enhancement across the entire CATT family of simulators with the appropriate tailoring. This need is foreshadowed by the AVCATT Operational Requirements Document (ORD), which calls out the requirement for an IOS [ref 3].

3. Objectives

The overall objective of this Feasibility Analysis Study is to develop the requirements and design concepts for a Generic Instructor Operator Station (GIOS) for US Army engagement simulators. The FAS is directed at engagement simulators for direct fire ground to ground and air to ground applications. Three target programs have been selected as the potential beneficiaries of this study: the Advanced Gunnery Training System (AGTS), the Close Combat Tactical Trainer (CCTT), and the Aviation Combined Arms Tactical Trainer (AVCATT).

More specifically, the primary objective of this study is the development of a design concept for a DIS compliant, stand-alone networkable asset that is reconfigurable via software and/or data changes to meet the range of applications indicated. Although DIS compliance is a primary requirement because the GIOS is initially targeted at legacy DIS systems, the design should also allow for migration to HLA systems in the future. Further, the GIOS should not be constrained to one IO per trainer or crew; rather, the intent is to develop a design concept that will support a user specified ratio of Instructor Operators to trainees (i.e., 1 to N). This will necessitate the minimizing of instructional functions such as crew monitoring and operator functions such as surrogate driver and loader functions to the extent practicable.

The output of this FAS is this report, which describes the requirements and a preliminary design approach for a GIOS. Potential follow-on activities are also described.

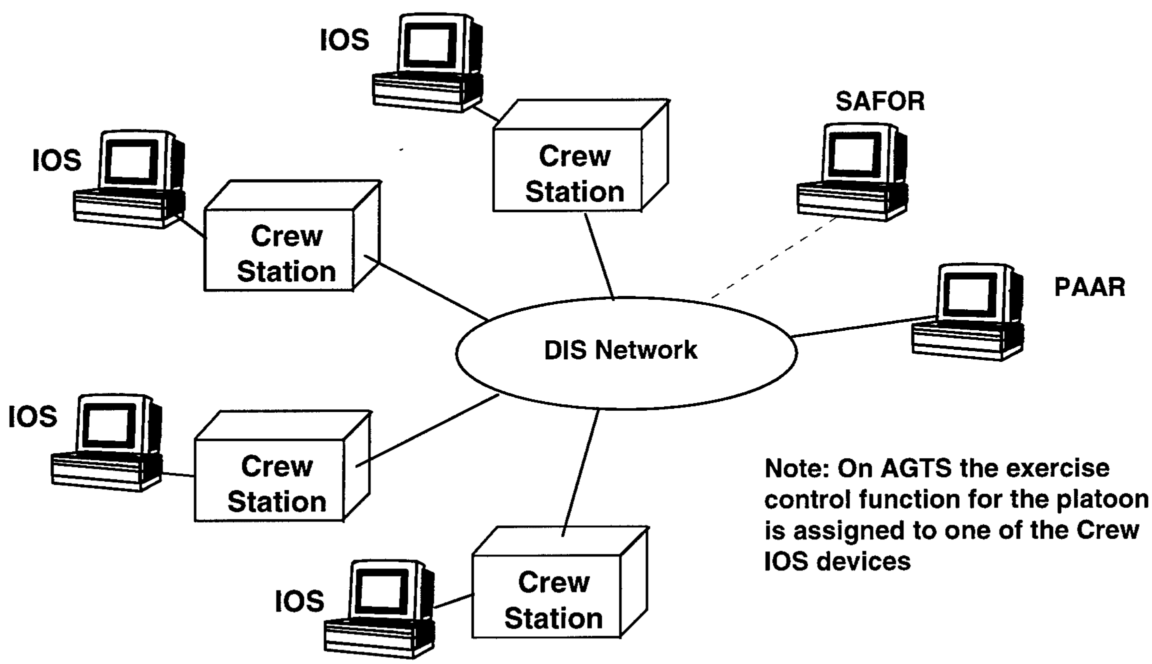
4. Approach

In order to keep the study manageable and within budget we limited the initial scope of the study to ground to ground and air to ground direct fire applications. In particular, we focused on three target programs: AGTS, CCTT, and AVCATT. The intent is that the GIOS design disclosed herein will be applicable to all three programs. The benefit to AGTS would be reduced manpower requirements for instructors and/or operators, and the benefit to the CATT programs would be the introduction of a structured training instructional program for direct fire to complement the inherent tactical training capability.

In addition, we have leveraged data collection efforts for the AC-130U and ARMS (Aviation Reconfigurable Manned Simulator) Delivery Orders to pick up requirements for fixed and rotary wing aircraft. A potential follow-on effort would extend the study to encompass indirect fire (FSCATT) and air defense applications (ADCATT). This is discussed in paragraph 7.3.1.

We have constrained the functionality of the GIOS within fairly traditional bounds - that is, instructor operator (IO) monitoring and control of crew and platoon level exercises. Extension to regimes above platoon is discussed in paragraph 7.3.2 as a possible follow-on activity. We do not advocate expansion of the IOS role to encompass After Action Review or Battlemaster functionality, or to replace these or other existing CATT assets with an all- encompassing universal IO Station. Rather, the intent is that the GIOS be treated as an additional and complementary training asset to the CATT sub-systems. This issue is dealt with in paragraph 6.4.1, as well as paragraphs 7.3.3. and 7.3.4.

Figure 4-1 illustrates the current architecture for the AGTS when it is fielded in platoon mode as a DIS compliant system.

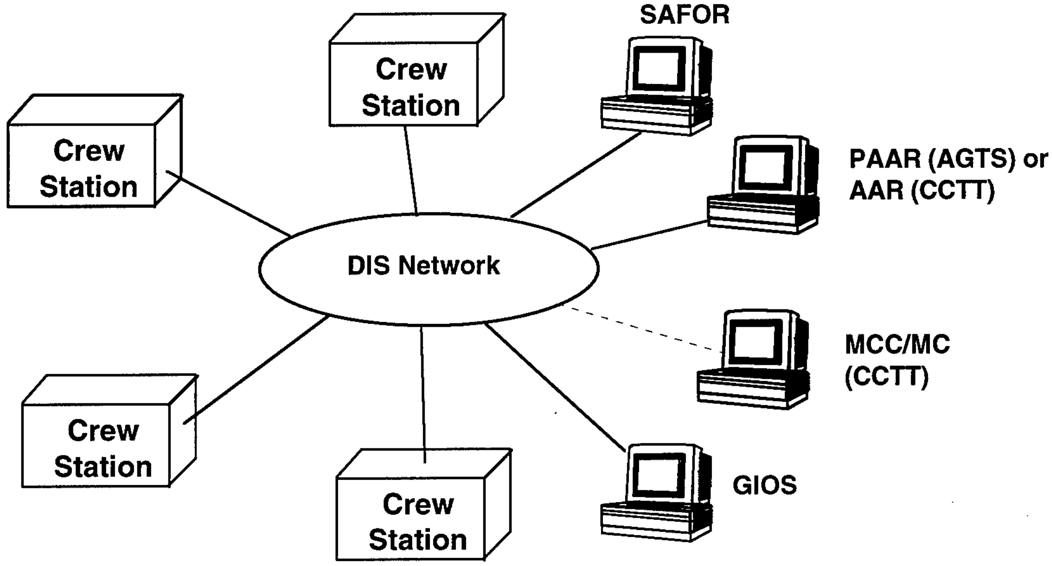


One IOS is dedicated per crew station in current gunnery training systems like AGTS and PGT; CCTT currently does not require an IOS

Figure 4-1: Current AGTS Platoon Architecture

Note that there is one IOS per crew station, and that it interfaces directly with the crew station as opposed to the DIS network. Further, there is a Prebrief/After Action Review (PAAR) device connected as a DIS asset to the network. A SAFOR is currently not required for AGTS; enemy vehicle movement is scripted and controlled by the host computer. However, some interest has been expressed in adding intelligent targets to AGTS, and this has triggered the initiation of trade studies to investigate how a SAFOR could be added to the network. Overseas users of AGTS-like devices have requested that a SAFOR be included with the training device. (Note: a prototype SAF capability was recently integrated and successfully demonstrated with an overseas platoon gunnery trainer).

Figure 4-2 illustrates a potential future architecture for platoon level training for AGTS and CATT type devices.



AVCATT and new gunnery trainers now on the drawing boards require a Generic IOS as a separate, networkable asset; provides easy reconfiguration of system and human resources. The goal is one GIOS for a platoon or a section.

Figure 4-2: Future AGTS/CATT Platoon Architecture

A Generic IOS is shown as a stand-alone networkable device, with an interface to the DIS network. The other components remain the same. By making the GIOS a networkable asset, it becomes possible to reduce the number of IO's per crew station, if crew IO workloads are sufficiently automated. It also becomes possible to add a GIOS to an existing CCTT system to add precision gunnery training capabilities. This is not to say that the GIOS is sufficient by itself; there are other issues such as scene update rate that also need to be addressed [ref 4], but a GIOS is a necessary condition. The impact of a GIOS on legacy systems like CCTT and AGTS is discussed in detail in paragraphs 6.4.1 and 6.4.2, respectively. As noted earlier, AVCATT, a future CATT system, calls out a requirement for an IOS in addition to the standard CCTT devices (MCC, AAR).

Table 4-1 lists the functions of such a GIOS and contrasts it with the existing Instructor Operator devices shown - the IOS as exemplified by the current AGTS

IOS, the MCC as exemplified by the CCTT MCC/MC, and the AAR as exemplified by the PAAR in AGTS and the AAR in CCTT.

Table 4-1: GIOS Requirements versus IOS, MCC and AAR in AGTS and CCTT

	IOS	GIOS	MCC	PAAR/AAR
System & Exercise Initialization	x	x	x	
Exercise Monitoring & Control	x	x	x	
- Start/stop/freeze/resume	x	x	x	
- Environmental conditions	x	x	x	
- System/Exercise Status	x	x	x	x (AAR only)
- Situation Monitor	x text	x graphical		
- Plan View Display	x platoon mode	x all modes	x static	x
- 3D Display	x repeaters, crew & pn level	x stealth, crew & platoon level		x stealth, pn & co level (AAR only)
- Data Record/Playback	x video + audio tape	x DIS (data + voice)		x DIS (data + voice)
- Data Extraction	x built-in	x will impact target sims		
- Ownvehicle Movement Ctrl	x Scripted+free	x Scripted+free		
- Target Movement Ctrl (SAFOR provides free movement)	x Scripted	x Scripted+free		
Training Management	x	x		
- Training Matrix	x	x		
- Student Records	x	x		
- Scoring/Reporting	x	x		x
Detailed Student Critiques				x

This table previews and summarizes the requirements analysis presented in Section 5.2.3. The reason for showing this table here is to provide an overall context for the GIOS, and to bound its scope. The GIOS is not intended to replace an AAR or an MCC, although much of the functionality overlaps these devices, as shown. Rather, the GIOS is intended to complement the existing AGTS and CCTT designs to the extent practical. This issue is dealt with further in paragraph 6.4, Integration with Legacy Systems.

Finally, in order to better understand the potential impact of a GIOS on the current AGTS-type training manpower profile, Figure 4-3 is offered to illustrate potential manpower benefits for a system containing a GIOS.

	CURRENT		STEP 1		STEP 2	
	IOS	Role Player	GIOS	Role Player	GIOS	Role Player
Ind/Crew	1	1	1	0	1	0
Section	2	2	1	0	1	0
Crew, Crew, Crew, Crew	4	4	4	0	2	0
Section, Section	4	4	2	0	2	0
Crew, Crew, Section	4	4	3	0	2	0
Platoon	4	4	1	0	1	0
3-Tank Platoon/Section	3	3	1	0	1	0

Figure 4-3: Potential GIOS Training Mode Combinations

This figure shows the various training modes possible with up to 4 crew stations networked together. Here we make the assumption that one GIOS can handle a crew station, a section, or a platoon; thus, the design for the GIOS must reduce the IO workload sufficiently to make this possible. This is one of the major goals of the project.

Note that each IOS has associated with it one IO and one or more role players, which is meant to indicate either a driver or loader for a ground vehicle or a pilot for an air vehicle. In the case of AGTS, a driver (either the actual crew member or a role player) would sit in front of a CRT and navigate with a joystick; in CCTT, the driver would be an actual crew member in a simulated driver compartment. Eliminating the need for a (human) driver is required to achieve the manpower reduction indicated. In the case of CCTT, the human driver may be present, but the design should allow for the case when the driver is not available. We envision an automated driver function, which responds to commander spoken commands just as a real driver would, with a terrain reasoning capability similar to that provided with existing SAF simulations.

We believe that the second column shown in the figure ("Step 1") is achievable via the incorporation of Natural Language Processing (NLP) and crew performance monitoring software. The NLP capability supports elimination of the role players, and the crew monitoring capability eliminates the need for a human IO at every crew station for section and platoon exercises. As shown, in the platoon mode the desired manpower reduction is 8:1. We believe that this is within the capabilities of today's commercially available technology.

The more difficult task is reducing the manpower requirements to the levels shown in the third column ("Step 2"). One IO assigned to two crew stations running independent crew level exercises will necessitate the introduction of an automated coach or tutor function. This might be implemented with an intelligent tutoring agent of some sort. This should be contrasted with the higher echelon training modes (section and platoon) where the trainees presumably have already passed crew level training programs, thus minimizing the need for remedial interaction (coaching) between the IO and the crew. Intelligent tutoring poses a much larger technical challenge than the more passive "crew monitoring function" mentioned above, and the payback in terms of IO manpower reductions is comparatively low, therefore we suggest that this be tackled at a future date.

The GIOS is intended to support individual, crew, section, and platoon level gunnery training exercises using either CCTT or AGTS assets. Extension to higher echelons is somewhat problematic since it brings into play a simultaneous requirement for tactical training. A combined "tactical-gunnery" trainer would require smart targets that can fight back and take evasive action, as well as increased tactical choices for the platoon and company leaders. Whether or not these tactical decisions should even be subjected to computerized scoring methods is an open question, since there will often not be one "right" approach for a given situation [ref 5]. Nevertheless, there appears to be an emerging demand for a Company level tactical-gunnery training device. This issue is further dealt with in paragraph 7.3.2.

We do believe that the approach described herein should be readily extendible to support mixed operations - that is, a portion of the networked devices could be executing tactical training, while another portion of the networked devices was executing precision gunnery. This should be simply a matter of system set-up and resource allocation.

The following two sections discuss the project as two overlapping phases: Data Collection (5) and System Design (6).

5. Data Collection

5.1 Introduction

The GIOS FAS data collection effort was undertaken to determine IOS requirements from three major sources: 1) candidate systems of interest (AGTS, CCTT, and AVCATT) and related systems; 2) specific training system program requirements; and 3) general user training requirements. Initial plans were to conduct on-site user/SME interviews and IOS system observations at training sites including Forts Knox, Hood, and Stewart. However, study funding limitations caused these trips to be deleted from the data collection effort to be replaced as necessary with telephone calls and opportunistic discussions with SMEs visiting Orlando in support of other training simulator programs such as AGTS. Data collection efforts on the principle systems of interest are documented in the following sections. The results of the data analysis effort are presented in Section 5.2.

5.1.1 AGTS

Work previously performed by one of the GIOS study principals on AGTS IOS requirements analysis was extended and served as a major source of data for AGTS [ref 6]. This effort included site visits to Forts Knox and Hood in late 1994, where SMEs were interviewed about current IOS strengths and weaknesses and what they would like to see in future IOS implementations. IOS operations during crew and platoon training sessions were observed to collect information on IO task loading and information requirements. The results of this effort were documented in internal AGTS reports [ref 7, 8]. Training program descriptions were derived from internal AGTS design documents [ref 9] and concept white papers [ref 10, 11], with additional personal communications with the primary authors.

5.1.2 CCTT

CCTT information was obtained primarily from system requirements and description documentation [ref 2, 12, 13, 14]. A visit to the heritage Loral Federal Systems development facility in Orlando was made to observe the CCTT equipment and conduct discussions with engineering personnel.

5.1.3 AVCATT

Little data was found on the AVCATT program. All information on requirements for this system were obtained from the AVCATT ORD (Operational Requirements Document) [ref 3].

5.1.4 AC-130U

Attempts were also made to leverage work performed on the ADST II AC-130U delivery order, where trips were made to several fixed- and rotary-wing aircraft training facilities, including Ft. Campbell, to assess training and IOS requirements and capabilities. Unfortunately, hard training requirements were not available. However, eight different IOS product configurations were evaluated and recommendations have been made by the Training Product Development Team (PDT) for the AC-130U Navigation/Fire Control Officer (Nav/FCO) Testbed IOS [ref 15].

5.1.5 Training Requirements Data Collection

GIOS training program and data requirements were principally derived from AGTS crew and, to a lesser extent, platoon training programs. Source data includes internal LMIS training analysis and requirements definition documentation generated on the AGTS program [ref 16, 17], and discussions with the personnel responsible for developing the training programs. Army training and field manuals [ref 18, 19] were reviewed to define at a relatively high level the training requirements of the systems of interest for this study. The outcome of this comparison is presented in the following section.

5.2 Data Collection Findings

5.2.1 Training Requirements

Relevant U.S. Army Training and Evaluation Programs (ARTEPs) and field manuals [ref 18, 19] were reviewed to categorize and compare the training requirements of the two major systems under consideration for this study - AGTS and CCTT. The outcome of this comparison is presented in Table 5.2.1-1. Requirements stated or inferred for AVCATT and AC-130U programs are also presented in the table for comparative purposes.

Table 5.2.1-1: Training Simulator Requirements Comparison

TRAINING AND EVALUATION REQUIREMENTS	**AGTS**	**CCTT**	**AVCATT**	**AC-130U**
CREW LEVEL TRAINING	X		X	X
SCORING	Graded Tank Table VII FM 17-12-1		TBD	TBD
ARTEP Training Missions:				
MANEUVER/TACTICS	X		X	X
JOINT COLLECTIVE TASK DEFENSE/OFFENSE SCENARIOS	X		X	X
FIRE SUPPORT	X		X	X
MOBILITY/COUNTER-MOBILITY/SURVIVABILITY	X		X	X
CREW COORDINATION	X		X	X
1. TC	X			
2. GUNNER	X			
3. LOADER	Simulated			
4. DRIVER	Simulated			
PRECISION GUNNERY	X			X
1. TC	X			
2. GUNNER	X			
3. LOADER	Simulated			
4. DRIVER	Simulated			
PLATOON/SECTION LEVEL TRAINING	X	X	X	X
SCORING	Graded platoon Tank table XII; Go/No Go	Go/NoGo	TBD	TBD
ARTEP Training Missions:				
MANEUVER/TACTICS	X	X	X	X
COLLECTIVE TASK DEFENSE/OFFENSE SCENARIOS	X	X	X	X
FIRE SUPPORT	X	X	X	X
MOBILITY/COUNTER-MOBILITY/SURVIVABILITY	X	X	X	X

TRAINING AND EVALUATION REQUIREMENTS	AGTS	CCTT	AVCATT	AC-130U
AIR DEFENSE		X	X	X
COMBAT SUPPORT		X	X	X
CREW COORDINATION	X	X	X	X
1. TC	X	X		
2. GUNNER	X	X		
3. LOADER	Simulated	X		
4. DRIVER	Simulated	X		
PRECISION GUNNERY	X			
1. TC	X			
2. GUNNER	X			
3. LOADER	Simulated			
4. DRIVER	Simulated			
COMPANY/TEAM LEVEL TRAINING		X	X	X
SCORING		Go/NoGo	TBD	TBD
ARTEP Training Missions:				
MANEUVER/TACTICS		X	X	X
COLLECTIVE TASK DEFENSE/OFFENSE SCENARIOS		X	X	X
FIRE SUPPORT		X	X	X
MOBILITY/COUNTER-MOBILITY/SURVIVABILITY		X	X	X
AIR DEFENSE		X	X	X
COMBAT SUPPORT		X	X	X
CREW COORDINATION		X	X	X
1. TC		X		
2. GUNNER		X		
3. LOADER		X		
4. DRIVER		X		
PRECISION GUNNERY		N/A	N/A	N/A

As can be seen in the table, the AGTS and CCTT training missions are largely complementary, with some degree of redundancy in Platoon/Section level training requirements (except for precision gunnery). The impact of these different requirements can be seen in the nature of the training programs and performance scoring implementations on AGTS versus CCTT, and in the data requirements to support the AGTS scoring algorithms (see Section 5.2.2).

It should be noted that the fact that there is no formal requirement for a system to support a specific level of training does not mean that the system provides no training value for that level. For example, CCTT's mission is not currently to provide crew level training during its exercises. However, the crew of a simulated vehicle obviously derives some training benefit during the execution of company or higher level exercises. Drivers maneuver their vehicles over terrain using high-fidelity controls and displays. TCs ensure that their vehicle supports their portion of the mission objectives; gunners operate their systems and fire at targets, and the loader participates as well. Thus, the crew at a minimum can obtain some skill sustainment training (presuming they are performing their tasks correctly). The difference is that a system such as AGTS supports crew training (for the TC and gunner) with specific, well-defined, repeatable, objective performance measures against which crew performance can be evaluated and tracked over repeated training sessions. CCTT crew performance evaluation is pass/fail assessment of how well they and their platoon, company, etc. supported the overall mission objectives.

CCTT is anticipating incorporating the SAMUTA "packaged" training approach to develop predefined missions to give the observer/controller a more structured performance assessment environment and methodology. However, the impact of this to CCTT is more in structuring the training mission and developing the software packages rather than imposing data extraction and scoring algorithm development requirements

The training programs used on AGTS and the training system defined for CCTT are described below. The majority of the description is on AGTS since it has well-defined training programs. This is intended to provide a general overview and to introduce concepts that will be useful in understanding Scoring Data Requirements defined in Section 5.2.2 and GIOS system requirements presented in Section 5.2.3.

5.2.1.1 AGTS Training Programs

5.2.1.1.1 Crew Training

AGTS as crew trainer supports precision gunnery training of one commander and gunner in a crewstation that replicates the turret of their weapon system. Each trainer is configured as a simulator system and an instructional system. The simulator system provides the functional and physical means to perform the individual tasks and crew duties required. The instructional system presents exercises and scenarios, provides performance measurement and feedback, and supports the data analysis needed by the Instructor Operator (IO).

Crew exercises vary in level of difficulty to provide training tailored to the proficiency of the crewmembers. In general, each exercise is designed so the firing vehicle can see and have the opportunity to destroy all vehicles presented during the exercise. The targets are grouped into "situations" for presentation during the exercise. The number of targets in a situation varies from 1 to 4 based on the level of difficulty of the exercise. Each exercise contains between 10 and 20 targets grouped into between 5 and 10 situations.

Level of difficulty is also determined by the position of targets and firing vehicles. The firing vehicle can be either moving or stationary. Targets can also be either moving or stationary. The crew training program uses pre-programmed paths for both targets and firing vehicles to ensure concentration of precision gunnery skills under controlled conditions.

The crew receives specific instructions for each exercise. These instructions describe the training objective and the conditions under which the crew will operate. Conditions include visibility, malfunctions, battlesight range, target type and quantity, and other parameters necessary to support practice on the training objective.

The duration of a crew training program exercise is about 10 to 15 minutes. After each exercise, the instructor is provided performance analysis information to support critique of the crew's performance. Progression between exercises is controlled by computer recommendation or by IO exercise selection. The normal training session lasts from 1 to 2 hours. A hardcopy session summary provides information for debrief and pre-brief of subsequent training sessions.

5.2.1.1.2 Platoon Training

The AGTS platoon training program is still under development, but is expected to follow the model of predecessor platoon gunnery training systems. The initial platoon training mission is to train M1A2 platoon gunnery tasks and procedures while conducting tactical maneuver operations in support of offensive or defensive tactical operations as part of a company or combined arms team. Platoons are required to conduct fire distribution planning and control as they execute their tactical missions. The focus of these operations is on training platoon gunnery tasks, not training tactical operations, even though tactical operations are addressed during the training. During the conduct of these operations, individual vehicles will use precision advanced gunnery procedures while engaging the target array.

Operations will be divided into three categories starting with missions requiring training of simple tasks and progressing in difficulty to more complex tasks. Platoons will progress through each of the three categories: Basic, Intermediate, and Advanced. A fourth category, Combat, includes missions from the three primary categories that will be conducted using free movement capabilities. Platoons will progress through these categories sequentially, advancing to the next category once the platoon has successfully demonstrated proficiency at the current level. The determination of proficiency will be based on the platoon attaining at least a qualified score on all the missions in the category. The four operations categories are briefly described below.

5.2.1.1.2.1 Basic

These missions will focus on training individual leader tasks and collective gunnery tasks while the platoon is conducting basic platoon tactical tasks under daylight and limited visibility conditions. The platoon training tasks will be performed while the platoon is conducting either defensive (e.g., defend a battle position) or offensive operations involving only Move and Assembly Area type missions. Company operations orders with specified and implied tasks will be developed for all missions. Platoon vehicles will move on pre-determined routes/paths, with the capability to adjust speeds or start/stop at any point. Tanks in hide positions or turret defilade can move to hull defilade (firing position), back again, and to an alternate or supplementary position as required.

5.2.1.1.2.2 Intermediate

These missions will focus on training platoon collective gunnery tasks while executing defined training tasks (e.g., hasty defense or attack, conduct a delay, disengage from the enemy, conduct movement to contact, attack and seize an objective) during the conduct of offensive and defensive missions under daylight and limited visibility conditions. Company operations orders with specified and implied tasks, along with fragmentary orders (FRAGO), will be developed for the missions. At least two offensive and defensive missions will have a FRAGO issued to the platoon that will require it to switch from offense to defense or vice versa. Missions will be conducted with vehicle movement controlled as in the Basic category missions.

5.2.1.1.2.3 Advanced

As in the intermediate category, these missions will focus on training platoon collective gunnery tasks while executing defined training tasks during the conduct of offensive and defensive missions under daylight and limited visibility conditions. Company operations orders with specified and implied tasks, along with fragmentary orders (FRAGO), will be developed for the missions. Each offensive or defensive mission will have two or more FRAGOs, with the first one issued to the platoon as it completes its initial mission requirements, and the second issued as the platoon completes the first FRAGO. All missions will be conducted with vehicle movement controlled as in the Basic and Intermediate category missions.

5.2.1.1.2.4 Combat (Free Movement)

As previously stated, combat includes missions from the three primary categories that will be conducted using free movement capabilities. Each vehicle commander verbally directs the movement of his vehicle. These vehicle movement directives will be executed by an operator at the IOS using a joystick controller interfaced to the crewstation's host computer. This joystick, along with a slide controller to increase/decrease vehicle speed, will control the movement of the vehicle. The operator will also have an out-the-window display presenting a view of the battlefield as would be seen by the vehicle driver, and will use the IOS IVIS map-view for orientation on the battlefield.

The addition of the Combat missions will increase the potential for disorientation and confusion on the battlefield, thereby increasing the platoon leader's responsibility to ensure all of the platoon vehicles maneuver and stay together within the prescribed company scheme of maneuver. Vehicle commanders will be responsible for ensuring their vehicles maneuver in the correct position according to the defined platoon formation.

5.2.1.2 CCTT Training System

As a tactical trainer focusing on collective armor and infantry tasks, CCTT is capable of providing training to individual crew and unit personnel covering the skills and knowledge of crew through company task force level doctrine for the execution of combat missions. As previously noted, CCTT's strength is in platoon and company tactics and doctrine training, extending to some battalion-level tasks. It utilizes a variety of manned simulators in conjunction with computer-generated semi-automated forces (SAFOR) to populate the battlefield with potentially large numbers of enemy and friendly forces engaged in a dynamic free-play combat environment. This ongoing exercise is monitored by operators manning various workstations (e.g., MCC/MC, AAR, SAFOR). These operators, chiefly the battlemaster or O/C, supervise and direct the action to attempt to maximize the desired training benefit.

After-action review (AAR) and performance assessment consists of overall summary statistics including killer-victim scoreboard, direct and indirect fire reports, ammunition expenditure, loss and force exchange ratios, etc. These reports can be generated and displayed/printed for individual module, platoon, or company levels.

5.2.1.3 AVCATT

The limited data available on AVCATT training system requirements precludes a detailed comparison to evaluate how it fits within the CCTT and AGTS envelope. The ORD defines AVCATT as a system "which trains and sustains individual, crew, collective, and joint task force/combined arms skills". It is to be interoperable with other CATT trainers and employ common components such as SAF and AAR. AVCATT is to support individual and crew level training for newly fielded systems that do not currently have dedicated trainers, such as the RAH-66 Comanche, as well as support these plus existing trainers (e.g., AH-64A Apache, UH-60 Blackhawk, and CH-47 Chinook) in collective and joint task force/combined arms training simulation. AVCATT is required to provide high fidelity weapons flyout models and high fidelity visual systems to support the capability to train and sustain critical individual and crew gunnery skills between live fire qualifications.

5.2.1.4 Summary

AGTS is the training requirements "high-driver" for GIOS, primarily in terms of data requirements, scoring software, and Instructor Operator workload. The scoring and data requirements impact is discussed in Section 5.2.2; the information display and system control requirements, their impact on operator workload, and ways to alleviate the workload are discussed in Sections 5.2.3, 6.2, and 6.3.3.

5.2.2 Scoring Data Requirements

The AGTS system, unlike CCTT, uses computer-based scoring algorithms to assess student performance during crew training exercises. Students are given three separate scores focusing on different training objectives: one score for Target Acquisition, one for Reticle Aim, and one for System Management. For platoon training, AGTS, like CCTT, primarily uses subjective instructor/company commander surrogate evaluation of tactical proficiency based on Tank Platoon Mission Training Plan Standards. The result of the evaluation is a GO or NO-GO (pass/fail) decision for the platoon. However, AGTS also provides an objective evaluation of platoon gunnery skills based on the percentage of targets destroyed and also by using Tank Table XII Gunnery Standards. CCTT does collect and present for AAR presentation a number of statistics concerning, among other things, module and platoon performance, including killer-victim scoreboard, direct fire reports, ammunition expenditure, loss exchange ratios, etc.

The following sections specify the AGTS crew training scoring criteria from which training system data requirements are derived. Specific simulation software variables used to support scoring can be obtained when and if required. This scoring criteria is summarized from an AGTS Exercise Detailed Design Document [ref 9]. Platoon training information was obtained from two LMIS internal platoon training concept documents [ref 10, 11]. For most of the scoring metrics there are alternate grading assignments depending on whether and what type of malfunctions are in effect for the exercise. These are not included in the summary since they impact only scoring, not data requirements, other than noting that the malfunction is in effect.

In addition to the crew and platoon training programs summarized in Section 5.2.1.1, there are several individual skills special purpose exercises that support individual skills training. The special purpose exercises include:

a. Acquisition/Manipulation
b. Boresight/zero/screening test
c. CITV handover
d. Killer tank
e. Evasive helicopter
f. Long range gunnery
g. IVIS message generation
h. OIP (Optical Improvement Package) gunnery
i. COAX machine gun

These exercises are either instructor-based or use existing crew scoring algorithms for performance evaluation so they do not add additional data requirements.

Following the crew training criteria specification is a tabular summary of the categories of scoring used to assess the training objectives previously identified in the Training Simulator Requirements Comparison matrix (Table 5.2.1-1).

5.2.2.1 Crew Training Performance Scoring and Data Requirements

5.2.2.1.1 Target Acquisition Scoring

Target Acquisition Scoring is based on two primary metrics: acquisition time and errors. Special scoring for CITV Target Handover exercises measures designate time instead of acquisition time.

I. Acquisition Time. This is defined differently for offensive and defensive mission scenarios:
   A. Defensive: Acquisition time is the time from ownvehicle in defilade <u>and</u> targets fully exposed (target activation + 3.5 seconds) to the time the ownvehicle reaches an enfilade position.
   B. Offensive: Acquisition is measured from the time the first target is fully exposed to the time when at least one round or burst is fired at each target in the situation. Score recorded is this time divided by 2. For Acquisition/Manipulation exercises, end time is at the activation of the assigned trigger for the exercise.

II. Classification and Identification is defined by firing errors:
   A. Round fired at a non-target, where a non-target is defined by the reticle aim point being greater than 20 mils from the center of mass of a point target or greater than 100 mils from the center of mass of an area target.
   B. No round fired at a target during exposure (target activation to deactivation).
   C. Round fired at a friendly (i.e., reticle aim point is within 20 mils of the center of mass of a friendly when round is fired).
   D. Target fired upon is not the highest valued threat of the targets active in the situation. Threat value is derived from a look-up table (LUT) and is based on target type, range, orientation, and target motion.
   E. For Acquisition/Manipulation exercises, identification errors are as defined in a) and b) above except measure is taken at trigger activation, not round firing

III. Designate Time for CITV Target Handover Exercises begins at full target exposure (target activation + 3.5 seconds) and ends at activation of the CITV designate switch.

A. Single targets: end time at first switch activation
B. Multiple targets: end time at last switch activation
C. Classification/Identification errors for CITV are the same as above except measured at switch activation.

5.2.2.1.2 Reticle Aim Scoring

Calculation of kill is critical to reticle aim scoring and is determined by ideal aim point, target type, and ammunition fired. The ideal aim point is dependent on the sight in use, target motion, and the fire control mode switch position. A LUT defines the ideal aim point for a specific exercise situation. Target damage is assessed by computing the trajectory of the ammunition fired based on the reticle aim point at the time of firing (and any other influencing factors such as tube bend, boresight, etc.). Each target has a defined catastrophic (K-Kill) hit plate and a mobility hit plate (loss of mobility but the target is still potentially lethal). Point targets are killed based on the ammunition type and the number of rounds impacting the target K-Kill plate. A single main gun round of appropriate ammunition for the target must impact within the K-Kill plate to score as a point target kill. A LUT defines kill capability of ammo for specific targets. Success against area targets, such as troops in a 10 man squad or RPG team, is assessed by percent coverage, defined by the number of troops killed (a troop is killed when struck by one or more rounds of COAX ammunition). If the number of COAX rounds fired at one area or point target is greater than 100, the reticle aiming evaluation is lowered one letter grade.

Reticle Aim Scoring is based on six primary metrics: time of first round or burst, time to kill, reticle aim error, time to trigger activation for Acquisition/Manipulation exercises, reticle aim at trigger pull error, and tracking accuracy.

I. Time of First Round or Burst. This is defined differently for offensive and defensive mission scenarios:
   A. Defensive: The time is measured from ownvehicle in enfilade <u>and</u> initial target in situation is active to the first round or burst fired.
   B. Offensive: If stabilization is operational, then time is measured from the first target fully exposed (3.5 seconds after activation) to the first round or burst firing. With announced stabilization failures, an additional five seconds is allowed for each grading level.

II. Time to Kill
   A. Defensive: Time from when one or more targets are active <u>and</u> ownvehicle reaches the enfilade position to target killed or deactivated.
   B. Offensive: Time from first target fully exposed (3.5 seconds after activation) to all targets in the situation killed or deactivated.
   C. Friendly targets: For any situation in which a friendly target occurs and no round is fired within 20 mils of that target, the Time to Kill

grade for that target is set to "B".

III. Reticle Aim Error is calculated only for main gun rounds and is based on 1) the outcome of rounds fired (first and second rounds are scored differently), where firing outcomes are: K-Kill, M-Hit, or miss, 2) type of ammunition, and 3) reticle aim status. For MPAT Air Mode, reticle aim error is based on distance in mils of round impact from target center of mass. For any situation in which a round is fired within 20 mils of or impacts a friendly target in either M-Hit or K-Kill hit plates, the reticle aim error score is set to an "F".

IV. Time to Trigger Activation for Acquisition/Manipulation Exercises
   A. Defensive: Time from initial target in situation is active and ownvehicle is in enfilade position to time trigger specified for exercise is activated.
   B. Offensive: Time from first target fully exposed (3.5 seconds after activation) to time trigger specified for exercise is activated.

V. Reticle Aim at Trigger Pull Error is calculated at the first activation of the trigger specified for the situation and is the total distance (azimuth and elevation) between the reticle ideal aimpoint and the centroid of the target. Score is based on the projected impact of the round within the K-Kill plate, M-Hit plate, or outside both plates.

VI. Tracking Accuracy is calculated from trigger activation to 3.5 seconds before target deactivation and reflects the percentage of time that the total distance between the ideal aimpoint and the reticle location is within the K-kill plate area (based on the projected impact of the round).

5.2.2.1.3 System Management Scoring

System Management grades are based on three criteria: pre-firing errors, time-of-fire errors, and procedure errors.

I. Pre-Fire error: Switch check is performed to determine if lasing occurs prior to firing each main gun round.

II. Time of Firing Errors: Switch check is performed when weapons fired or at designated trigger pull in Acquisition/Manipulation exercises to determine ammunition and reticle switch status.
   A. Ammunition: For second and subsequent rounds fired, an error is logged if the ammo selected is not appropriate for the target. Appropriate ammo is defined in a LUT specifying ammo type, target type, target range, and target aspect.
   B. Reticles: Error defined for following switch states at time of fire:

1. GPS/GPSE is in use and at low power
2. Ammo selector does not match the ammo fired
3. The GAS is in use and the reticle doesn't match the ammo fired
4. The gunner's thermal sight is in use and an OIP cue is active

III. Procedure Errors:

A. Muzzle Reference Sensor (MRS) Update error - one MRS update error occurs for each situation in which the number of main gun rounds fired since last MRS update is greater than six

B. Defilade error : 1) Ownvehicle returns to defilade before all targets are killed and there has been no enemy projectile near-miss
2) Ownvehicle fails to start to return to defilade position within 10 seconds of an enemy projectile near-miss.

C. Ownvehicle hit

D. NBC Mode Backup error - Commander fails to activate NBC mode backup within 15 seconds of warning message "NBC FILTER CLOGGED" appearing on the IVIS display.

IV. Two errors are defined for special purpose CITV target handover exercises and are categorized as CITV Target Handover Pre-Fire Errors:

A. Stadia Rangefinder error: The commander, using the stadia reticle, fails to determine the range to the target(s) within the time allowed to an accuracy of at least 200 meters

B. Target Designation error: The commander, within the time allowed, fails to designate the target(s) with an accuracy of no more than 3 degrees.

5.2.2.2 Scoring Applied to Crew Training Tasks

The following table illustrates how these three major scoring criteria are applied to the previously defined crew level training tasks on AGTS (see Table 5.2.2.2-1). Automated crew-level scoring is either not applicable or undefined for other training systems evaluated. The table also indicates that for AGTS, like CCTT, platoon tactical performance is subjectively evaluated by the instructor (company commander surrogate) and graded on a GO/NO-GO basis. AGTS also provides automated gunnery scoring in the form of percent targets destroyed, i.e., number of K-Kills logged during the exercise divided by the total number of targets presented. Mobility hits are not counted, and fratricide results in a five percent gunnery score penalty.

Table 5.2.2.2-1 AGTS Scoring Applied to ARTEP Training Tasks

TRAINING TASKS	SCORING

TRAINING TASKS	SCORING
CREW LEVEL TRAINING	
ARTEP Training Missions:	
MANEUVER/TACTICS	Target Acquisition, Reticle Aim, System Management
JOINT COLLECTIVE TASK DEFENSE/OFFENSE SCENARIOS	Target Acquisition, Reticle Aim, System Management
FIRE SUPPORT	IO Subjective GO/NO-GO
MOBILITY/COUNTERMOBILITY/ SURVIVABILITY	Target Acquisition, System Management (Procedure Errors ii and iii)
CREW COORDINATION	Target Acquisition, System Management (e.g., b(i), c(ii))
PRECISION GUNNERY	Target Acquisition, Reticle Aim, System Management
PLATOON/SECTION LEVEL TRAINING	IO Subjective GO/NO-GO for Tactics; Percent targets destroyed for gunnery skills

5.2.2.3 Follow-On Data Definition Efforts

An effort similar to this GIOS data definition was previously undertaken by Loral during ADST I. They conducted an evaluation of the capabilities of DIS standards and protocols to support precision gunnery. The basis for their evaluation was a comparison of tasks and data used by the M1A1 U-COFT against the requirements existing for DIS 2.04 standards and protocols at the time of the study. Their results [ref 20] indicate that DIS 2.04 can support precision gunnery for about 98% of the required functions. Any follow-on GIOS efforts to completely specify training data requirements for AGTS and CCTT will use this initial report as the foundation upon which further efforts will be built. In addition to simply identifying data content, as this report did, other issues such as data update frequency, criticality, and numerical precision would also have to be evaluated.

5.2.3 GIOS System Requirements

This section summarizes the GIOS system requirements identified using the previously identified AGTS, CCTT, AVCATT, and other (e.g., AC-130U) source documents. One additional reference document, the AGTS System Specification [ref 22], also served as a significant resource. It was originally intended during the course of the GIOS data collection effort to identify training system requirements for systems other than the three primary systems (AGTS, CCTT, AVCATT) that would reinforce or possibly extend the requirements identified for these systems. However, the only additional system requirements identified of any significance were for the Aviation Reconfigurable Manned Simulator (ARMS) system [ref 21].

The requirements identified for this system are included in the following summary matrix (Table 5.2.3.1-1).

In order to be compliant with the training systems' original specifications, the identified requirements must also be met by the GIOS unless specific relief can be justified and is granted. Section 5.2.3.1 identifies these explicit existing system requirements for AGTS, CCTT, AVCATT, and ARMS. Section 5.2.3.2 identifies requirements that GIOS must meet that are implied by or derived from desired or required GIOS-unique capabilities.

5.2.3.1 Legacy System Requirements

Table 5.2.3.1-1 summarizes the requirements that must be accommodated at some level by GIOS if it is to be compatible with the listed systems. AGTS has all real-time simulation monitoring and control functions allocated to the IOS. CCTT, AVCATT, and ARMS have distributed these real-time functions to different workstations including an IOS, an AAR (real-time), and an MCC/MC. The following table identifies how the training system requirements defined primarily for the AGTS IOS have been allocated by the other training systems, with the default 'X' cell entry noting an allocation to the IOS. However, other training system unique requirements not found in AGTS have been included to the extent that they have been identified.

Table 5.2.3.1-1 Legacy System Instructor Operator Subsystem Requirements

Requirement	Source AGTS	CCTT	AVCATT[1]	ARMS[1]
General				
DIS Compliant	Platoon	X	X	
Information Displays				
Video Displays				
Crewstation Display Repeaters, (e.g.: UVBs, GAS, GPS, GPSE, CITV, IVIS)	X	(Goal) AAR		
Driver's Display	X (Platoon)	(Goal) AAR		
Dismounted Infantry Display		(Goal) AAR		
Stealth Visual Display		AAR	AAR	AAR
Plan View Display (Topo)	X[3]	AAR	AAR	AAR
Data Displays				
Student Performance Metrics	X	AAR		
Student Records	X			
Exercise Descriptions/Op Ords	X	MCC/MC	?	
Exercise Control Parameters	X	MCC/MC	MCC	
System Performance Status	X	MCC/MC	MCC	MCC
Entity/Module Status		MCC/AAR		
Compass Heading	X (LAV)	AAR		
Aural Displays				
Communications (Crew I/C, Platoon, Company, IO net)	X	MCC/AAR		
Hardcopy Printouts		MCC/AAR		
Crew Performance Summary	X		X	
Control Inputs				
Training System Control				
Initialization	X	MCC/MC	X/(MCC)	MCC
Daily Readiness	X	MCC/MC		
Configuration	X	MCC/MC	X/(MCC)	
Student Record Management	X			
Termination	X	MCC/MC	X/(MCC)	MCC
Training Scenario Control				
Scenario Selection/Initiation	X	MCC/MC	X	X
Exercise Real-Time Intervention				
Re-initialization		MCC/MC		
Reconstitution		MCC/MC		X
Pause/Resume (see Freeze/Unfreeze)		MCC/MC		
Missing Crewmember Simulation				
Loader	X			
Driver (Discrete)	X			
Driver (Continuous (Free movement))	X			
Environmental Effects	X	MCC/MC	X	X
Digital Message Control	X	Note 2		

Requirement	Source AGTS	CCTT	AVCATT[1]	ARMS[1]
Malfunctions	Note 3	Note 2		
Tactical Support				
Smoke	X	Note 2		X
Artillery/Indirect Fire	X	Note 2		
Flare Illumination	X	Note 2		
Reconnaissance	X			
Instructional Control				
Video Source Select for Monitoring	X	AAR		
Freeze/Unfreeze	X	MCC/MC	X	X
Replay Control	X		X	X
Communication Network Select	X	MCC/AAR		
Network Voice Communications	X	MCC/AAR		
Entity Status Select	X[4]	MCC/AAR		
Instructional Data Display Select	X	AAR		
Digital Voice Note-taking	X	AAR		
Event Marking	X[3]		X	X
Plan View Display Control	X[3]	AAR	AAR	AAR
Stealth View Control	X[4]	AAR	AAR	AAR
Target Activation/Control	X	SAFOR	SAFOR	
Print Crew Performance Summary	X		X	
Processes				
Scoring of Crew Performance Data	X			
Read and use PDU data for image generation, scoring, audio, etc.	X	X	X	
PDU generation of IO control inputs	X	X	X	
Information generation (text and non-imagery graphics)	X	X	X	
Data recording for instant replay	X			
Target generation (Scripted for crew; SAFOR for platoon	Scripted	SAFOR	SAFOR	
IOS/Trainer Ratio				
Crew	1:1			
Section	1:1	1:2 or 3		
Platoon	1:1	1:4		
0ther				ARMS 1:6 at Co. level
MCC Control of Independent Exercises	-	Up to 5	Indiv. & collective	

Notes: (1) AVCATT and ARMS requirements specify an IOS, AAR (real-time), and MCC. An 'X' signifies an IOS requirement; AAR and MCC requirements are explicitly noted.
(2) The system has capabilities for these effects but no operator control requirement has been identified.
(3) Capability currently is either not funded or not required.
(4) Capability exists in the PAAR but is not currently utilized for AGTS.

5.2.3.2 Implied or Derived GIOS Requirements

The requirements defined in the previous section are those that can be traced back to specific requirements documents. Obviously, the instantiation of common requirements across systems may be different for each, driven by differences in hardware and/or software architectures, secondary design goals or requirements, etc. For GIOS, several derived requirements have been identified. These are driven by various factors such as the requirement to be a stand-alone DIS workstation, the desire to reduce IO manpower by providing automation enhancements over existing systems, the necessity of being reconfigurable to meet several different systems' demands, and the desire to minimize hardware requirements. These GIOS derived requirements are discussed below.

The AGTS implementation of most of its IOS requirements is through direct interconnections between computational and visual display subsystems, e.g., video distribution amplifiers, local ethernet, direct PIE (programmable interface electronics) connection, RS-232, etc. The implementation of these requirements for a portable (across systems), stand-alone, DIS compliant GIOS workstation implies a new solution. Some implications of this include the following:

- *GIOS will require an image generator.*

  AGTS fulfilled the requirement for IOS monitoring of crewstation sights and in-vehicle video displays by providing analog repeaters of the video generated for the crewstations. GIOS will require an image generator to regenerate selected in-vehicle displays from PDU-based data.

- *The GIOS image generator will require at least two channels.*

  The number of monitors used to display crewstation video at the AGTS IOS is fixed per vehicle type but varies between vehicles. For the M1A2, for example, up to seven separate display monitors are part of the IOS for platoon training. The number of displays available at GIOS will be fixed based on the number of channels available from its IG. Based on user feedback obtained during AGTS data collection, the IG needs a minimum of two channels to support simultaneous display of the commander's and gunner's views.

- *Access to other crewstation video by the IO at the GIOS must be quick and easy if manpower reductions proposed are to be realized.*

  The AGTS solution for the requirement to provide the capability for the IO to view any in-vehicle display is to provide a dedicated monitor to repeat each display channel in the crewstation. Thus, the IO visually samples the desired information from the spatially distributed array of information displays. If one IO was to conduct platoon training, up to 22 displays would need to be monitored in the current AGTS implementation (7 displays per vehicle x 4 vehicles = 28, minus 3 each duplicate PVDs and situation monitors). As indicated above, GIOS potentially will provide two display channels simultaneously. Thus, GIOS must provide the IO with easy and quick access to other displays. A means for "intelligent" dynamic display switching based on a real-time assessment of the situation (e.g., individual vehicle crew performance), on IO demand by voice or other selection means, or customized by each IO will be investigated. The number of actual video display monitors required at the GIOS depends on several factors including number of simultaneous displays required, video windowing capabilities of workstations, display resolution requirements, etc.

- *Natural language processing (NLP) is required in order to eliminate IO driver/loader simulation tasks and the need for a role player at each IOS during platoon free movement scenarios.*

  Currently, AGTS simulates loader and driver functions through manual "Wizard of Oz" simulation by the IO. To support IO workload reduction in the effort to reduce IO manpower requirements for platoon training, this function can be allocated to a voice recognition system. This could easily handle the loader functions and discrete driver tasks ("Driver move up", "Driver move back", etc.), and could work in conjunction with route planning and terrain following algorithms to support free movement exercises currently planned for platoon training. The goal would be to locate NLP hardware and software at the GIOS to make it simulator independent and to potentially support its use by the IO as a control device. Also, separate voice recognition systems may be required for each crew "channel" to handle multiple requests during platoon exercises. However, an NLP system may need to reside on the host processor at each crewstation if voice quality issues warrant. This is largely an empirical question.

- *The plan-view display (PVD) must be generated by the GIOS workstation.*

  The AGTS implementation of the PVD is still being worked. However, we believe a PVD can effectively serve as a primary resource for monitoring the ongoing exercise and extracting additional information desired or required by the IO. AGTS presents all exercise and system status information as text on a dedicated "situation monitor" display. Any PVD presentation will be on a physically separate display. Given the limitations of GIOS display real estate and the desired approach of intelligently integrating information, it is believed that this situation monitor and PVD information can be combined, with much of the situation monitor information displayed graphically on the PVD either continuously or on-demand as required.

- *GIOS must contain a PDU data logging capability.*

  AGTS has a requirement for "instant replay", which is a limited duration but total capability visual scene and event replay function. AGTS meets this requirement by keeping a 'sliding window' of event and database information in the host computer's memory. A stand-alone GIOS will need to store PDUs in order to re-create the desired temporal window of events and imagery.

- *Embed all IO functionality possible into the DIS compliant GIOS; provide a common core of software and hardware.*

  To minimize the impact to existing systems and to make the system as "generic" or extensible as possible, GIOS must be as self-contained and capable as practicable. This core capability should encompass the majority of requirements identified for the key systems to date, but must be designed in a modular fashion so capabilities can be easily added as required for future systems. Maintaining DIS compliance is one way to help ensure this compatibility.

5.2.3.3 Summary

The requirements identified for the core systems of AGTS, CCTT, and AVCATT should serve as the basis for development of the GIOS and verification of its completeness. It is believed that how well the derived requirements are met will largely determine the suitability or utility of GIOS in an operational setting. Design options or considerations for meeting these requirements are discussed in the following section, along with a proposed design concept strawman.

6. System Design

A preliminary design approach has been developed for the Generic IOS. A common hardware suite with software and data tailored to the application is proposed. Software portability has been stressed so that the IOS may be used on different platforms. COTS and GOTS components have been used to the maximum extent practicable.

Traditional IOS designs containing multiple hardwired displays were reviewed and contrasted to software controlled, workstation based windowing schemes. Scoring requirements for the various domains were consolidated into a unifying training matrix framework. Potential DIS protocol extensions were identified, along with an assessment of network loading induced by the new data types. Implications of the HLA on the design of the Generic IOS were considered. This was done by leveraging work that is underway on Lockheed Martin Internal Research and Development (IR&D) projects.

In the development of this preliminary design we have leveraged existing assets, such as the AGTS IOS and Exercise Manager to the extent practicable. We are also taking advantage of the ADA-based real-time simulation software architecture developed by Lockheed Martin under IR&D funding.

We have investigated new technologies such as natural language processing (NLP) in order to reduce instructor and/or operator task loading. New low cost image generators were reviewed to assess feasibility of utilizing these devices to render imagery on demand, as opposed to hardwired video repeaters. We have also looked into relevant intelligent tutoring work.

6.1 Introduction

The GIOS design must be evolutionary so that it verifiably continues to meet the requirements and user expectations of the legacy AGTS and CATT systems. However, it must also be revolutionary to the extent necessary to achieve reconfigurability, display consolidation, and I/O workload reduction goals that have not been achieved in any IOS fielded to date. We also believe it is this latter challenge that will ultimately determine the operational effectiveness and user acceptance of the GIOS.

In developing the design considerations discussed in the following sections, we referred back to user interviews and on-site observations conducted during the AGTS IOS data collection effort described in Section 5.1. In addition, a brief literature review was conducted to identify design issues and recommendations relevant to the GIOS effort. We have undertaken our GIOS concept definition with a user-centered design approach, integrating available technologies with advanced man-machine interface design concepts. There are many general human-computer interface (HCI) design references that are relevant to the GIOS design effort [e.g., refs 31, 32, 33], and there exist standards for physically integrating the human into a video display terminal (VDT) workstation environment [ref 34]. However, the references discussed in the following sections are generally restricted to those that deal specifically with IOS design issues.

6.2 Design Considerations

The three areas of the GIOS design that we consider key for an operationally successful system are: (1) automating operator and role-player functions currently assigned to the I/O, (2) reducing workload so that potential manpower savings can be realized, and (3) identifying cost-effective solutions to the GIOS display generation requirement. Of course, the automation of functions will be undertaken as part of an overall integrated design solution, not simply as piecemeal replacement of I/O functions. These three areas form the core of subsequent design consideration discussions and the strawman concept description.

Successfully meeting the goals defined in (1) and (2) will ensure that GIOS supports the primary mission of any training simulator: to successfully train personnel on the tasks defined for that simulator. Item (3) above will determine to a large extent whether GIOS is an economically viable solution to the requirements identified in this FAS.

6.2.1 Automated Functions

In an article discussing training device design in general and IOS design issues specifically, an Army psychologist [Ref. 35] states that the "real difficulty in designing a quality IOS comes when the instructor and operator duties are combined. Tremendous workload stress is placed upon instructors who must handle both chores" (page 52). The article goes on to list tasks that should be performed by an instructor. These include tasks such as simulation and exercise initialization, simulation control and trainee performance monitoring, evaluation of crew proficiency and diagnosis of performance problems, crew debrief, data files management, etc. The list does not contain any of the operator or role player duties identified as an AGTS IOS requirement. We concur that the GIOS user should not be required to carry out tasks that have no instructional value.

Users at Forts Knox and Hood also voiced similar sentiments [ref 7, 8]. They stated the desire that either crew positions be added for the driver and loader or that these functions be automated so that the instructor could concentrate on monitoring crew performance and providing feedback and critique. It has been previously discussed (Section 5.2.3.2) that these AGTS operator/role player functions could be automated. This would relieve the instructor of these tasks and allow him to focus on instructional tasks in crew mode, and to potentially reduce manpower requirements for platoon training. The methods for automating these functions are discussed in Sections 6.2.1.1 and 6.2.1.2.

In addition to off-loading the loader and driver simulation functions from the instructor, it is anticipated that further instructor aiding will be required to achieve manpower reductions for platoon training. The rationale and concepts for implementation of this aiding are presented in Section 6.2.1.3.

6.2.1.1 Automated Loader Functions

Automating or simulating the loader for a vehicle crew would be a relatively straightforward application of voice recognition (VR) and natural language processing (NLP) technologies. Current speaker independent VR systems are achieving the robustness that is required for applications such as this. Using a speaker independent system eliminates the need for lengthy and tedious training by the students. NLP requirements for this application would be relatively minor, since the vocabulary of TC commands to the loader is small and the syntax relatively well defined (i.e., 'LOAD' command and/or ammo type, e.g., SABOT, Heat, MPAT, etc.). Voice generation representing the loader's response (UP!) is already in place on AGTS. There are potential issues regarding the VR operation in a noisy environment and under stressful training situations that would need to be assessed and resolved if necessary.

The NLP and VR system would be integrated into the tank commander's (TC) voice intercom, either at the source or as reconstituted from PDUs at the GIOS. Voice quality and recognizer keying issues will determine where the system is integrated. The VR would activate on a defined cue. For example, the system could 'watch' for the keyword "Load" or an ammo type to trigger its recognition/response processes. It would then interpret the command and send out the appropriate discrete signal that is currently generated in response to the instructor's key press.

6.2.1.2 Automated Driver Functions

Simulating the driver in AGTS would essentially be the same as described above for the loader for those driver tasks that are relatively discrete, such as moving up/back to enfilade/defilade, moving to an alternate position, and all other tasks currently accomplished via a keypad entry at the IOS. Again, the VR system could key on a specific word such as "Driver" and issue the same discrete as is output by the current dedicated key at the IOS. The VR/NLP system would have to be integrated such that it would accept input from either the TC or the gunner, since either can issue commands to the driver.

Complications to driver function automation arise from those platoon training exercises that involve free movement. The proposed AGTS solution is for the driver role player to use a joystick to maneuver the vehicle over the terrain in response to TC (or in limited instances gunner) commands. While the VR/NLP system is capable of capturing and responding to these commands, the continuous vehicle control over terrain and around obstacles will require additional automation. This type of terrain reasoning and terrain following/obstacle avoidance route generation capability exists (e.g., for ModSAF) and could be extended to this application. According to the current AGTS free maneuver concept, the endpoint for this route planning will always be available as an IVIS checkpoint that has been designated as a waypoint. Subsequent checkpoints and all objectives, battle positions, or other locations to which the platoon will maneuver will have checkpoint designations. Final vehicle maneuvering into defilade position may require "snapping" into a predefined location, since this is a precise maneuvering task. Having a vehicle fall behind or wander off course in order to pose a training challenge to the platoon leader could be handled in a manner analogous to system malfunctions or could be instructor initiated.

6.2.1.3 Automated Instructor Aiding

Once the instructor has been relieved of operator/role player responsibilities, his workload during crew training should be acceptable. This conclusion is based on previous AGTS analysis. In fact, even with existing COFT loader and driver simulation tasks, some IOs reported that training sessions can sometimes be boring. They wanted to leave operator/role player functions assigned to them so that they could have more to do to help 'keep their heads in the game'.

However, when attempting to aggregate training tasks responsibilities and allocate to one instructor during platoon training, workload issues emerge as a predominant concern. Even if IO crew training workload is acceptable, multiplying this by four and adding additional platoon-unique task requirements clearly poses a workload issue. This is an intuitive assessment that is consistent with research in this area. For example, a recent study assessed the impact of having a single operator monitor and control more than one device [ref 36]. While the context was that of an industrial security task and not an IOS for a training simulator, the basic structure of the tasks is similar enough to warrant comparison.

In the study, there were three major tasks that each operator had to perform: 1) monitor one or more (up to three) displays for the presence of an intruder (basic monitoring task analogous to monitoring crew repeater displays), 2) determine the orientation and perspective of each active sensor (which could be fixed or mobile) and develop a single spatial model of the depicted information (similar to determining the orientation of vehicles in a platoon through viewing their repeater displays), and 3) integrate the information from multiple displays to construct a single model of the environment and its situation (information the PVD aids in conveying at an IOS). The operator response for the study was to indicate the number of intruders detected and their locations within the building containing the simulated camera sensors.

The general result of interest was that increasing the number of displays, particularly for mobile sensors, significantly increased operator workload (inferred, not measured) and degraded performance, i.e., the time it took the operator to perform the tasks. While preliminary, the results of this study are consistent with the body of human factors literature regarding human performance under multiple task demands, and is also consistent with our intuitions regarding assigning multiple crew performance monitoring demands to a single IO. Of course, any GIOS design actually implemented, either as a prototype or dynamic mock-up, would be evaluated to assess instructor workload.

The implication is that for a single IO to be able to achieve effective platoon-level instructional capability, some assistance must be provided to him to reduce his monitoring load. These observations are supported by user comments, some of which are reproduced here from previously referenced AGTS documents. The following aiding-related comments are from IOs at Forts Knox and Hood:

- Have a menu (pick list) of probable crew errors pop-up on the screen when an error or a number of same-type errors are identified by the computer scoring. Allow the instruction to select error type and enter as a marker.
- Provide help menus on the situation monitor
- The computer should provide a summary of crewman deficiencies and recommend corrective exercises
- The system should be designed so that manpower resource requirements for platoon training do not exceed one instructor and one operator.

Given all of this, we believe the case is well made for instructor operator aiding, primarily during platoon training.

Since the instructor will most probably be able to view the vehicle sight repeater displays for only one crewstation at a time, and his primary focus of attention will generally be on the PVD, a significant IO aid would be a crew performance monitoring function. This function could use existing crew scoring algorithms to monitor individual crew gunnery performance during platoon exercises. It is a stated assumption by most platoon training programs that crews will be proficient at using their vehicle's weapons systems to engage targets prior to participating in platoon-level training. Assuming this to be true, it is envisioned that a crew having performance problems in these areas will be the exception rather than the rule. If so, instructor monitoring of individual crew performance during platoon exercises would be unnecessary and uninformative for the majority of crews for the majority of the time. Only when a crew is having some trouble would the instructor need to be alerted to direct his attention to a particular crew. In addition to performing this display-by-exception monitoring/alerting function, this performance monitoring aid could also provide a crew performance score in addition to the overall platoon gunnery summary at the end of a training session.

The next progression beyond a crew performance monitoring/alerting function would be some form of intelligent tutoring system. This is a more radical extension of the scoring algorithm baseline that would not only monitor crew performance, but would diagnose problems and propose remedial actions or exercises. This crew feedback could be accomplished through the use of text messages on existing crewstation displays or through speech synthesis over the intercom. The benefit to the instructor would be the elimination of crew-level performance monitoring and troubleshooting for even those crews encountering problems in basic gunnery skills. The instructor could focus his attention on the platoon's overall performance. Adding this capability represents a significant effort that is beyond the proposed near-term follow-on activities.

6.2.2 Information Presentation Alternatives

The original M1A1 COFT trainer IOS has two video monitors, one for the commander's view and one for the gunner's, plus a situation monitor. PGT adds a topographic map or planview display. As the vehicles that the trainers simulate have added more displays in the crewstation, such as in the M1A2, the solution to the IOS monitoring problem has been to simply add more repeater displays. As previously noted, the AGTS M1A2 platoon IOS has up to six displays in addition to the situation monitor. See Figure 6.2.2-1.

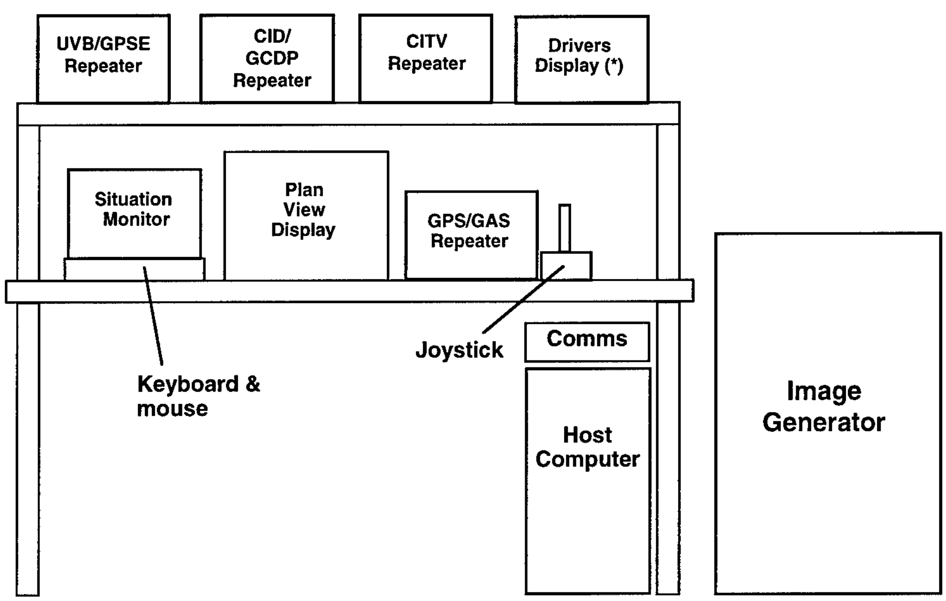


Figure 6.2.2-1: Existing AGTS IOS Design Approach

This solution minimizes the software impact to the IOS but pays the penalty of additional hardware costs. Also, as discussed above in Section 6.2.1, asking a single instructor or operator to monitor multiple displays can present performance and workload problems. The alternative is to limit the number of physical displays to perhaps two or three and provide the capability for I/O or software controlled switching among display options. The information content and format of these displays should also be optimized to convey the information the instructor needs to perform his job in a timely and efficient manner.

Even with the limited number of displays used at the IOS in COFT and PGT, user interviews indicated the desire to have different display options or information presentation alternatives. Again returning to some of the relevant AGTS IOS study findings, IOs at Ft. Knox and Ft. Hood provided the following comments concerning information presentation at the IOS:

- The COFT IOs look at the gunner's view and the situation monitor almost exclusively. They secondarily refer to the commander's view. They were not opposed to an idea presented to them about having the commander's view appear as a lower resolution insert into another display, i.e., using a picture-in-picture approach.
- PGT IOs also used the PVD display a great deal, in addition the gunner's view and situation monitor.
- The IOs would like to be cued on the PVD where targets will come up when they are activated. They would like to see the PVD better utilized to present additional information, and would like coordination of information displayed on the PVD and situation monitor.
- They would like a graphic means of displaying tracking errors.
- They would like to see information that is currently displayed on separate pages of a display (e.g., situation monitor and performance analysis data) integrated into a single display page.
- They would like real-time access to performance analysis data (COFT).

Other sources identified during the literature review also have stressed the importance of the methods of information presentation at an IOS. Madden and Englert [ref 37] performed a literature review and conducted a survey of instructor operators to assess the utility of a number of IOS instructional features. They assessed the amount each feature was used, its ease of use, the training value of the feature, and the amount of training the I/Os received in the use of the feature. The report discusses the survey data and the desirable and undesirable aspects of IOS designs and instructional features. Some of the pertinent items discussed in the report include the following:

- "The most common problems identified by instructors involved information presentation (e.g., number of hierarchical *(sic)* levels in the software, number of pages containing related information). The user-computer interface was mentioned frequently as a source of errors and frustration." (page 7)
- "Instructors who used graphical repeater displays commented favorably on the capability to select a section of cockpit instruments to be viewed rather than having all instruments continuously displayed." (pages 37-38)
- A computer mouse, touchscreens, and dedicated function keys were preferred input devices. At the time, voice recognition technology was not in use at any IOS, although the report discusses this as a potentially viable input approach.

A conclusion of the report is that "Efficient training console design can be accomplished, but only if display and control designs are based on information and action requirements . . ." (page 17). We have tried to follow this approach in defining the GIOS requirements in Section 5.2.3. This was the approach followed in the AGTS IOS requirements definition study and will continue to be the process followed in any further GIOS design efforts.

One of the IO comments cited above was a desire for more graphical depiction of information. This was discussed in the article cited above, and was further explored in a paper presented at NAECON by Meyn [ref 38]. The central tenet of the paper is summed up by the following quote: "One way to reduce instructor's workload and increase effectiveness is to optimize the use of graphics at the IOS. When this occurs, raw data is no longer presented to the instructor, but rather useful extractions of relevant information is provided" (page 1035). The paper goes on to discuss the use of color, highlighting, windowing, icons, and various input devices.

The key concept put forward in this paper with which we concur is that of presenting the instructor with information rather than data. Again, it is relatively easy from a design and software implementation perspective to simply present the instructor with lists of simulation variables and performance data from which he can extract and synthesize the information he needs to assess student performance, diagnose problems, and provide feedback. It is more difficult and time consuming to perform the human factors analysis to define instructor tasks, determine information and control requirements, and assess the best methods for presenting this information and implementing control methods. But, as we have seen through user comments and the references above, the outcome of this process will be a better product and in some cases may determine the difference between a successful and unsuccessful one.

Much of the foundation analyses that would be directly applicable to GIOS have already been conducted for AGTS. Also, a first step towards re-designing the COFT-type IOS interface from text-based to GUI-based displays was undertaken as a final project for an advanced engineering course [ref 24] conducted under the auspices of MMIS (now LMIS). The project looked at alternate GUI standards (OpenLook versus Motif), developed a prototype window environment for the IOS, and briefly examined issues relating to redesign of specific display screens, such as the situation monitor and performance analysis screen. The project also developed a preliminary hardware and software interface design. While not directly applicable to the GIOS architecture, some of the issues explored would still be relevant to the GIOS design effort.

To summarize, the primary displays as defined by the users seem to be the gunner's and, to a lesser extent, commander's displays, the situation monitor, and the PVD. Their desire to integrate more information onto the PVD and have it correlated with other displays is reflected in our initial GIOS design concept (Section 6.3). Integration of this information should be primarily graphical in format to realize the potential benefits described above and to maintain consistency with the information already displayed on a PVD. The data presented to the instructor should be pre-processed as necessary to meet his task requirements, i.e., should be compiled into information, not merely displayed as data.

The current assumption is that GIOS will not be able to display all potentially useful or necessary information at one time. Thus, the instructor must be able to access this "hidden" information easily and in a timely manner to support his task at hand. Control/display options to achieve this include pop-up windows, fixed, pop-up, or 'soft switch' menus, voice generation, or full-display page switching in response to operator selections via traditional mouse, keypad, or touch-screen selections. Voice, through the use of VR and NLP, could serve as a means to alleviate potential problems encountered with menuing structures (navigating menu depth, breadth, etc.) required to provided all necessary functionality with limited control and display resources. NLP processing could offer a single-layered command structure where any function or operation could be accessed via a one- or two-word command. Obvious integration issues include directing IO comments to the VR system versus to crew members and assessing the impact of the additional verbal burden on existing voice communication workloads.

Alternately, it is possible, albeit more difficult, to provide automatic, dynamic information display reconfiguration. An expert system-type process could monitor ongoing training events and switch or present information to the instructor based on rules developed out of the task-based information and control requirements analysis. This type of dynamic display configuration based on an assessment of operator intent has been under research and development in aviation and process control environments for some time. We are not aware of any use of this technique at this time outside of the R&D arena.

Finally, the strawman GIOS design concept defines the potential display real estate as a virtual display space. This is primarily because the number, size, and technology to be used as the display (and possibly control) interface has yet to be determined. The goal is to achieve something approaching this virtual display space, whether using large CRT or flat panel displays with windows or using smaller, independent displays. More details concerning the GIOS strawman design concept are presented in the following sections.

6.2.3 Stealth Alternatives

The preceding sections have discussed design considerations that primarily impact GIOS system software, although some issues regarding input/output devices have been reviewed. This section discusses the major GIOS hardware component - the image generator (IG). The IG will largely determine the effectiveness of GIOS in presenting the necessary gunner display view with the resolution and image detail required for the instructor to monitor performance and diagnose problems. The IG selection will also primarily determine the cost viability of the GIOS design, in terms of recurring hardware expenses.

As previously described, AGTS provides the instructor with the required crew sight monitoring capability by repeating at the IOS the video generated for the crewstation sights and displays by an SE 1000 IG. This is a viable solution because each crewstation has a dedicated IOS. However, GIOS must be a stand-alone DIS network asset that requires all of its inputs to come over the network via PDUs. Thus, all information presented to the instructor, whether voice, video, or data, must be extracted from the PDUs and reconstituted into the required format at the GIOS. This yields the derived GIOS requirement for an image generator as discussed in Section 5.2.3.2, with the additional derived requirement for at least two channels of imagery. In addition, the IG must be interoperable with both CCTT and AGTS databases, and the interface needs to be adaptable to the GIOS host software. The IG needs to provide a reasonable approximation of the views seen by the various crews, but it does not need to precisely replicate the crewstation display imagery as long as the necessary information content is provided to the GIOS instructor. This necessary information is determined by the analysis of the instructor's training task requirements.

The following sections establish basic IG performance requirements and identify candidate IG systems. A cost/performance comparison of these IGs provides the basis for establishing a ranking of the systems as viable solutions to the GIOS stealth/IG requirement.

6.2.3.1 Performance Requirements

Based on these general requirements, specific performance requirements can be derived. We concentrate on the two parameters that typically limit IG performance: polygon rate and pixel fill rate.

- *A Polygon Capacity of 262,500 polygons per second is needed*

The CCTT requirement is to process 3500 polygons per channel at 15 Hz update with a visibility range of 4 km. To support precision gunnery and aviation requirements, longer visibility ranges and higher update rates are needed. Using 5 km and 30 Hz update as precision gunnery requirements [ref 22], and assuming the use of CCTT databases, we get 3500*5/4*30*2 = 262,500 polygons per second. Aviation requirements could easily quadruple this figure, if we assume 10 km visibility and 60 Hz update, to over 1 million polygons per second.

- *A Pixel Fill Rate of 110 million pixels per second is needed*

Assuming two channels of 640 by 480 resolution, and a depth complexity of 6 (i.e., 6 visits to every pixel), we derive the textured pixel fill rate requirement as 640*480*2*6*30 = 110 million pixels per second.

6.2.3.2 Alternatives

The primary contenders are IG's manufactured by E&S, Lockheed Martin, and SGI. The E&S candidate is the Liberty. The Lockheed Martin candidate is the Real3D Pro, and the SGI candidate is the Maximum Impact. We picked these three candidates for the following reasons:

- Compatibility with CCTT and/or AGTS databases (Liberty, Real3D Pro)
- Existing interface with proposed host software (Maximum Impact, Real 3D Pro)
- Low cost, high performance capabilities (all 3 exhibit Level II performance)

The three contending IG's were compared using published performance data. The 1996 IMAGE Society Resource Guide and IG Survey was particularly useful [ref 29]. Table 6.2.3-1 summarizes the results of this comparison.

Note that both the Real 3D Pro and the Maximum Impact exceed the polygon requirements for precision gunnery, and approach the requirements for aviation. Therefore we focus the remaining discussion on the Real3D Pro and the Maximum Impact. We note from Table 6.2.3-1 that the Real 3D Pro exceeds the Maximum Impact performance with respect to pixel fill rate and texture capacity. This finding is supported by the third party performance analysis described below.

Table 6.2.3-1: IG Performance Comparison

Performance	Liberty	Real 3D Pro	Max Impact
Polygons/sec	50K or 100K or 150K	750K	676K
Textured Pixels/Sec	25 or 50 or 100M (1)	50 or 100 or 200M	119M
Texture Memory	1 or 2 or 4MB (2)	8 or 32MB	1 or 4MB
Video Output	640 by 480 to 1024 x 1024	640 by 480 to 1024 x 768	640 by 480 to 1280 x 1024
Video Channels	up to 16	1 or 2	up to 4
Occultation	Hybrid	Z buffer	Z buffer

(1) "Span full" technique increases effective capacity by 2 or more
(2) Assumes 16 bits per texel (capacity expressed in terms of number of texels)

Gemini Technology Corporation published a proposed set of benchmarks for Image Generators [ref 25]. These benchmarks are normalized to the SGI RE2 in a typical single pipe configuration. Gemini developed a set of test suites stressing polygon performance and pixel fill rates in realistic situations; i.e., flying/driving through real 3D data bases via predetermined paths. Preliminary results of these test suites applied to a number of low cost IG's were recently published [ref 26]. The tests were conducted at a 60 Hz update rate with double buffering. Double buffering is employed by all real-time IG's so that screen updates are not perceptible to the observer. The following devices were tested: SGI RE3 (Infinite Reality), SGI RE2 (the "control" case), LM Real 3D Pro 1100, SGI Maximum Impact, 3DFX Obsidian 2200, and Intergraph TDZ/GLZ5. Results for the ground benchmark, called gvf re2stone, are shown in Table 6.2.3-2, along with the published list prices (before discounts are applied). Unfortunately no results are available at this time for the E&S Liberty.

Table 6.2.3-2: IG Benchmark Test Results

Image Generator	gvr re2stone results	List Price
SGI RE3 (1)	1.74	$205K
LM Real 3D Pro 1100 (2)	1.61	$37K
SGI RE2 (3)	1.00	$135K
SGI Maximum Impact	1.00 (5)	$54K

(1) SGI Infinite Reality configured with one raster manager and two R10000 processors; multi-channel capability built-in
(2) Entry level Real 3D Pro with one channel at 640 by 480 output and 50M Pixels per second write capacity
(3) SGI RE2 configured with two 250Mhz (R4400) processors and a graphics pipe with 2 raster managers; single channel output
(4) SGI Maximum Impact with one R10000 processor; single channel output
(5) Estimated performance

Note that the Real 3D Pro out-performs the Maximum Impact by a significant margin in its base (minimal) configuration. For GIOS we recommend use of the Real 3D Pro Model 1400; it is configured with two 640 by 480 NIL channels (reconfigurable as one 1024 by 768 NIL channel), 200 Mpixels per second, 30 or 60 Hz operation, and 8MB of texture memory. List price is $75K, which is discounted by 35% in quantity one to $49K.

The Real3D Pro can utilize existing AGTS databases, MultiGen databases (the preferred format), and can import CCTT databases in SIF format.

6.3 Strawman Concept

The strawman design concept is based on a modular software architecture and a common hardware suite. The software architecture is a real-time, reconfigurable design composed of application segments built on a core services layer. This is described in paragraph 6.3.1. The hardware design is based on commercially available components, including a Unix Workstation, a low cost Image Generator, a virtual radio, and two or more CRT's comprising a virtual display. The hardware is described in paragraph 6.3.2. Paragraph 6.3.3 describes the design concept for Natural Language Processing.

6.3.1 Software Architecture

The software architecture proposed for the GIOS Strawman design is based on the Ada host software originally developed by Lockheed Martin on IR&D funds, and subsequently augmented by various government programs including STRICOM's Collective Scene Manager project. It was selected because of its availability to the project at no cost, and because of the large amount of existing code that could be used "as is", thereby facilitating a rapid prototyping effort with minimal software development.

Note: the host software has associated with it limited rights in accordance with DFARS 252.227-7013. This gives the government the right to use, duplicate, or disclose the technical data (software) with the express limitation that disclosure outside the Government, use by the Government for manufacture, or in the case of computer software documentation, for preparing the same or similar software shall not be made without the written permission of LMC.

The host software is a real-time, modular architecture composed of segments that plug into a central Core Services Layer or CSL [ref 27]. Segments are groups of objects or functions closely related to one another (e.g., weapons functions). Segments distribute data between each other via messages on a virtual network implemented by the CSL.

The CSL hides the message transaction process from the segments. It supports multiple CPUs on the same or different workstations connected on a network. The CSL utilizes shared memory and/or remote core services for message passing. A key feature of the CSL is its ability to support reconfiguration of segments and the virtual network at run-time.

Figure 6.3-1 illustrates the host configuration proposed for the GIOS. The segments shown shaded are existing segments that are available for use in GIOS (partial shading indicates partial implementation). The segments are written in Ada, C, and/or C++. As implied by the diagram, most of the programming effort will go into development of the Information Manager Segment and the Language Parser and Dialogue Controller Segment.

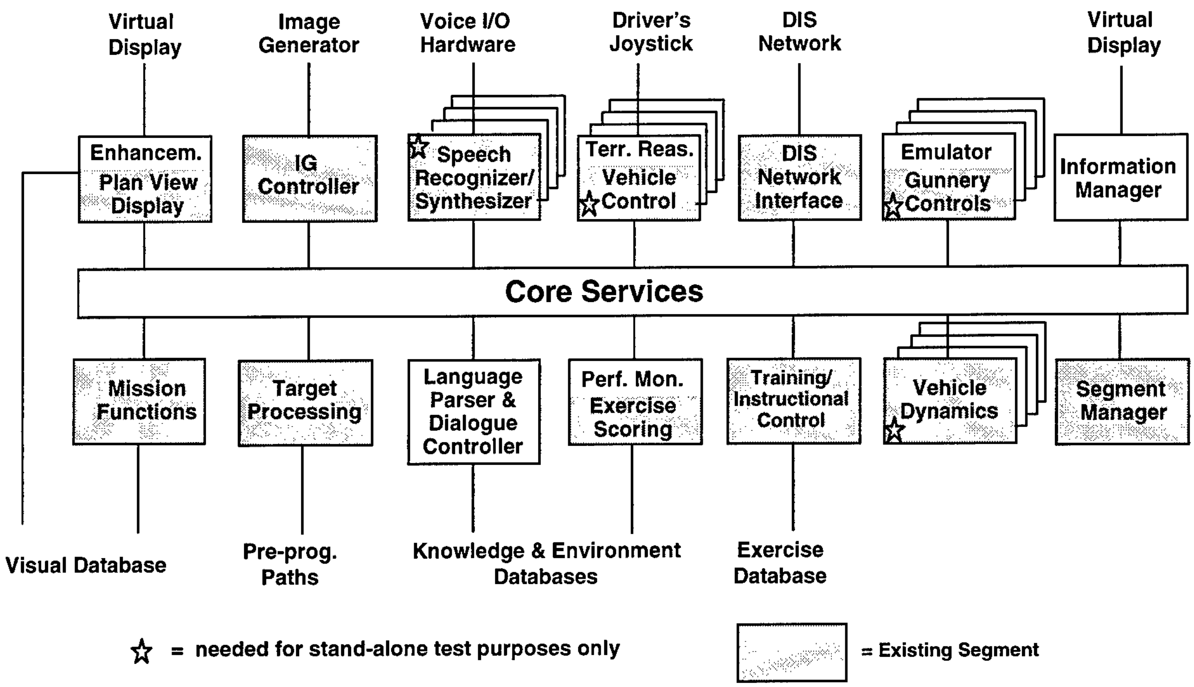


Figure 6.3-1: Software Architecture

6.3.1.1 Segments

Plan View Display: The Plan View Display Segment presents an overhead or map view of the simulation data base on the Virtual Display. The view is created from a PVD database that is derived from the 3D visual database, thus assuring correlation. This PVD presents terrain, cultural features, 3D features, and battlefield entities in user selected combination on the display. Battlefield events such as weapons firing and impact are also shown. The operator can utilize the PVD to select entities for tethering to the stealth viewer (i.e., the IG). The PVD will be enhanced with additional graphics and other overlay data to represent information normally provided in textual form on the situation monitor.

IG Controller: The IG Controller segment interfaces the host software with the selected Image Generator. It currently uses an ethernet interface. Versions of the IG Controller have been developed for the CompuScene SE IG, the Real3D Pro, and another version is being developed for the SGI Maximum Impact on the Terrain Fidelity DO. This segment provides system synchronization timing via the regular ethernet packets received from the IG. 30 Hz and 60 Hz update rates are supported.

Speech Recognizer/Synthesizer: This segment consists of COTS software; it is discussed in paragraph 6.3.3.

Vehicle Control: This segment provides a mechanism to control the direction and speed of the ownship. It is used in conjunction with terrain following (a Mission Function) so that the vehicle stays properly oriented with the underlying terrain. Since a major objective of this project is to provide an automated means to maneuver the ownship, the joystick control aspect of Vehicle Control will be used primarily for test and debug.

This segment will be augmented with a terrain reasoning module that will be extracted from ModSAF or other similar source. The concept for free maneuver, as previously described in paragraph 6.2.1.2, is that waypoints will be known ahead of time; therefore the terrain reasoning segment simply needs to find an obstacle-free path from point A to point B.

DIS Network Interface: This segment interfaces the host software with the DIS ethernet network. It performs the functions of filtering, coordinate conversion, time correction, dead reckoning and smoothing [ref 30].

Gunnery Controls: A Gunnery Controls segment augmented with software to emulate the actions of up to four gunners will provide the mechanism to test and evaluate the GIOS in crew and platoon exercises. This segment will include an emulation of the weapon effects that would accompany the actions of the gunners.

Information Manager: This segment will be developed to provide the interface with the virtual display for all information not supported by the PVD segment. This is expected to include both visual and aural forms of information. This segment is also responsible for managing the overall information presentation from all sources - the IG imagery, the PVD and overlays, and audio.

Mission Functions: This segment performs line of sight tests, collision tests, weapon impact determinations, and terrain following calculations in real-time in response to battlefield events. A private copy of the visual database is interrogated by this segment to perform the calculations. This approach minimizes the transport delay time as compared to the IG performing these calculations.

Target Processing: The Target Processing segment controls the target vehicles when the GIOS is operating in "scripted target" mode. Scripted targets are pre-programmed to follow pre-specified paths. They can be activated and deactivated by the IO, and they will stop when killed by a weapon. They will also speed up and take an alternate pre-programmed path when fired upon. Note that this segment will be disabled when a SAFOR is used to control intelligent targets.

Language Parser and Dialogue Controller: The software comprising this segment is discussed in paragraph 6.3.3.

Exercise Scoring: This segment is based on existing AGTS crew training scoring software as described in paragraph 5.2.2. It provides a post-exercise performance grade for crew training exercises and will serve as the basis for the real-time crew performance monitoring instructor aid during platoon training exercises.

Training/Instructional Control: This segment is based on existing AGTS crew training software that performs the exercise initialization and control for the training programs described in paragraph 5.2.1.1. It serves to load student data files, performs exercise selection and initialization, and provides the IOS functionality for real-time exercise monitoring and control.

Vehicle Dynamics: The Vehicle Dynamics segment provides a realistic simulation of the dynamics of the ownvehicle. Since the initial application of the GIOS will be for an M1A2 CCTT Quick Start module, M1A2 dynamics will be used. This segment includes an auto-pilot function which will be used in conjunction with the terrain reasoning logic added to the Vehicle Controls segment to simulate automated maneuver.

Segment Manager: The Segment Manager is used to spawn and start the other segments. Unlike other segments, it does not use any messages to communicate. The Manager Segment reads the CSL configuration file to determine how to allocate the memory area for the messages that will be passed between the segments (this is discussed further in paragraph 6.3.1.2). It is also responsible for monitoring timing information, calculating CPU loads and informing segments of the allowable run time.

6.3.1.2 Core Services Layer

The Core Services Layer provides the infrastructure to interconnect the segments with each other over a virtual network. As mentioned earlier, the CSL supports multiple CPUs on the same or different workstations over the network. The CSL hides the message transaction process from the segments. The CSL utilizes shared memory and/or remote core services for message passing. A key feature of the CSL is its ability to support reconfiguration of segments and the virtual network at run-time. This is further discussed below.

Configuration Files: Configuration Files define the segments and the messages to be sent between the segments. However, the CSL does not need to know the type of data stored in the messages. Message information required includes the message name, its size, a buffer factor (the number of instances to be saved at one time), a protect flag, and (X,Y) position of the message on the display.

Segments are stand alone executables. The CSL needs to know the following about each segment (via the configuration file): segment name, host computer, processor (which CPU), path, priority, locking (to prevent swapping), message names and associated access method (read, write, or read and write), and (X,Y) position of the segment on the display.

Graphical Configuration File Editor: A Motif based GUI was developed to create and modify configuration files. It permits visual adding/deleting/modifying of messages, segments and connection lines. Host computers and specific CPUs are graphically identified. This is a powerful tool that permits new configurations to be created quickly and accurately, typically by modifying an existing configuration file.

6.3.1.3 HLA Extensions

Under IR&D Lockheed Martin is developing an approach to make the host software compliant to emerging HLA standards. This work is being led by UCF professors Dr. B. E. Petrasko and Dr. R. F. Demara under subcontract to Lockheed Martin.

Furthermore, Lockheed Martin, UCF, and Veda have recently teamed to respond to the recent BAA released by the HLA government team to bring more contractors into the development process.

The focus of the HLA IR&D effort has been on development of an Attribute Object Model (AOM) as the key component required to integrate the CSL of the host software (an examplar Simulation Object Model or SOM) with the HLA's Run Time Infrastructure or RTI (representing the Federation Object Model or FOM). Thus, the AOM is defined in terms of its FOM/AOM interface and its SOM/AOM interface. The FOM/AOM interface provides the RTI a direct means of reassigning attributes of a SOM whenever necessary. The SOM/AOM interface allows simulation suppliers to embed attributes in Object Request Broker (ORB) or legacy simulations such as the IRAD host software for enhancement and/or HLA compliance.

This work is expected to continue through next year on Lockheed Martin IR&D funds. Results will be available for use by the GIOS project.

6.3.2 Hardware

The hardware design utilizes commercially available components, including a Unix Workstation, a low cost Image Generator, a virtual radio, and two or more CRT's comprising a virtual display. Figure 6.3.2-1 illustrates the design concept.

Unix Workstation: A Sun Ultra 2 Workstation with 2 CPUs and Solaris 2.5.1 is recommended to host the Ada real-time host software described in 6.3.1. The proposed host software was developed (and continues to be developed) on a multi-CPU Sun Workstation, so this approach will minimize costs. It will be configured with two 20 inch color monitors in a dual-head configuration.

Low Cost IG: Low cost IG alternatives were discussed in paragraph 6.2.3. In accordance with the data presented, we recommend the Real3D Pro Model 1400 as the best value for this project. In addition, it has already been interfaced with the host software. Two color multisync monitors will be included to provide dedicated viewing of one or two channels.

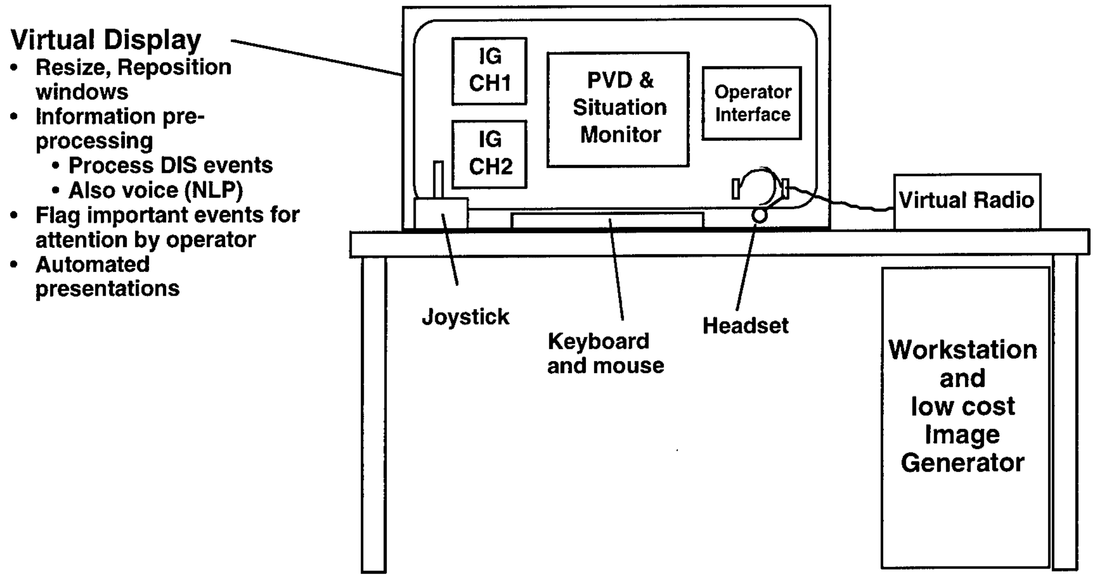


Figure 6.3.2-1: GIOS Hardware Design Concept

Virtual Radio: The TSI Virtual Radio is the tentative selection, given its low cost and availability. Furthermore, other ADST II DO's are using this radio (CDF Upgrade, Dismounted Warrior Network, STP-21), which should provide some synergistic benefit to GIOS.

6.3.3 Natural Language Processing (NLP)

The software design for the NLP portion of the host software is shown in Figure 6.3.3-1. It is modeled after work done by Research Triangle Institute for a National Guard M1A1 Maintenance Trainer. It is briefly described below.

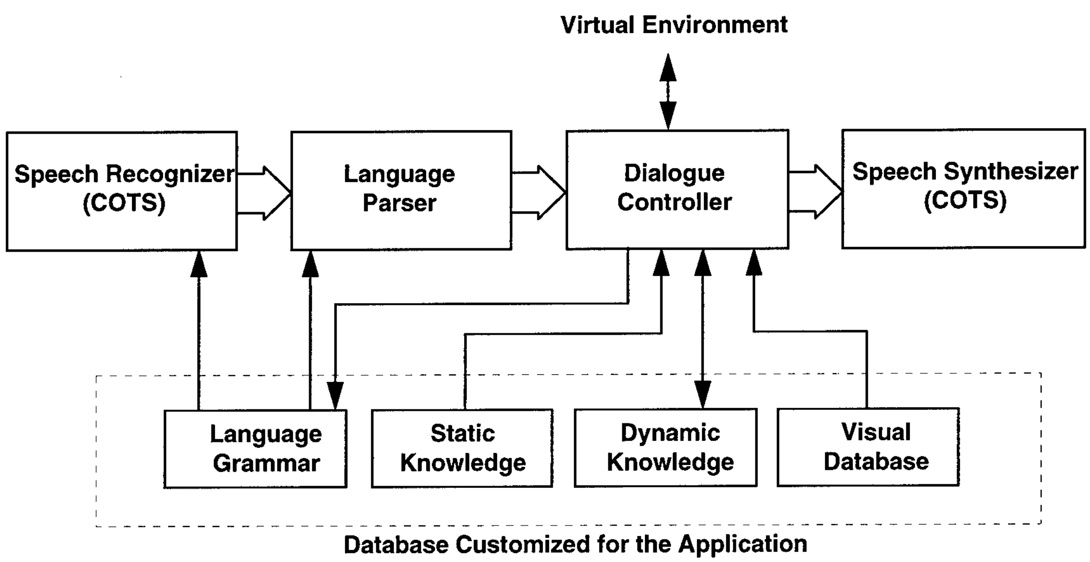


Figure 6.3.3-1: Natural Language Processing Design

Dialogue Controller: The Dialogue Controller uses goal-driven processing in its interpretation and generation of utterances.

Virtual Environment: The virtual environment is a three-dimensional model of the interior of the crew station. The Dialogue Controller communicates with the Virtual Environment (VE) in order to change the state of the world based on user utterances. The Dialogue Controller must also monitor the user's interactions in the Virtual Environment to keep up to date with the current state of the world.

Speech Synthesis: The IO Assistant communicates with the user by modifying the Virtual Environment (text boxes, arrows, etc.) and also by speaking. Current implementations use a COTS package called DECtalk to perform text-to-speech synthesis.

Speech Recognition: Users can communicate with the IO Assistant by interacting with the Virtual Environment or by speaking. The current PC based implementation uses IBM's VoiceType Application Factory for speech-to-text conversion. This system is speaker independent, thus the computer does not need to be trained to understand each individual speaker. This recognizer also recognizes continuous speech where words do not have to be separated by pauses. Thus speakers can talk in their natural manner. A limitation of IBM VoiceType is its limited active vocabulary. To combat this problem, the program constantly changes its active vocabulary depending on the current dialogue context. This technique greatly increases the effective vocabulary size.

Language Parser: A Minimum Distance Translator (MDT) parser is utilized. This parsing technique tries to match the spoken words to the closest sentence that is acceptable to the parser. Thus a user could speak an utterance that is out-of-grammar and be understood. The Language Parser may be able to correctly interpret the utterance if it is close to something in the grammar. For instance, the user's utterance "tank working" might be correctly matched with "the tank is working".

Language Grammar: The Language Grammar is a model of acceptable spoken statements. The representation language is quite free; literally any sentence can be encoded in the grammar. In practice, grammars must be relatively small because of the speech recognizer. Thus the Dialogue Controller selects which grammars should be active based on the current context. This increases the reliability of the speech recognition and also speeds up the parsing process.

Static Knowledge: Static Knowledge related to operation of the crew station is maintained.

Dynamic Knowledge: New knowledge is gained during an interaction with a user. Examples are procedural errors, what steps have been carried out, what procedures did the trainee have problems with, and so on.

Visual Models: In order to appropriately manipulate and interpret the Virtual Environment, the NLP software maintains 3D models of the environment. The software must be able to correctly map the state of the Virtual crew station to appropriate knowledge in its database.

6.4 Integration with Legacy Systems

6.4.1 CCTT

Addition of a GIOS to a CCTT environment would require changes in a number of areas. These changes are not only driven by the incorporation of GIOS, but by the requirements of simulation for precision gunnery training. These include but are not necessarily limited to the following items.

Host Software Modifications: the CCTT host software (i.e., the M1A2 Manned Module Simulator CSCI) will require modifications to extract the necessary information from the associated crew station and from the appropriate host modules. In particular, all gunner and commander switch settings that are controllable by the soldier in the crew compartment need to be extracted on a regular basis and prepared for transmission to the GIOS via the DIS network. Since the Programmable Interface Electronics (PIE) used on CCTT is similar to the PIE used on AGTS, we know that this information is available via the PIE interface to the host computer at a regular update rate. On AGTS all of the crew compartment data, representing approximately 300 bytes, is transmitted to the host every 1/30 of a second.

Additional information that needs to be extracted from one or more of the host software modules is gun related information, such as the number of times the gun has been fired since it was calibrated. This is used by the GIOS scoring algorithm to compute gun droop. Other required data includes line of sight data for firing and lasing, exact time of lase and fire, and turret stabilization status.

Finally, the local copy of the NLP software will need to be integrated with the host software, along with terrain reasoning software for automated maneuvering through the terrain data base.

DIS PDU Modifications: The main issue with PDU modifications is the packaging of the required data (described above), most likely in a Data PDU, and its subsequent transmission to the GIOS over the DIS network. We do not believe this poses a bandwidth loading concern, since PDUs are only sent when there is a change in state. We estimate that once per second is more than sufficient, on average; with 4 crew stations in a platoon, this yields 4 PDUs per second additional load on the network. With CCTT sized to accommodate 851 entities and 1285 PDUs per second [ref 12, pages 3-11 & 12], the additional network load imposed by this information is negligible.

We will rely on the PDU translator being supplied by the CDF Upgrade DO to perform the necessary conversions between DIS 2.0.4 r (for revised) used by CCTT and the DIS 2.0.4 used by GIOS. Figure 7.2-1 in paragraph 7.2 illustrates.

Event Synchronization: An important issue in precision gunnery is accurate representation of position and time by all participants in a gunnery exercise. Prior to AGTS, gunnery systems utilized dedicated networks with synchronized clocks, thus permitting all entities to move at a synchronous 30 Hz update rate. AGTS and future gunnery training systems must cope with asynchronous networks and dead reckoning. The AGTS approach is to use Network Time Protocol (NTP) to synchronize all clocks in the network to a reference clock combined with small dead reckoning thresholds to minimize dead reckoning errors [ref 30]. The impact to CCTT would be higher PDU rates and the introduction of NTP or similar scheme to support absolute time stamps. The higher PDU update rates should not be an issue since gunnery exercises do not require as many simultaneous moving models as tactical exercises [ref 22]. Absolute time stamps should be implementable via software changes only.

IG Update Rate Change: An important lesson from the platoon gunnery training experience in Europe is the need for 30 hz scene update. Unless the scene is geometrically recomputed (not just refreshed) at a minimum of 30 Hz, target acquisition during turret slew, shooting on the move, and shooting at fast moving targets is unrealistically difficult and therefore forces incorrect procedures to be learned [ref 4].

The CCTT IG was specified to run at 15 Hz, which was deemed adequate for the tactical tasks trained on CCTT. Increasing the update rate to 30 Hz should be straightforward, but it may be expensive to do so while maintaining the same database content. Additional polygon processing capability would be required to maintain the same scene detail of 3500 polygons per channel at the higher update rate. Alternately, the data base could be thinned to approximately 1750 polygons per channel, which is comparable to the AGTS polygon load per channel [ref 22]. Since fewer moving models are required for a gunnery exercise than a tactical exercise, it should be possible to accommodate the higher update rate for moving model processing in the IG by computing fewer model positions and attitudes at the higher rate. Note that the Multiple Image Suppression overscan feature of the CCTT IG would not solve the "smooth track" problem for moving targets (they would still update their position at a 15 Hz rate).

Database Modifications: The CCTT database will require some thinning to support the higher update rate required for gunnery training, as mentioned above. The modified database will then be converted to run in GIOS native formats. This includes visual, plan view display, and exercise database formats. Tools to accomplish these conversions should be available to the ADST II program in the near future.

Weapon System Simulation Fidelity: Recently troops from Fort Hood received training on both the AGTS and the CCTT M1A2 simulators. Discussions with these troops were held after they had completed their training on both simulators [ref 42]. One of the major concerns they expressed regarding CCTT performance was the inaccurate representation of force feedback in the gunner's handles, as well as an inaccurate turret response transfer function. Since both the AGTS and CCTT simulators utilize a common crew station developed by the same vendor, it should be a straightforward matter to retrofit the force feedback upgrades made by the AGTS program to CCTT. Further, the turret transfer function should be a relatively minor software modification to the CCTT host software.

Sensor System Simulation Fidelity: During the abovementioned discussions with the Ft. Hood troops, they also expressed the opinion that the CITV simulation in CCTT needed improvement, as did the overall thermal simulation capabilities. Specifically regarding the CITV, they felt that both the controls and the display resolution did not provide a realistic simulation of the actual vehicle system performance. Again, improvements that have been made to the AGTS CITVsystem may serve as the basis for CCTT enhancement. Increasing the overall fidelity of the thermal simulation is a more general issue, one that is continuously being addressed by simulation enhancements.

MCC/MC Modifications: We do not anticipate any changes to the MCC/MC. It will be used to initialize and monitor the CCTT equipment. The GIOS will be used to initialize, monitor and control the gunnery exercise after the MCC/MC has initialized the CCTT equipment.

Display Resolution: Display resolution was another issue raised by the Ft. Hood troops. They expressed an inability to identify targets at ranges that they could in the vehicle or even in AGTS. This is an unexpected finding that will need to be investigated further. These issues stem from the 5km target range required of AGTS versus 4km for CCTT, and the relative fidelity of the reticle simulations. For purposes of the gunnery evaluation discussed in paragraph 7.2, it may be possible to overcome these issues via the use of data base modeling techniques, such as artificial enlargement of targets at long ranges.

6.4.2 AGTS

Integration of a GIOS with AGTS should be relatively straightforward. The main issues revolve around host computer and PDU modifications.

Host Software Modifications: The primary task here is to disable the IO related functions from the host software, and make the necessary modifications to interact with the IO functions externally hosted on the GIOS. Also, the local copy of the NLP software will need to be integrated, along with terrain reasoning software for automated maneuvering through the terrain data base.

DIS PDU Modifications: The main issue here is addition of the new Data PDU. As described above under CCTT Integration, this PDU will include all of the crew compartment switch settings; it will be transmitted from the AGTS host computer to the GIOS whenever there is a change in the PDU dataset.

7. Potential Follow-On Activities

As mentioned earlier, we recommend a two phase Proof-of-Principle (POP) implementation approach. The first phase POP is a stand-alone implementation of a prototype GIOS; this is described in paragraph 7.1. Given a successful first phase, then the logical second phase POP would be an integration of the prototype GIOS with a CCTT M1A2 Quick Start module in the ADST II Operational Support

Facility; this is described in paragraph 7.2.

7.1 Stand-Alone Prototype Implementation

The purpose of a stand-alone first phase POP is to prove the feasibility of the GIOS with respect to the following:

- The viability of NLP in a noisy, DIS environment;
- The capability of NLP and terrain reasoning to automate driver and loader functions;
- The capability of NLP combined with scoring algorithms and an intelligent monitoring function to eliminate the need for a dedicated crew station IO during platoon gunnery training;
- The ability to manage the data from multiple crew stations such that a single IO can cope with the resulting information flow;
- The adequacy of two channels of IG imagery;
- The effectiveness of expressing situation monitor data in graphical form and combining it with a plan view display;
- The cost-effectiveness of a stand-alone DIS compliant GIOS; and
- The ability to automate the IO processes well enough to reduce IO requirements from 8 to 1 in a platoon setting.

7.1.1 Approach

To accomplish this evaluation we propose to implement a prototype GIOS as described in Section 6.3, "Strawman Design". The approach is as follows:

System Specification: the process begins with the development of a System Specification, which will be reviewed with STRICOM prior to implementation.

Technology Interchange Meetings: TIM's will be conducted on a regular basis to ensure that work proceeds in IPT fashion. Four TIM's are proposed: (1) at project kick-off, (2) at the conclusion of the system specification phase, (3) at the conclusion of the design phase, and (4) after the system evaluation phase.

Software Development: Software development is estimated at two full-time programmers plus support from Research Triangle Institute (RTI) for the NLP related software effort. Subtasks include development of (1) a software framework, (2) language parser and dialogue controller (RTI), (3) terrain reasoning, (4) information management, (5) plan view display enhancements, and (6) gunner emulation.

Knowledge Base Development: a knowledge base will be created to support NLP and performance monitoring requirements for an M1A2 environment. It will be done such that it can readily be adapted to other vehicle types, such as the M2/M3A3.

Exercise Database/Path Generation: assuming the use of an existing visual database, this task will create the ground paths and other exercise set-up data required to perform the GIOS evaluations.

Integration and Test: This phase of the project brings together the hardware, software and databases into a complete system.

Evaluation: During this phase of the project the GIOS is evaluated as a tool to support platoon gunnery via the use of emulated gunners. The evaluation will consider the issues identified in the beginning of this Section.

Final Report: A Final Report will be prepared describing the work performed on the contract. It will include a proposal for a follow-on POP to integrate the prototype GIOS with a CCTT M1A2 Quick Start Module in the ADST II OSF. Therefore it will address a number of implementation issues in depth, such as bandwidth requirements, impact on CCTT host software, fidelity issues such as IG update rate and resolution, etc. These subjects were dealt with in summary form in this report in paragraph 6.4.1.

7.1.2 Schedule

The proposed schedule is shown in Figure 7.1-1. It assumes a start Date of November 1, 1996.

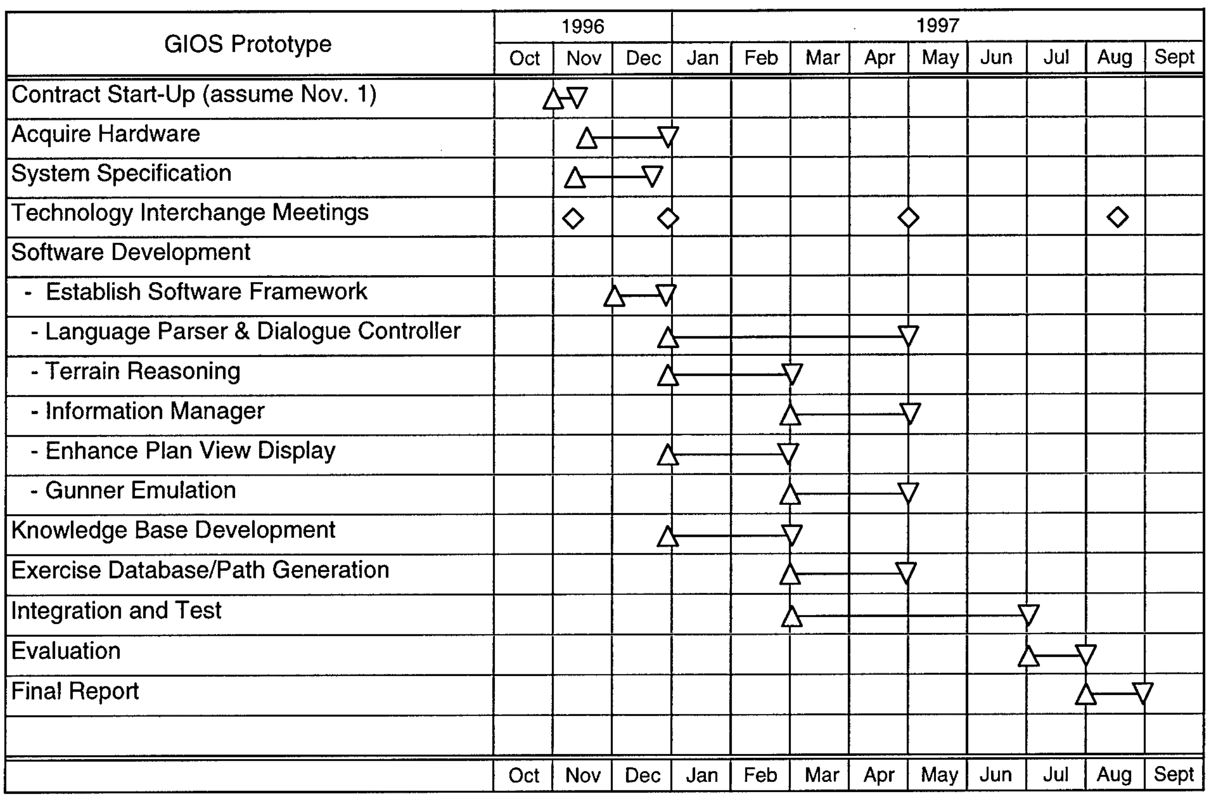


Figure 7.1-1: Prototype Development Schedule

7.1.3 Budgetary Costs

For budgetary purposes only we have estimated the cost to develop a prototype GIOS as $700K. A detailed cost proposal will be prepared separately. The breakdown is as follows:

- Material Costs: $100K

  Includes a Low cost IG (Real3D Pro 1400), a Sun Ultra Multi-CPU Workstation, and miscellaneous hardware and software licenses.

- Software Development: $350K

  Includes 2 full time software engineers and a subcontract to RTI for NLP work.

- Systems: $150K

  Includes 1 full time system engineer , and a full-time technician for database work and general support.

- PMO: $100K

  Includes a part-time Project Director, contracts, subcontracts, and finance support, and proposal development.

7.2 Prototype Integration with CCTT

Assuming a successful first phase POP, then the logical second phase effort would be the integration of the prototype GIOS with a CCTT M1A2 Quick Start Module. This phase of the project is more difficult to scope at this time, since it requires a detailed understanding of CCTT host software, IG capabilities, and so forth. Since the CDF Upgrade DO will soon be integrating the CCTT M1A2 into the OSF and MWTB facilities, we propose to leverage this work for Phase 2 of GIOS. During Phase 1 of GIOS, while the CCTT M1A2 integration effort is occurring, we will develop detailed costs for the efforts required to integrate GIOS with the CCTT environment. A general description of the integration effort that we foresee at this time was presented in paragraph 6.4.1. Integration with AGTS is also discussed; see paragraph 6.4.2.

We anticipate that the test and evaluation environment will consist of the GIOS networked with an M1A2 module, an MCC/MC, ModSAF, and a data logger, as shown in Figure 7.2-1.

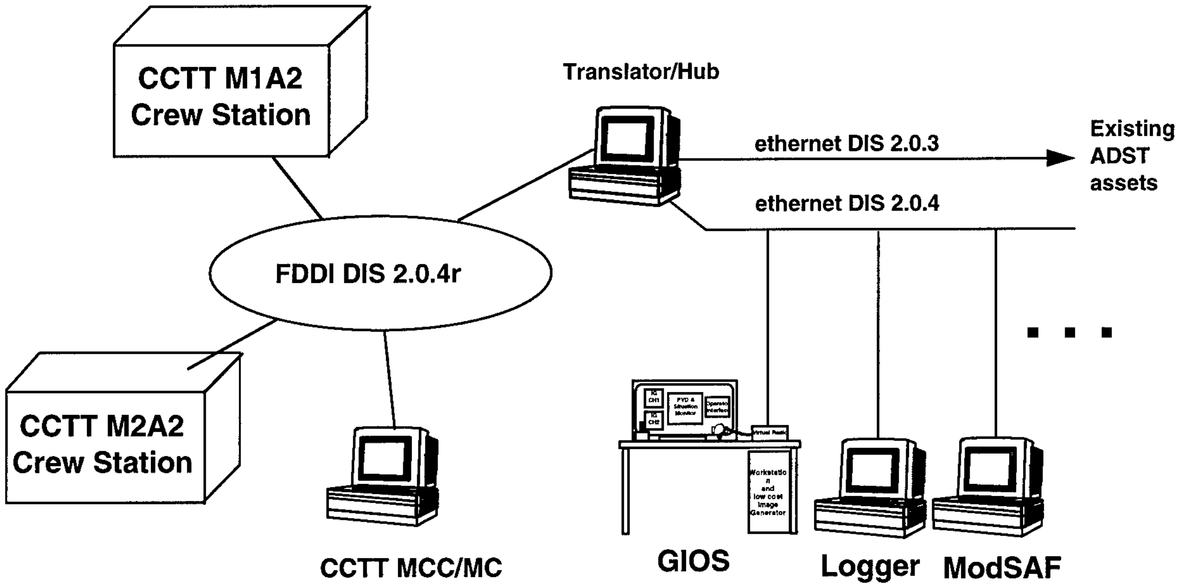


Figure 7.2-1: Prototype Integration with CCTT M1A2

As shown, this approach leverages work that is currently underway on the CDF Upgrade DO to integrate an M1A2 and M2A2 into the OSF. Note that a Translator is being implemented to translate CCTT PDUs between DIS 2.0.4 r and DIS 2.0.4 and DIS 2.0.3. The Hub bridges the different media (FDDI and ethernet).

The evaluation process will assess the capabilities of the GIOS in the CCTT environment as follows:

- Ability to train precision gunnery with or without the loader and driver;
- Fidelity of the modified system in terms of update rate, resolution, etc.;
- Impact on host computer hardware and software;
- Interoperability issues with respect to databases, PDUs, and bandwidth; and
- Cost effectiveness - i.e., the cost in terms of manpower and equipment to retrofit GIOS devices to fielded CCTT systems.

7.3 Extensions to Other Applications

GIOS, as an independent, reconfigurable, DIS-compliant workstation, offers a flexible platform that can support other functional capabilities within the presently defined domain of Combined Arms Tactical Trainers (CATT) simulators and precision gunnery trainers, as well as extension to other training domains. It provides the capability for the generation and display of high fidelity images and traditional computer graphics, logging of PDU data, network voice communications, and simulation and training exercise control. It can support either real-time or after-action simulation activities. The inherent capabilities and flexibility (through software modifications) of GIOS make it an attractive solution to a wide range of DIS applications. Some of these potential applications were identified in the GIOS proposal and are discussed in the following paragraphs.

7.3.1 Indirect Fire and Air Defense

It is clear that extension of GIOS to the indirect fire (FSCATT) and air defense (ADCATT) domains will require an assessment of requirements for instructor training support in the same manner as has been conducted for the AGTS and CCTT systems. Without such a clear statement of requirements, it is impossible to adequately assess the ability of GIOS as currently configured to meet system training needs. However, inasmuch as the systems are DIS-compliant simulators, integrated into an overall network of CATT-family simulators - i.e., CCTT, FSCATT, AVCATT, ADCATT, and ENCATT (Engineering CATT) - GIOS's basic capabilities should be able to support the majority if not all required functionality. The PVD can represent the overall simulation environment and provide access to information on individual simulation assets. The image generation capability can reproduce the visual perspective and scene content from any entity or independent location in the database. Personnel operating GIOS can communicate over the network with any asset configured with a DIS radio/receiver. Specific issues regarding unique software capabilities, quantities of GIOS workstations to support a simulation, number of displays, etc. await the detailed analyses. Since this is beyond the scope of this current effort, a general description of the FSCATT and ADCATT systems is provided to support our initial assessment of GIOS's ability to support them.

<u>Fire Support Combined Arms Tactical Trainer (FSCATT)</u>

The FSCATT is a distributed-process, networked simulation system which will provide combined arms collective training of Field Artillery units. FSCATT consists of a family of five devices that provides battery-level initial and sustainment training of Field Artillery gunnery teams (Forward Observer, Fire Direction and Firing Battery personnel), giving them feedback on their proficiency while conserving fuel and ammunition. FSCATT Phase II provides the capability for the closed loop system to interoperate with other CATT systems. Additional manned modules enable howitzer batteries and Battalion Staffs to conduct tactical fire support operations in a combined arms, computer simulated environment. Using common CATT component and DIS technology, FSCATT manned modules are capable of stand-alone combined arms operations using SAF and emulator workstations. It is also capable of conducting training with other systems of the CATT family.

GIOS-related requirements for the FSCATT system are to monitor student activities, record performance and produce after action review for individual skills, crew drills, and partial unit drills in executing all manner of artillery fire missions.

<u>Air Defense Combined Arms Tactical Trainer (ADCATT)</u>

The ADCATT is a distributed processing, networked simulation system which allows short range Air Defense (SHORAD) units to train collective tasks associated with the support of Mechanized and Armor Maneuver units. It consists of mobile platoon sets of the Avenger or M2 BFV Stinger Under Armor. Emulator workstations represent the Forward Area Air Defense (FAAD) Command and Control network. Combat Support and Combat Service Support functions of the combined arms battlefield are included in each platoon set. SAF workstations can provide OPFOR and BLUFOR entities in a stand-alone operational mode or ADCATT can be networked to operate with other CATT systems. It can be anticipated that requirements for crew performance monitoring and AAR will be similar for ADCATT as for FSCATT and other CATT systems.

7.3.2 Higher Echelons

Precision gunnery simulators were originally developed to support individual and crew level training. The Conduct of Fire Trainer (COFT) pioneered the use of objective scoring methods for gunnery training. A three dimensional training matrix was developed to create a logical framework for progressively more difficult training exercises. Figure 7.3.2-1 illustrates a generalized form of the training matrix.

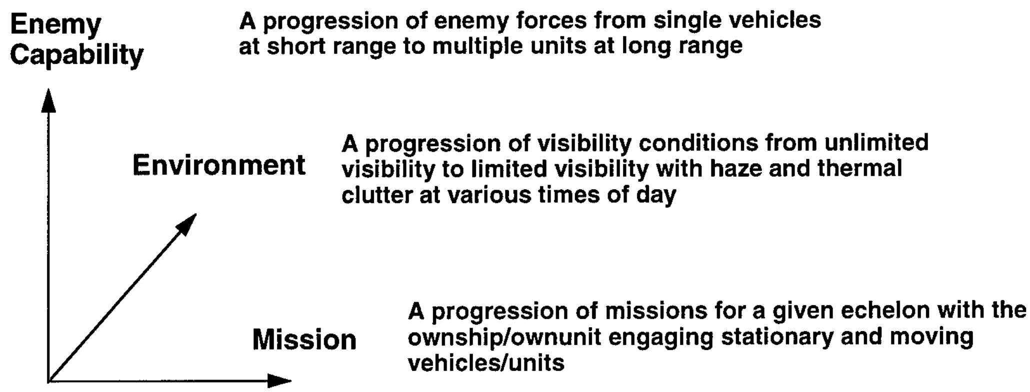


Figure 7.3.2-1: Generalized Training Matrix

The axes of the three dimensional matrix represent mission objectives, environmental conditions, and enemy capabilities, as shown. Exercises are organized as cells within the matrix with increasing levels of difficulty along each axis. Progression through matrix exercises is determined by the proficiency of the crew. As the crew demonstrates successful performance, conditions are automatically changed, resulting in more difficult exercises. Changing conditions include number of targets, range to target, visibility, and malfunctions. A major benefit of this automated scoring methodology is that crews are trained against established standards which are objectively scored by the simulator system [ref 40].

With the advent of the PGT and its successor AGTS, platoon level training has been added to the precision gunnery training regime. Platoon exercises begin with simple offensive and defensive missions against proficient enemies. They then progress to complex missions against a combat ready enemy. The platoon exercises are conceptually organized into a three dimensional matrix. This permits the change of conditions in any one of three directions based on performance.

Platoon gunnery training incorporates within it a limited amount of tactical training. The platoon leader needs to make tactical decisions within the context of the given gunnery exercise. However, the issue of scoring tactical performance in a hybrid tactical-gunnery environment has yet to be fully addressed. This becomes a significant issue if the training regime is notched up another echelon to Company or Team levels.

The natural evolutionary step would be to extend the training matrix methodology to the tactical domain. Figure 7.3.2-2 illustrates this extended concept in notional form.

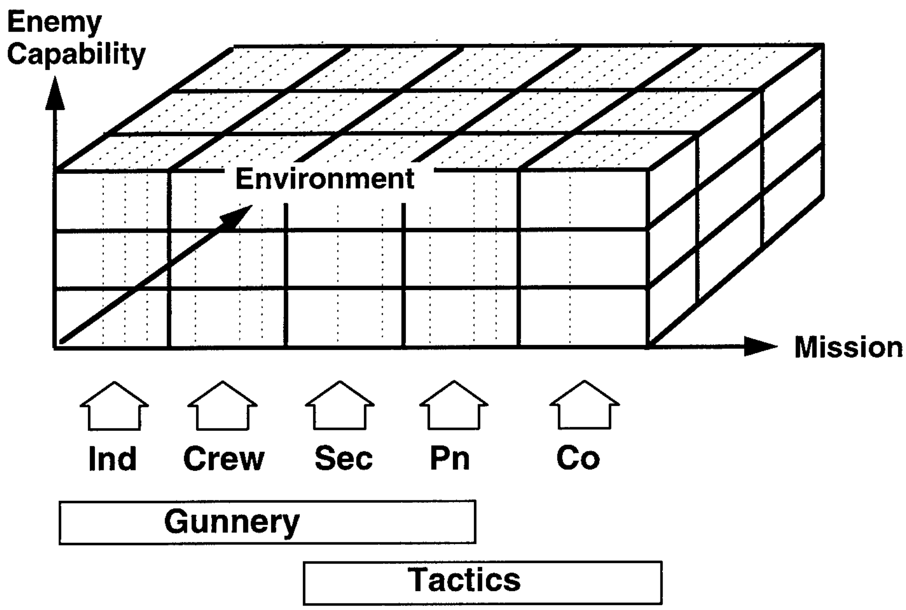


Figure 7.3.2-2: Tactical Extension of the Training Matrix

For prior and current systems, the IO judges whether the tactics employed for a given exercise are appropriate. The challenge for the hybrid gunnery/tactical system is in determining how to apply automated, computer based scoring methods to augment subjective human judgments. It is probably not feasible nor desirable to completely eliminate human judgment from the evaluation process; however, even a partial solution would be beneficial as an aid to the IO.

RFP's released by some overseas buyers have expressed an interest in hybrid tactical/gunnery training systems that extend to Company level. Furthermore, briefings by TSM CATT have presented the notion of a "Tactical Proficiency Matrix" that looks very similar to our notional concept shown above [ref 41]. A follow-on study could explore these concepts in depth, and develop a candidate scoring methodology for combined tactical/gunnery training.

7.3.3 AAR

According to the Army Master Plan for DIS [ref 39], one of the required capabilities that DIS must provide to the training community is an after action review (AAR). Specifically, the plan calls for an AAR capability which (from page III-6):

- Automatically synchronizes multimedia (voice, video)
- Provides instantaneous feedback/replay upon demand to capture all events defined by the user as critical
- Supports customization to meet user defined needs
- Captures data on the network which is interactive information, and should also record local information within the simulations/simulators
- Even though the focus of the exercises may be on collective training, data on individual and crew performance should also be recorded
- Has the capability to rapidly process a wide variety of data and produce meaningful presentations of desired information.

The basic GIOS capabilities are consistent with these as well as with existing AGTS and CCTT AAR requirements and implementations. Since these latter requirements are more completely defined and instantiated in proposed or existing designs, the ability of GIOS to support the AGTS and CCTT AARs is assessed in the following paragraphs.

AGTS PAAR

The current AGTS PAAR (prebrief and AAR) concept (for platoon training only; crew debrief consists of instructor review of a printed crew performance summary) includes a workstation with a data logger that can regenerate voice communications PDUs, a PVD that can display vehicle movements, firing events, etc., and a capability to generate graphic displays of general platoon gunnery performance statistics. Crewstation sight replay and stealth views are not provided. The AGTS PAAR is intended for use solely as a pre- and post-exercise asset; no real-time requirements currently exist. Instructors post-process the exercise to identify and mark significant events and otherwise construct the AAR. PVD graphics, voice communications, and charts/graphs indicating platoon performance statistics are displayed to the platoon on a PAAR CRT display during the AAR.

Given these requirements, it is clearly within the proposed capabilities of GIOS to support these features. In fact, the IG is not required to meet the AGTS requirements. For AGTS, GIOS represents an opportunity to enhance the AAR capabilities to include crew performance features such as sight replay and stealth view generation that users have requested for inclusion in an AAR.

CCTT AAR

The CCTT AAR workstation allows the operator to monitor, record, playback, analyze, and report on exercises. The operator can see the entire battlefield, access the current status of vehicles, and listen to voice communications. These capabilities are available both during exercises and at playback. During an exercise, the operator can make verbal and time-stamped textual notes that are available during playback. AAR data analysis and reporting allows the operator to analyze the exercise by providing statistical summaries of exercise data. Three display monitors provide an IG-created line-of-sight view that can operate in one of three modes: 1) Slaved mode, which displays the sight or visual display for either the gunner or commander's view for any selected manned module, 2) Independent mode, in which the operator has the capability to position the eyepoint anywhere in the gaming area from ground level up to an altitude of 300 meters, and 3) Tether mode, in which the eyepoint is tethered (direction and velocity) to any vehicle in the database.

In addition to these display monitors, the AAR console also has a PVD which gives the operator an overall view of the battlefield. A separate menu display is also provided to allow the operator to control AAR functions.

Again, these AAR requirements are consistent with the basic GIOS concept. The basic capabilities required for the CCTT AAR - IG-generated stealth view, PVD, voice communications, miscellaneous text/graphics display - are all provided by GIOS. The software controlling the AAR processes is of course unique to CCTT and its interfaces, but the overall requirements could be instantiated in a GIOS-configured console.

In summary, the Army's general requirements for a DIS AAR could be realized in a GIOS-derived console, including the integration of existing CATT and AGTS AAR stations.

7.3.4 MCC/MC

The CCTT master control and maintenance consoles (MCC/MC) are supported by the same software CSCI (computer system configuration item), although two separate consoles may still be needed for hardware redundancy and on-line troubleshooting during exercise conduct. Generally, the MCC/MC provides the capabilities to allow the operator(s) to initialize, monitor, and control the exercises and to monitor and control the CCTT physical network, software maintenance, and fault localization. Detailed MCC/MC requirements and capabilities were presented in Section 5.2.3.1.

The primary operational use of the MCC functions is for the initial configuration, parameter selection, and initiation of the CCTT training exercise. During exercise conduct, the MCC operator has very little to do, based on personal communications with CCTT personnel. However, there are several real-time capabilities that the MCC provides on demand, such as changing exercise parameters (weather conditions, time of day, fuel and ammunition loads, vehicle locations and orientations, vehicle status, etc.), reinitialization, reconstitution, and pause/resume. The execution of all of the MCC functions is controlled by the MCC software in response to operator intervention through the MCC software-user interface. This interface is a standard GUI format supplemented by a same-display PVD to assist in vehicle location and placement. No image generation capability is required.

The implications of these requirements for GIOS are similar to those previously discussed for the AGTS PAAR - the GIOS capabilities far exceed those needed to implement the required functions. What is required is basically a workstation to support the necessary CCTT or equivalent software, network, and other hardware/display interfaces. The primary issues are in terms of compatibility, storage capacity, and memory. There is no inherent limitation in GIOS restricting it from being extended to the MCC/MC application.

8. Summary

This Feasibility Analysis Study Final Report has presented the results of an ADST II study effort conducted to examine the feasibility of a Generic Instructor Operator Station (GIOS) for use on US Army engagement simulators. The effort has focused on three specific STRICOM programs: AGTS, CCTT, and AVCATT, with emphasis on the first two due to a lack of hard requirements data for AVCATT. The approach taken has been to re-engineer the AGTS IOS such that it could be added to CCTT to provide structured gunnery training, or to AGTS as a DIS compatible device to support reducing instructor manpower requirements during platoon gunnery training. Further, the study addressed the inclusion of semi-automated Instructor Operator (IO) functions to give each IO a greater span of control, again with the goal of significantly reducing IO manpower requirements for platoon training while maintaining current crew-level training capabilities. Natural Language Processing was shown to be a key technology required to achieve this level of manpower reduction.

The study concluded with a preliminary design concept for the GIOS and a phased approach to implement the design. The first phase develops a stand-alone console; the second phase integrates it with a CCTT manned module. Finally, an assessment was made of the viability of extending the GIOS design concept to other CATT training systems, to higher echelons, and to other functional training components, such as an AAR and MCC/MC station.

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