

HLA Compliance for a Live Instrumented Training System: A Case Study

John W. Shockley

Reginald E. Ford

Gerald V. Lucha

SRI International

333 Ravenswood Ave.

Menlo Park, CA 94025

650-859-4165, 650-859-4375, 650-859-4434

shockley@sri.com, r_ford@sri.com, lucha@sri.com

Keywords:

HLA Compliance, Live-Virtual Interactions, Live Training System, Federation Development Process

ABSTRACT: *The Deployable Force-on-Force Instrumented Training System is a 60-player, instrumented, live-training system developed for ground force training of National Guard units. To address needs for live-virtual interaction involving live DFIRST participants, an effort was initiated to make DFIRST HLA-compliant. This paper describes the first step of that effort--development of a simulation object model (SOM)--with the intent of providing lessons learned on the process of making an existing, live instrumented training system HLA-compliant. Future efforts will involve development of a blind federation object model (FOM)--i.e., a FOM for which other federates are hypothesized. Recommendations are made with respect to the implications of HLA compliance for live systems and the relevance and utility of proposed reference FOMs.*

1. Introduction

Several technical demonstrations have been conducted to investigate some of the issues of live/virtual interactions and identify the capabilities and limitations of these interactions. Many of these demonstrations used Distributed Interactive Simulation (DIS)-based standards. As part of the DIS standards development process, a recommended architecture for live systems, or Field Instrumentation, was developed along with a list of issues affecting live/virtual interactions [1] [2]. A number of the issues and architectural recommendations developed for DIS Field Instrumentation were incorporated into the new High Level Architecture (HLA) requirements.

This paper addresses a case study of applying HLA requirements to an existing, live-training system: the Deployable Force-on-Force Instrumented Range System (DFIRST). The intent of this paper is to demonstrate the applicability of these requirements to a real operating instrumented training system and to determine issues involved with HLA compliance for a live system--in particular, the development of a simulation object model (SOM). Future efforts will expand on this work and develop a blind federation object model (FOM) for which other members of the federation are hypothesized.

Because the SOM and FOM both use the HLA Object Model Template (OMT) and can be closely related for a federation of similar federates, development of the DFIRST SOM used several published FOMs as a starting point. In that regard, the SOM development effort provided some insight on the broader applicability of proposed reference FOMs.

DFIRST was chosen as the system for this case study for a variety of reasons:

- It is a recently-developed and currently operational training system that represents state-of-the-art training range instrumentation.
- It provides the primary engagement simulation (i.e., tank gunnery) via a non-cooperative pointing angle technique, and, therefore, is more amenable to live/virtual interaction than cooperative techniques.*
- Although the original system requirements were limited to live-live engagements, the system was designed for growth to live-virtual interaction. The system currently has a DIS-compliant interface.
- Since SRI developed the system, the authors have familiarity with all aspects of design, capabilities, and applications of the system.

* See Section 2.

2. DFIRST*

DFIRST was developed by SRI International under contract to the Defense Advanced Research Projects Agency (DARPA) as a prototype system for use in training National Guard armored units. The system provides state vector data and engagement simulation for up to 60 ground combat vehicles over a training area of 20x30 km. It has been deployed twice--in October 1995 and June 1996--at the Orchard Training Area (OTA) to support training of the 116th Cavalry Brigade of the Idaho National Guard. Figure 1 provides a top-level view of the DFIRST system.



Figure 1. DFIRST

The DFIRST instrumentation provides the following functions to support live training of ground forces: (1) State Vector Tracking (provided via Global Positioning System [GPS] instrumentation), (2) Platform Interface, (3) Data Communications, (4) Processing, (5) Real-time Casualty Assessment (RTCA), and (6) After Action Review (AAR). As shown in Figure 1, DFIRST consists of a Base Station control subsystem, an AAR station, ground vehicle participant instrumentation (Participant Instrumentation Packages [PIPs]) for up to 60 players, and a datalink providing connectivity between the players and the Base Station. The principal participants are armored ground vehicles; the system currently supports ten specific platform types.†

* The DFIRST system description material, including figures, contained in this section is based on system capabilities described in References [3] and [4].

† These are listed in the DFIRST Object Class Structure Table (Table 1).

In addition to providing state vector tracking data on instrumented participants, DFIRST provides engagement simulation and RTCA for the following types of engagements:

- 120-mm M1A1 Main Gun
- 25-mm M2/M3 Gun
- 7.62-mm Coaxial Machine Gun
- TOW Missile
- Artillery Fire (as indirect fire)
- Mine Field Engagements (as indirect fire).

Figure 2 illustrates a more detailed block diagram of the system, including a proposed HLA gateway in the Base Station. Participants transmit entity state and engagement data to all other participants and the Base Station.‡ If the Base Station is non-LOS, it receives the messages via relay. The uplinks sent from the Base Station to participants are RF network slot assignments, ammo loads, GPS differential corrections data, indirect fire results, and administrative kills and rebirths.

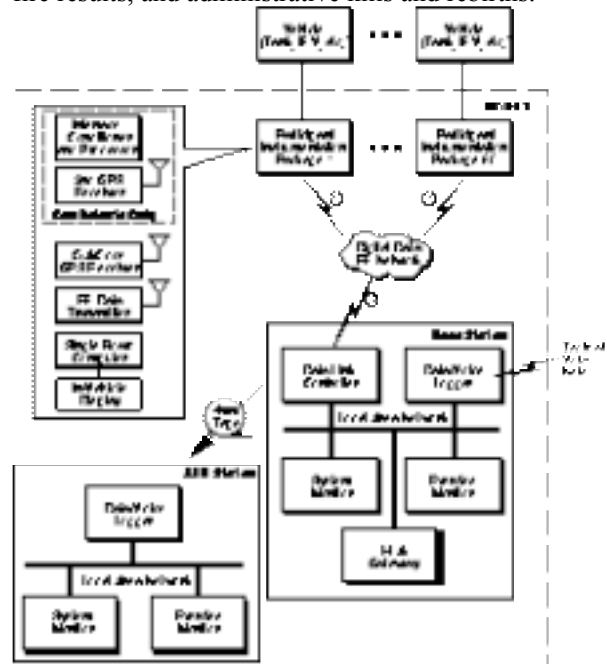


Figure 2. DFIRST Block Diagram

Direct fire events are acted upon by targeted participants as they are received directly from the shooter, so the Base Station has no role in direct fire RTCA. Because participant data are not uplinked from the Base Station, there is no current path that would support direct-fire

‡ Note that, though not shown in Figure 2, participant-to-base station communications may be via relay.

interaction between individual participants and outside participants via the HLA.

For HLA applications, however, the Base Station communications software will be modified to uplink participant data to enable interactions between DFIRST participants and potential HLA federation participants. The SOM presented in the next section reflects this capability by indicating both publish and subscribe capabilities for these entities.

Another principal characteristic of the DFIRST that is not readily apparent in Figure 2 is that the direct-fire engagement simulation technique employs GPS interferometry. The important characteristic of GPS interferometry for the purpose of this paper, and live/virtual interaction via HLA in general, is that this technique is non-cooperative--i.e., it does not require any indication of target pairing from the actual target. All that is needed for RTCA is the target position. The important distinction of non-cooperative target pairing is that it permits target pairing across federates. Targets may be either DFIRST-instrumented vehicles or they may be other vehicles whose data are provided to DFIRST via the HLA. For limitations on live-virtual interaction, see Section 3.1, last paragraph. Reference [4] provides additional information on the GPS interferometry and DFIRST in general.

3. DFIRST SOM

The principal elements of the DFIRST SOM developed for this effort are the Object Class Structure Table, the Object Interaction Table, and portions of the Attribute/Parameter Table. These are presented as Tables 1 through 3, respectively. Additional tables (the lexicon, enumerated data types, etc.) were considered to be too detailed for inclusion in this paper.

In subsequent sections, we present lessons learned regarding interaction between live and virtual systems, and some observations on the SOM development process.

3.1 Object Class Structure Table

Table 1, the Object Class Structure Table, contains the objects defined for the DFIRST SOM. Because it was a SOM, we chose to provide as much detail in the Class Structure Table as was available for the types of participants included in DFIRST. We also decided to divide the classes and subclasses as they are treated functionally within DFIRST. So, for example, the Class

Structure Table has a single one object class: "Entity." This class has the only attributes shared by all entities--i.e., identification and force affiliation. Three subclasses under Entity are "PositionedEntity," "AreaEntity," and "TrainingOfficer." These subclasses differentiate the entities that are: (1) tracked by DFIRST instrumentation or have a defined position and velocity in space (PositionedEntity), (2) defined within the DFIRST system as occupying a static area (AreaEntity), and (3) a special class, the DFIRST TrainingOfficer.

The PositionedEntities include the participants that are typically considered in a live range system--i.e., the real vehicles. Because DFIRST is a ground-combat training system, all of these participants are included in the "LandPlatform" subclass. LandPlatform objects are divided between "NonShooters" and "Shooters," which is a distinction that is reflected directly in the DFIRST hardware.*

PositionedEntities also include objects that are simulated within DFIRST. These include: "DirectFireMunitions," "ArtilleryUnits," "FireMission," and "IndirectFireMunition." They are included as PositionedEntities because they share with the LandPlatform class a position attribute that can be described by a single set of coordinates.

ArtilleryUnits, FireMission, and IndirectFireMunition are at the same class level because of the attributes defined for each class. That is, this is the class level at which none of the classes shares common attributes. (The Attribute/Parameter Table, Table 3, defines the specific attributes.)

In DFIRST, the AreaEntities include MineFields and EnvOffLimitsArea. Minefields are modeled as an indirect-fire weapon that has a probabilistic effect on a participant that travels within the defined area of the minefield. EnvOffLimitsAreas address a constraint imposed on some live ranges that areas are closed due to environmental concerns. The SOM has been designed to reflect the situation in a real DFIRST operation--i.e., when a participant enters an EnvOffLimitsArea, the region behaves like a minefield of infinite lethality, and the participant's vehicle is killed.

In general, we chose to group classes and subclasses according to the updateable attributes they share. So even though artillery fire and minefield effects are both

* DFIRST PIPs are built for either "shooters" or "nonshooters." Shooters have an additional GPS receiver to provide for gun-pointing angle via GPS interferometry.

accomplished via indirect-fire simulations, they are in different subclasses because minefields are area entities, while artillery units and their munitions have a single position.

Also evident in Table 1 is the decision we made regarding the level at which objects publish and subscribe attributes to the RTI--i.e., “P” and “S.” We determined that every entity within DFIRST that publishes also subscribes. In other words, if the HLA gateway provides participant data at a given level, DFIRST is capable of routing that data, subject to bandwidth limitations, to an individual participant or groups of participants as needed, and the participants are capable of reacting appropriately. We also chose to publish and subscribe at the lowest--i.e., most detailed--level of the class structure. The system could publish data at a higher level if requested by a federate. However, subscribing at a higher level would be meaningless to DFIRST unless equivalent specific entity types were indicated by enumerated types added to the superclass.

Although DFIRST can subscribe to all classes it publishes, there are limitations to what it can do with some of the information it receives regarding virtual objects. For example, a virtual M1A1 can kill a DFIRST platform and be shown on the DFIRST map display, along with the engagement symbology, but the virtual entity will be invisible to real DFIRST vehicles and so cannot be a target. This would violate the principle of a fair fight.

3.2 Object Interaction Table

Table 2 is the Object Interaction Table for DFIRST. As shown in the table, there are only four interactions defined for the system: (1) MunitionDetonation, (2) AdminKill/Rebirth, (3) ArtillerySalvo, and (4) WeaponFire. The definition of interactions reflects the way they are supported functionally within DFIRST. The most notable characteristics of the interactions are: (1) the presence of the AdminKill/Rebirth, and (2) the small number of interactions in the table.

Table 2 omits the Initialize/Sense/React (I/S/R) column of the Object Interaction Table. For the DFIRST SOM, all interactions are IR, since the interactions can both be initialized and reacted upon.

The AdminKill/Rebirth interaction reflects a capability that is common in live training systems--i.e., the capability for training officers to override the RTCA and initiate kill commands. In DFIRST, as in other combat training systems, this capability is used to inject the

human judgement of range training officers by enabling them to decide on an engagement outcome, rule violation, etc., independent of the RTCA of the instrumentation system. This function is similar to that of the Observer Controller (OC) “God gun” at Army Combat Training Centers (CTCs). The interaction also allows a training officer to rebirth participants--e.g. to restage a scenario and start again.

Table 1. DFIRST Object Class Structure Table

Class 1	Class 2	Class 3	Class 4	Class 5
Entity	PositionedEntity	LandPlatform	NonShooter	M1026 HMMWV (PS)
				M1025 HMMWV (PS)
				M998 HMMWV (PS)
				M981 FISTV (PS)
				M977 HEMTT (PS)
				M978 HEMTT (PS)
				M113A3 (PS)
				OtherVehicle (PS)
			Shooter	M2A0 BFV (PS)
				M3A0 BFV (PS)
		DirectFireMunition	DirectFireGuided	TOW (PS)
				DirectFireBallistic
			120mmHEAT (PS)	
			Coax (PS)	
			ArtilleryUnit (PS)	25mmHEI (PS)
		25mmAPDS (PS)		
		FireMission (PS)		
		IndirectFireMunition	M449 A1 (PS)	
			M483 A1 (PS)	
			M107 TNT (PS)	
	M107 CB (PS)			
	AreaEntity	MineField	ScatteredFullWidth (PS)	
			ScatteredBlast (PS)	
			ConventionalFull WidthLight (PS)	
			ConventionalBlast Light (PS)	
			ConventionalFull WidthMedium (PS)	
			ConventionalBlast Medium (PS)	
			ConventionalFull WidthHeavy (PS)	
			ConventionalBlast Heavy (PS)	
		EnvOffLimitsArea (PS)		
		TrainingOfficer (PS)		

Table 2. DFIRST Object Interaction Table

Interaction Structure	Initiating Object		Receiving Object		Interaction Parameters
	Class	Affected Attributes	Class	Affected Attributes	
Munition Detonation	DirectFire Munition	None	LandPlatform	TacticalState	FiringObjectID
	IndirectFire Munition				DetonationTime
	EnvOffLimitsArea				TargetObjectID
	MineField				QuantityDetonated DetonationLocation
AdminKill/Rebirth	TrainingOfficer	None	LandPlatform	TacticalState	Kill/Rebirth Type
ArtillerySalvo	FireMission	None	IndirectFireMunition	None	None
WeaponFire	Shooter	AmmoRounds	DirectFire Munition	None	FiringLocation
		FiringSignature			QuantityFired
					TargetObjectID GunOrientation

The relatively small number of overall interactions is, perhaps, the most important aspect of this table, and even the SOM in general, in that it indicates the relatively few specific interactions that are simulated and recorded in instrumented live training. The reason for this is that many of the interactions in live ranges are *real*. They include pilots being affected by the position of the sun in the sky, combat personnel being affected by fatigue, and sensors being obscured by dust and smoke. In a live training environment, these interactions occur naturally; they do not need to be simulated. They also are typically not recorded. The implications for HLA of a live system's reliance on an environment known to participants but largely unknown to the computers is addressed in Section 4.

3.3 Attribute/parameter Table

Table 3 is the Attribute/Parameter Table for DFIRST. Because we tried to take full advantage of class inheritance, and made uniqueness of attributes a primary criterion for designing a class structure, there is very little repetition of attributes in the table. The small total number of attributes reflects once again the characteristics of live-training instrumentation, which leaves many parameters unsensed.

Not shown in Table 3 are the more detailed aspects of the table. These were considered beyond the scope of this paper. One characteristic that merits mentioning, however, is that of accuracy. The Attribute/Parameter

table has a provision for accuracy and the conditions under which that accuracy applies. Since this SOM applies to a live range system, accuracy is important to the overall functioning of the system, and is critical to the accuracy of engagement simulation in particular. The DFIRST SOM, along with SOMs for other live systems, must take full use of this capability within the HLA Object Model Template (OMT), and any system envisioned to be federated with a live system must be able to accommodate live range data of varying accuracies in order to effect a viable live/virtual interaction. The virtual federate must reflect accuracy considerations in the design of its interaction algorithms.

4. Implications for Live/Virtual Interactions via the HLA

The relative simplicity of the DFIRST SOM raises three principal issues in the application of HLA to live systems. These are:

- Information available from live instrumentation systems is limited.
- Interactions supported by live instrumentation systems are limited.
- Live systems are capable of limited interactions with virtual systems.

The following subsections provide additional detail on these points.

Table 3. DFIRST Attribute/Parameter Table (Partial Rendition)

Object/Interaction	Attribute/Parameter	Datatype	Cardinality
Entity	EntityCallSign	string	1
	Force	ForceIDEnum	1
	EntityID	unsigned long	1
AreaEntity	BoundaryCoordinates	PositionStruct	1
PositionedEntity	Position	PositionStruct	1
LandPlatform	TacticalState	TacticalStateEnum	1
	VelocityVector	VelocityStruct	1
	Orientation	OrientationStruct	1
Shooter	GunOrientation	unsigned short	1
	WeaponType	WeaponTypeEnum	3
	MunitionType	MunitionTypeEnum	4
	AmmoRounds	unsigned short	4
	FiringSignature	FiringSignatureStruct	1+
DirectFireMunition	MuzzleVelocity	float	1
FireMission	FireMissionAimpoint	PositionStruct	1
	FireMissionEventTimes	FireMissionTimeStruct	1
	NumSalvos	unsigned short	1
	RoundsPerSalvo	unsigned short	1
	Sheaf	SheafTypeEnum	1
IndirectFireMunition	FuseType	FuseTypeEnum	1
MineField	MinefieldDensity	float	1
MunitionDetonation	FiringObjectID	unsigned long	1
	DetonationTime	unsigned long	1
	TargetObjectID	unsigned long	1
	QuantityDetonated	unsigned short	1
AdminKill/Rebirth	Kill/Rebirth Type	KillRebirthEnum	1
WeaponFire	FiringLocation	PositionStruct	1
	QuantityFired	unsigned short	1
	TargetObjectID	unsigned long	1

4.1 Information Available from Live Systems

Live systems depend on the real environment to provide much of the training experience. Much of what is provided by modeling in virtual systems is not measured by instrumentation. Therefore, live systems have limited data to describe in the HLA SOM.

This characteristic of live systems is evident in all three of the tables presented herein. The Object Class Structure Table might appear to be an exception because it is of comparable size and complexity to others we have seen. However, much of its complexity is based on our choice to delineate completely the individual participant and munition types down to the leaf level of the table--details that have typically been included in the enumeration table. If this particularity were to be removed, this table would be as sparse as the Object Interaction Table and the Attribute/Parameter Table.

Much of the information that is important to providing a fair fight between a live and virtual system is not captured by the instrumentation. Some of this--e.g., environmental data, such as current weather conditions--could conceivably be provided by operator input. However, other attributes-- notably, "fog of war" elements such as smoke and dust-- cannot be sensed by the instrumentation or provided supplementally by an operator.

The lack of information available to virtual systems means that the fidelity and fair-fight aspects of any HLA-based live-virtual interactions must be examined carefully. In essence, the data that cannot be supplied by or used by the live system must not be critical to the overall outcome of the live-virtual simulation.

4.2 Types of Interactions Supported

The impact of limited information available from live systems is likely to result in a limit on the types of

interactions and exercises that can be realistically supported.

The first limitation is evident in comparing the level of detail that DFIRST provides with that which is typical of virtual simulations. One of the important parameters of virtual entities are their appearance. The DFIRST Attribute/Parameter Table (Table 3) provides no information on entity appearance. Any appearance details that would be used for a virtual simulation would need to be generated--with only a generic relationship to the real entity (e.g., M1A1 tank.) In contrast, virtual simulations generally provide more detail than can be used by DFIRST. Injecting virtual participants to augment a live exercise, therefore, appears to be a better application of live-virtual interaction than vice-versa.

An example of the second limitation is the way DFIRST handles tactical radio traffic. As DFIRST is currently configured, simulated radio traffic cannot be included in a realistic manner. DFIRST only monitors the actual radio nets, rather than collecting sufficient data to emulate them. If DFIRST could emulate the radio net, radio messages from simulated entities could be realistically injected. A practical implication of this limitation is that live/virtual interactions that are best supported are those involving adversarial forces for which no direct entity-to-entity communication is needed

4.3 Design for HLA

Even though the system addressed in this study is a fully functional standalone training system, it may not provide all the information expected by a virtual federate, or be able to use information provided by the federate. It is easy to dismiss DFIRST as a “legacy” system; however, other live instrumentation systems still under development will have comparable limitations. For such systems to provide extensive HLA-interaction capability, they will need to be designed for such virtual interactions from the start and will be more costly.

Radio transmissions and laser range-finder are examples of information that is not currently monitored by DFIRST. DFIRST records tactical radio traffic for use in the AAR. However, sender or receiver are not identified. Radio transmissions could be added to the DFIRST SOM if PIPs were modified to monitor and report keying of the tactical radio microphone. This represents a system modification but, for DFIRST, not a particularly complicated or expensive one.

When a participant uses a laser range finder, it is not only aiding in its own firing solution, it is also revealing its

position to adversary forces. But while including radio transmissions is relatively straightforward for DFIRST, monitoring the use of a laser range-finder may be a more difficult platform interface problem, especially for older, non-digitized platforms.

Providing interfaces to real entities that enable realistic stimulation from virtual entities is an even greater challenge. Virtual players have been injected into real systems in dedicated demonstration efforts that have proven the technical viability of live-virtual interaction. A training system-level capability to inject a significant number of virtual participants into real entities may require significant system level design changes in platforms, and some aspects of the design are likely to be unique to each platform. Furthermore, the design issues are particularly challenging because training instrumentation cannot be allowed to interfere with tactical systems.

Future live training systems will be designed for HLA compatibility. However, many of the capabilities are likely to incur significant additional system cost. DoD needs to consider the level of HLA interaction that needs to be supported.

5. Lessons Learned Regarding the SOM Development Process

The DFIRST SOM generation effort also yielded lessons related to the SOM development process. Some of these may apply also to developers of SOMs and FOMs for virtual simulations. We have classified these items into the following three categories:

- The SOM process in general.
- Use of the automated Object Model Development Tool (OMDT)
- Use of Reference FOMs

5.1 Constructing a First SOM

This was our first SOM, and although the reference materials and the few extant examples provided much guidance, we found in the process of defining classes, attributes, and interactions that we needed to establish some rules of our own. We have distilled some of these decisions in the following remarks and examples.

- We initially restricted the leaf level of the Object Class Structure to subclasses that would have unique publishable attributes. However, we subsequently decided that entity types whose uniqueness is captured in static data (e.g., AMSAA tables) rather than in published attributes, should be leaves instead of enumerated types to emphasize that their behaviors are highly individual rather than generic, e.g., it

makes a world of difference whether the munition that hits you is a 120 mm Sabot or HEAT. We also decided that issues of interacting with other systems would be more readily apparent if we exposed the fundamental types of objects supported by DFIRST in the class structure rather than buried them in enumeration types.

- The DFIRST Object Class Structure includes only classes and characteristics that are meaningful to DFIRST. We decided that we should faithfully reflect the system “as is” and add other levels of abstraction, e.g., distinguishing between military and civilian platforms, when generating SOM and FOM for interacting with actual federates.
- In developing the object classes we contemplated defining a “Turret” object as a component of a tank or Bradley Fighting Vehicle. We decided in favor of including the turret angle as an attribute of the shooter class because we would not publish “turret” as an independent entity and, therefore, found no benefit of defining an object once as a component of multiple objects.
- We found that the demands of the interactions table required revisions to our object class structure. Object classes needed to fit naturally with the “initiating” and “receiving” classes.

A guidebook for SOM/FOM development that is more detailed than the “High Level Architecture Object Model Template” would save authors time and effort and would promote a greater degree of uniformity. Such a guide would need to reflect the experience of a diverse group of developers working on a range of dissimilar systems.

5.2 Use of Automated Object Model Development Tool (OMDT)

Overall, we found the automated OMDT available via the DMSO HLA web site to be enormously useful. The tool provided a ready mechanism for not only entering DFIRST-specific data but also experimenting with possible object and attribute classifications. A few minor problems and recommendations will be reported directly to the tool developers and not discussed here.

5.3 Use of Reference FOMs

In developing a SOM and FOM for DFIRST, we heavily borrowed from past efforts. Specifically, we examined the Real-time Platform Reference (RPR) FOM, the Joint Training Protodefederation (JTFp) FOM, the Joint Precision Strike Demonstration (JPSD) FOM [5], and the Platform Protodefederation FOM and Joint Tactical Combat Training System (JTCTS) SOM [6]. The RPR FOM is being developed as a reference FOM for DIS-based systems, while the other FOMs have been developed for various HLA demonstrations. Although reuse of existing models

is strongly encouraged by M&S sponsors, we chose to examine these models based on sound engineering practice, i.e., there is no need to redo other relevant/applicable work.

We found considerable advantages in studying these FOMs including:

- The FOMs and SOMs provided a starting point for the DFIRST SOM and FOM development.
- The FOMs and SOMs provided an indication of the type of data that are needed for the types of systems addressed, i.e., ground, training, live, etc.
- To the extent that we saw DFIRST participating in a given federation, the specific FOM provided a goal for the type of data we needed to include.

We created the DFIRST SOM by loading the RPR FOM in the OMDT and then editing. After paring away non-applicable classes and attributes, and modifying structures to accurately represent DFIRST, most of the original content was replaced. This result does not negate the value of using the RPR FOM as a template because we believe that we learned more and created a better product than if we had started from scratch. However, the substantial differences between the example FOMs/SOMs and what we ultimately developed for DFIRST convinced us that standardization of Reference FOMs should be approached with caution. Reference FOMs should only be applied to the specific types of federates for which they are designed. Just as DIS was specified as a standard for systems to which it really did not apply, specifying inappropriate Reference FOMs could contradict some of the basic principles of flexibility provided by the HLA.

6. Summary and Conclusions

This paper documents the development of a SOM for DFIRST and some of the issues we identified in the process. The SOM development described here is only the first step in making DFIRST HLA compliant. Further efforts will include developing a blind FOM. A full DFIRST SOM was created, but this paper shows only the Object Class Structure Table, the Object Interaction Table, and a partial Attribute/Parameter Table.

As a result of this process, we have identified implications for HLA applicability to live-virtual interactions and have included lessons learned on the SOM development process.

Specific implications for HLA-based live-virtual interactions are:

- Limited information critical to establishing a fair fight is available from live systems.

- Live systems can support only limited interactions with virtual systems.

A number of conclusions regarding the SOM process were also documented. These include:

- A highly articulated set of Object Class Structure Table leaf nodes represents the substantially different behaviors of related objects more faithfully than an more generic class that particularizes using an enumerated list of types. It also exposes the capabilities and limitations of the system more prominently.
- A core SOM should reflect the subject system's specific design and include only classifications and attributes that are meaningful to that system. Abstractions and additions needed to interact with other systems should be introduced when preparing for an actual federation.
- Reference FOMs (and other previously-developed FOMs) are useful to the FOM/SOM development process as long as they are used as a tool or a reference standard for a relevant set of simulations, rather than misapplied as a mandatory standard to simulations for which they are ill-matched.

working on modeling and simulation aspects of these systems and has since participated in DIS/HLA standards development activities for the past eight years, concentrating on integrating live and virtual simulations.

REGINALD E. FORD is a Senior Systems Analyst at SRI International. Over that past 17 years, he has worked on many Navy, National Guard, and Marine Corps test and training range systems. This work includes software specification and development, technical studies, and system test, evaluation, and improvement. He is the lead software engineer for DFIRST.

GERALD V. LUCHA is a Principal Engineer at SRI International. For the past 23 years he has worked on a wide variety of SRI projects related to instrumented test and training ranges of the Army, Navy, and Air Force. His experience not only includes studies and analysis of range requirements, instrumentation concepts, and performance, but also on-site assessments of numerous land, air, and sea combat training ranges in the United States and abroad. He is the chief engineer for DFIRST.

7. References

- [1] DIS Field Instrumentation System Architecture Working Group, System Architecture Subgroup: "DIS Field Instrumentation Architecture Models," Ver. 0.9, November 1996.
- [2] DIS Field Instrumentation System Architecture Working Group, Live Entity Integration Subgroup: "Field Instrumentation Issues Brief," June 1996.
- [3] Maj. Jeff Grant: "War Games: Troops Train with GPS-Enabled Battlefield Simulation," GPS World, Vol. 8, Nr. 11, pp. 22-31, November 1997.
- [4] David Harvey, et al: "System Design Document for the Deployable Force-on-Force Instrumented Range System (DFIRST)," Ver. 2.0, SRI Report 4721-97-TR-72, October 1997.
- [5] Example FOMs are available via internet at <http://hla.dmsi.mil>.
- [6] "Joint Combat Tactical Training System (JTCTS): High Level Architecture (HLA) Object Model Template (OMT) Suitability to JTCTS Study," Raytheon Electronics Systems, 16 October 1996.

Author Biographies

JOHN W. SHOCKLEY is a Senior Research Engineer at SRI International. Over the past 14 years, he has worked at SRI on a broad variety of projects--primarily in the areas of test and training range instrumentation systems for the Army, Navy, and Air Force. He began

