An Introduction to the HLA
Part 1

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Overview

- Introduction
  - What is the HLA?
  - Motivation
  - Goals
  - History
- HLA Components
  - The RTI
  - HLA Rules
  - Object Model Templates
- For Next Time …

Introduction

- What is the HLA?
- Motivation
- Goals
- History

What is the HLA?

- A general framework facilitating interoperability and reusability of distributed simulation components
- Developed by the Defense Modeling and Simulation Office (DSMO)
- Developed for the United States Department of Defence (DoD)
- IEEE Standard 1516-2000

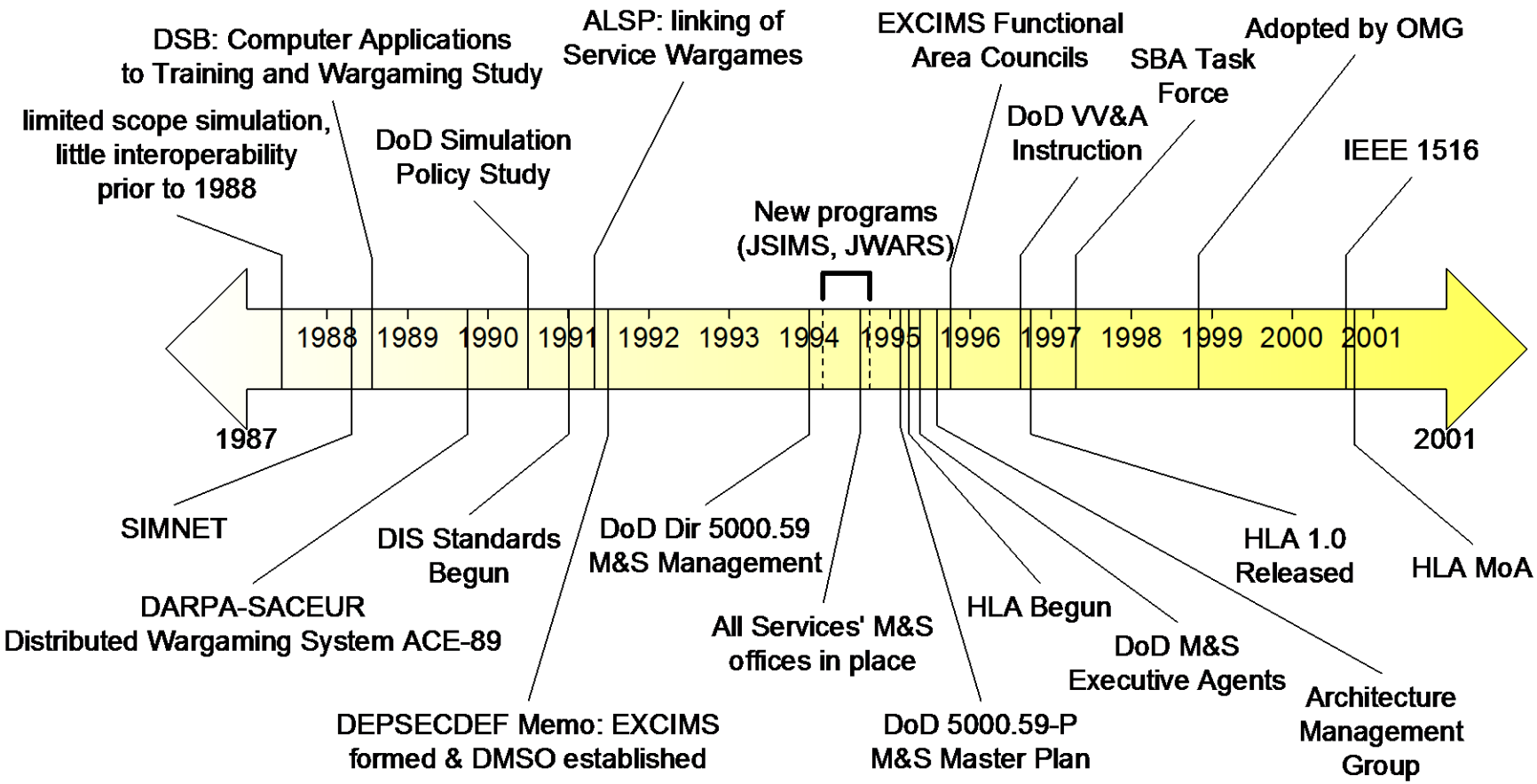
Motivation

- Many large/complex simulations involve individual “sub-simulations” of components
- “Sub-simulations” are often heterogeneous (in the type of simulation and type of component)
- Simulators for the components may already exist
- Re-implementing or retrofitting a simulation system is risky and expensive

Goals

- Reusability
  - A component simulation may be used in different scenarios and applications over its lifetime
- Interoperability
  - Aggregate simulations composed of multiple component simulations
  - Aggregate simulations distributed across heterogeneous hardware and software platforms
  - Reuse without significant code change or development cost
  - Combine component simulations with diverse models of computation and representation

History


limited scope simulation, little interoperability prior to 1988
DSB: Computer Applications to Training and Wargaming Study
DoD Simulation Policy Study
ALSP: linking of Service Wargames
New programs (JSIMS, JWARS)
EXCIMS Functional Area Councils
DoD VV&A Instruction
SBA Task Force
Adopted by OMG
IEEE 1516
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001
1987
2001
SIMNET
DARPA-SACEUR Distributed Wargaming System ACE-89
DIS Standards Begun
DEPSECDEF Memo: EXCIMS formed & DMSO established
DoD Dir 5000.59 M&S Management
All Services' M&S offices in place
DoD 5000.59-P M&S Master Plan
HLA Begun
DoD M&S Executive Agents
HLA 1.0 Released
Architecture Management Group
HLA MoA

HLA Components

- Definitions & Terms
- Technical Architecture
- HLA Rules
- Object Model Templates
- Run-Time Interface Specification

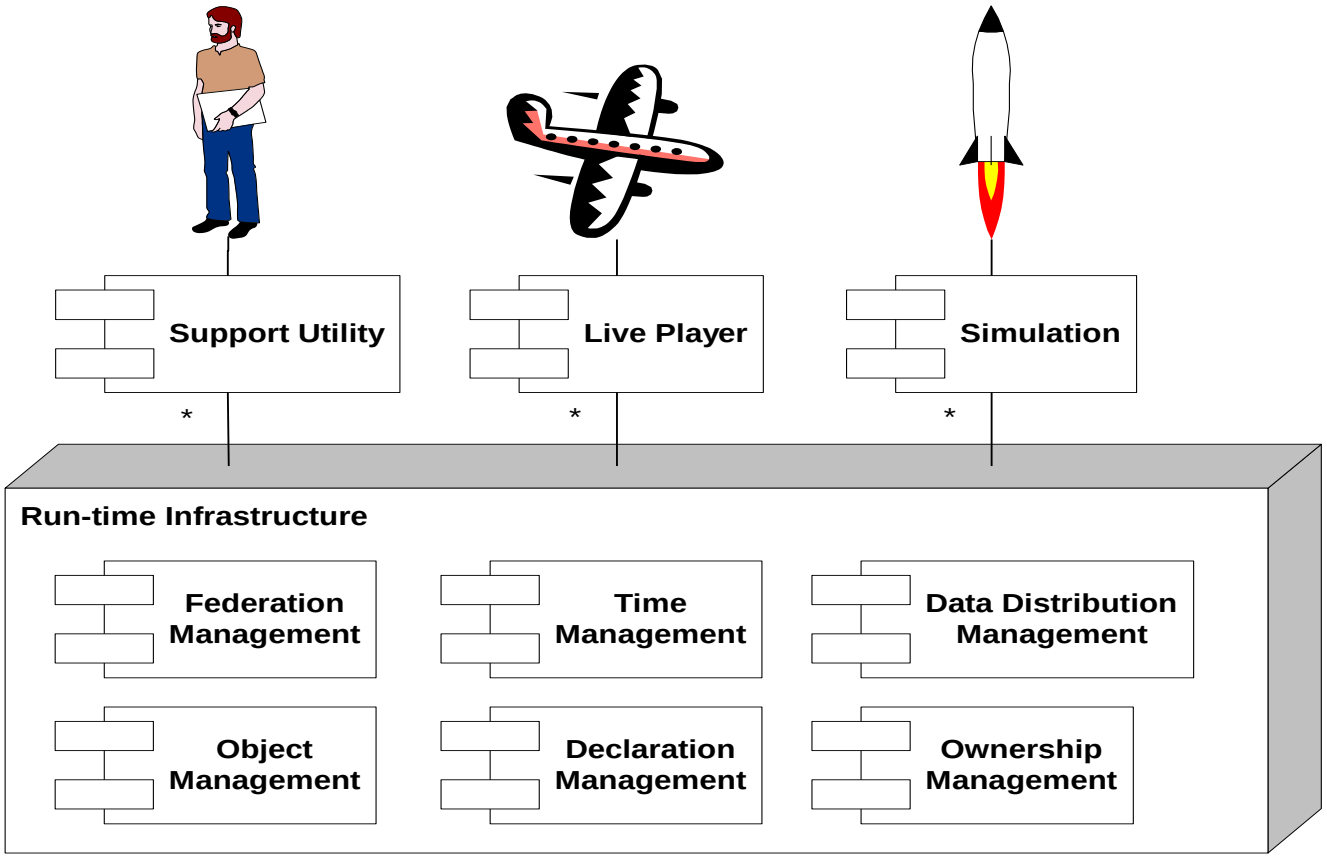
Definitions & Terms (1)

- Federate
  - An application which supports the HLA and is capable of participating in a simulation.
- Federation
  - A declaration between federates describing how and what will be simulated.
- Federation Execution
  - A run-time instantiation of a Federation; that is, an actual simulation execution.

Definitions & Terms (2)

- The HLA provides the **Federation** formalism by which **Federates** can be modeled such that the framework can support **Federation Execution**
- This is really no different from any other type of modelling and simulation application!

Technical Architecture



Run-Time Infrastructure (1)

- Software layer providing common services to federates
- RTI Specification defines the interfaces federates must use to obtain services and interact with other federates
- RTI Specification defines interfaces to be exposed by federates in order to be recognizable by the services and by other federates

Run-Time Infrastructure (2)

- Improvements on older standards
  - DIS
  - ALSP
- Provides efficient inter-federate communications
- Separate simulation concerns from communication concerns
- Language and platform independent

Service Groups

- Federation management
- Declaration management
- Object management
- Ownership management
- Time management
- Data Distribution management
- Support services

Federation Management

- Controls federation-wide activities during a federation execution
- Services offered:
  - Creation and destruction of federation executions
  - Joining and resigning of federates
  - Pause/Resume federation execution
  - Save/Restore federation execution

Declaration Management

- Manages the publisher/subscriber model for information exchange
- Services Offered:
  - Publish Object/Interaction class
  - Subscribe to Object Class Attribute
  - Subscribe to Interaction Class
  - Control Updates
  - Control Interactions

Object Management

- Manages the lifecycle and message passing for object instances
- Services Offered:
  - Register/Discover Object
  - Update/Reflect Attribute Values
  - Send/Receive Interaction
  - Remove Object
  - Manage Transport/Ordering

Ownership Management

- Supports cooperative modelling by allowing attribute ownership to be transferred across instances
- Services Offered:
  - Assume/Divest Attribute Ownership
  - Acquire/Release Attribute Ownership
  - Notification of ownership changes

Time Management (1)

- Coordinates federate time advancement along the federation time axis
- Attempts to preserve causality and ordering
- Mechanisms supported:
  - Conservative synchronization (with look ahead)
  - Optimistic synchronization (e.g., time warp)
  - Hybrid methods
  - Time-stepped
  - Real-time driven

Time Management (2)

- Federates request permission to advance their local time
- Services offered
  - Request Time Advance
  - Notification of Granting of Time Advance
  - Request Next Event
  - Notification of Granting of Next Event
  - Queue Management

Data Distribution Management

- Efficient data transmission between federates
- Uses routing spaces to direct data only to the interested parties
  - Publisher specifies the update region
  - Subscribes specify their interest region
  - Intersection define routing space

Support Services

- Miscellaneous functionality useful to joined federates
  - Name-to-handle transformation
  - Handle-to-name transformation
  - Setting advisory switches
  - Manipulating regions
  - RTI start-up and shutdown

HLA Rules

- Define the behaviour and capabilities of federates and federations
- Five rules for Federates
- Five rules for Federations

Federation Rules

- Must have an Federation Object Model (FOM) documented using the OMT
- All object representation occur in the Federates, not in the RTI
- Data exchange between instances of objects in different Federates occurs via the RTI
- Federates must interact with the RTI in accordance with the HLA Interface Specification
- During Federation Execution, an instance attribute may be owned by at most one federate at any given time

Federate Rules

- Must have a Simulation Object Model (SOM) documented using the OMT
- Must be able to update/reflect instance attributes and send/receive interactions as specified in their SOM
- Must be able to dynamically transfer/accept ownership of attributes during federation execution as specified in their SOM
- Must be able to vary the conditions under which they provide attribute updates as specified in their SOM
- Must manage their local time in a manner which allows them to coordinate data exchange with other federates

Object Model Templates

- Provide a mechanism for specifying data exchange and coordination within a federation
- Provide a mechanism for describing the capabilities of federate
- Facilitates design and implementation of common tools for building HLA compliant objects

Types of Object Models

- Simulation Object Model (SOM)
- Federation Object Model (FOM)
- Management Object Model (MOM)

SOM – Simulation Object Model

- Information exposed/consumed by a federate
  - Objects
  - Interactions
  - Attributes (of Objects and Interactions)
  - Parameters (of Objects and Interactions)

FOM – Federation Object Model

- Specifies data exchange between federates
  - Objects
  - Interactions
  - Attributes (of Objects)
  - Parameters (of Interactions)
- Provides the “information model contract” which governs the simulation
- Provides the foundation for interoperability

MOM – Management Object Model

- A predefined set of information elements to be included in the FOM
- Contains data relevant to Federation Execution
- Federates may also include referenced to the MOM if they may influence Federation execution.

OMT Components (1)

- Object model identification table
- Object class structure table
- Interaction class structure table
- Attribute table
- Parameter table
- Dimension table
- Time representation table

OMT Components (2)

- User-supplied tag table
- Synchronization table
- Transportation type table
- Switches table
- Datatype tables
- Notes table
- FOM/SOM lexicon

Object Model Identification Table

- Describes object model's identity
- Useful for developers seeking reusable object models
- Why the object model was constructed
- How the object model was constructed
- Who knows about the object model
- Where to look for more information

Example – Object Model Identification Table

Category	Information
Name	Object Model Name
Type	“SOM” or “FOM”
Version	Version Identifier
Modification Date	Last Modified Date (YYYY-MM-DD)
Purpose	Why was this object model developed
Application Domain	Type of Application
Sponsor	Name of Sponsoring Organization
POC	Point of Contact’s Name
POC Organization	Point of Contact’s Organization
POC Telephone	Point of Contact’s Telephone Number
POC Email	Point of Contact’s Email Address
References	Where to look for further information
Other	Any other relevant data

Object Class Structure Table

- Defines super/sub-class relationships
- For a SOM, classes may be tagged …
  - P: The federate is capable of publishing at least one attribute of the object class.
  - S: The federate is capable of subscribing to at least one attribute of the object class.
  - PS: Both publish and subscribe
  - N: The federate is neither capable of publishing nor subscribing to any attributes of the object class.
- For a FOM, the same tags indicate if least one federate is capable of publishing or subscribing to any attribute of the object class

Example – Object Class Structure Table

HLA Object Root (N)	Customer (PS)				
	Bill (PS)				
	Order (PS)				
	Employee (N)	Greeter (PS)			
		Waiter (PS)			
		Cashier (PS)			
	Food (S)	Main Course (PS)			
		Appetizer (S)	Soup (S)	Clam Chowder (PS)	Manhattan (P)
					New England (P)
				Beef Barley (PS)	
			Salad (S)		
		Entrée (S)	Seafood (S)	Shrimp (PS)	
				Salmon (PS)	
			Pasta (PS)		

Interaction Class Structure Table

- Specific actions which a federate may perform
- Hierarchy similar to Object Class Structure Table
- SOM Interactions may be tagged
  - P: The federate is capable of publishing the interaction class
  - S: The federate is capable of subscribing to the interaction class
  - PS: Both publish and subscribe
  - N: The federate is neither capable of publishing nor subscribing to the interaction class
- Same tags used for a FOM meaning there does (not) exist a federate capable of publishing/subscribing to the interaction class.

Example – Interaction Class Structure Table

HLA Object Root (N)	Customer Transaction (P)	Customer Seated (PS)	
		Order Taken (P)	From Kids Menu (P)
			From Adult Menu (P)
		Food Served (P)	Drink Served (P)
			Appetizer Served (P)
			Main Course Served (P)
			Dessert Served (P)
		Customer Pays (P)	By Credit Card (P)
			By Cash (P)
		Customer Leaves (P)	

Attribute Table

- Properties of an object
- May be published by the object
- Other objects may subscribe to an attribute
- Declare how/when an attribute value changes
- Declares if attribute ownership may be transferred between objects
  - DA = Divest & Acquire
  - N = Neither
- The transport used to communicate the attribute

Example – Attribute Table

Object	Attribute	Data Type	Update Type	Update Condition	D/A	P/S	Available Dimensions	Transportation	Order
Root	PTDO	NA	NA	NA	N	N	NA	HLAReliable	Timestamp
Employee	PayRate	Dollars	Cond.	Merit	DA	PS	NA	HLAReliable	Timestamp
	Seniority	Years	Periodic	+1/year	DA	PS	NA	HLAReliable	Timestamp
	Phone	Text	Cond.	Empl. Req.	DA	PS	NA	HLAReliable	Timestamp
	Address	Text	Cond.	Empl. Req.	DA	PS	NA	HLAReliable	Timestamp
Employee. Waiter	Efficiency	WaiterValue	Cond.	Perf. Rev.	DA	PS	NA	HLAReliable	Timestamp
	Manner	WaiterValue	Cond.	Perf. Rev.	DA	PS	NA	HLAReliable	Timestamp
	State	WaiterTask	Cond.	Work Flow	DA	PS	NA	HLAReliable	Timestamp
Food. Drink	Cups	DrinkCount	Cond.	Cust. Req.	N	PS	BarQuantity	HLAReliable	Timestamp
Food. Drink. Soda	Flavour	FlavourType	Cond.	Cust. Req.	N	PS	BarQuantity, SodaFlavour	HLAReliable	Timestamp

Parameter Table

- Additional information to characterize an interaction
- Identify the transport used to deliver the parameter
- Identify the ordering constraints for the parameter
  - Timestamp
  - Receive (indeterminate order)

Example – Parameter Table

Interaction	Parameter	Datatype	Available Dimensions	Transportation	Order
Customer Seated	NA	NA	NA	HLAReliable	Timestamp
FoodServed. MainCourse Served.	TemperatureOK	ServiceStat	WaiterID	HLAReliable	Timestamp
	AccuracyOK	ServiceStat			
	TimelinessOK	HLABoolean			

Dimension Table

- Maps domain specific data values onto integer values ranging from zero to some upper bound
- Specifies the legal values which may be transmitted across the RTI
- Enables Data Distribution Management (DDM) and Declaration Management (DM)
- Used to specify update and subscribe regions to the RTI

Example – Dimension Table

Name	DataType	Upper Bound	Normalization	Value If Not Specified
SodaFlavour	flavourType	3	LinearEnumerated(Flavour, {Cola, Orange, Grape})	[0..3)
BarQuantity	DrinkCount	25	Linear(NumberCups, 0, 25)	[0..1)
WaiterId	EmpId	20	Linear(WaiterId, 0, 20)	Excluded

Time Representation Table

- Declares the format used to represent time
  - For a federate
  - Across a federation
- Declares the semantics of time
  - For a federate
  - Across a federation
- Used by the RTI to coordinate federates during federation execution

Example – Time Representation Table

Category	Datatype	Semantics
Timestamp	TimeType	Floating point value expressed in minutes
LookAhead	LAType	Non-negative floating point value expressed in minutes

User-Supplied Tag Table

- Extensible mechanism for specifying auxiliary data
- Provides additional control and coordination of services provided by the HLA

Example – User-Supplied Tag Table

Category	Datatype	Semantics
Update/Reflect	NA	NA
Send/Receive	NA	NA
Delete/Remove	HLAascii	Reason for deletion
Divestiture Request	PriorityLevel	High value for immediate transfer
Divestiture Completion	NA	NA
Acquisition Request	PriorityLevel	High value for immediate transfer
Request Update	NA	NA

Synchronization Table

- Provides a federate synchronization mechanism
- Federates declare the synchronization points they support
- Federations describe the synchronization points to be used

Example – Synchronization Table

Label	Tag Datatype	Capability	Semantics
InitialPublish	NA	Achieve	Achieved when all classes are published and subscribed, and all initially present objects are registered
InitialUpdate	NA	Achieve	Achieved when instance attribute values for all initially present objects are updated
BeginTimeAdvance	NA	Achieve	Achieved when time management services are invoked
PauseExecution	TimeType	Register Achieve	Achieved when the time advance after the time in the user-supplied tag is attained; time advance requests should then cease

Transportation Type Table

- The RTI provides different mechanisms for transport of interactions and attributes between federates
- Allows a federate designer to describe the transports supported by the federate
- Allows federation designers to describe the transportation contracts between federates

Example – Transportation Type Table

Name	Description
HLAreliable	Provide reliable delivery of data in the sense that TCP/IP delivers its data reliably
HLAbestEffort	Make an effort to deliver data in the sense that UDP provides best-effort delivery
LowLatency	Choose the delivery mechanism that results in the lowest latency from service initiation to callback invocation at the receiving federate

Switches Table

- Configuration of RTI activities performed on behalf of a federate
- A few services are configured globally for the federation
  - Auto Provide, Convey Region Designator Sets
- Most services are configured per federate
  - Attribute Scope Advisory, Attribute Relevance Advisory, Object Class Relevance Advisory, Service Reporting
- Services may be either enabled or disabled

Switch Definitions (1)

- Auto Provide
  - (Global) Should the RTI automatically solicit updates from instance attribute owners when an object is discovered.
- Convey Region Designator Sets
  - (Global) Should the RTI provide the optional Sent Region Set argument with invocations of Reflect Attribute Values and Receive Interaction.
- Attribute Scope Advisory
  - Should the RTI advise federates when attributes of an object instance come into or go out of scope.

Switch Definitions (2)

- Attribute Relevance Advisory
  - Should the RTI advise federates about whether they should provide attribute value updates for the value of an attribute of an object instance.
- Object Class Relevance Advisory
  - Should the RTI advise federates about whether they should register instances of an object class.
- Interaction Relevance Advisory
  - Should the RTI advise federates about whether they should send interactions of an interaction class.
- Service Reporting
  - Should the RTI report service invocations using MOM.

Example – Switches Table

Switch	Setting
Auto provide	Disabled
Convey region designator sets	Disabled
Attribute scope advisory	Enabled
Attribute relevance advisory	Enabled
Object class relevance advisory	Enabled
Interaction relevance advisory	Enabled
Service reporting	Disabled

Data Type Tables (1)

- Globally define data types referenced in other tables
- Basic Data Table
  - Name, Size in Bits, Interpretation, Endian, Encoding
- Simple (Scalar) Data Table
  - Name, Representation, Units, Resolution, Accuracy, Semantics
- Enumerated Data Table
  - Name, Representation, Enumerator, Values, Semantics

Data Type Tables (2)

- Array Data Table
  - Name, Element Type, Cardinality, Encoding, Semantics
- Fixed Record Data Table
  - Record Name, Field-{Name,Type,Semantics}*, Encoding, Semantics
- Variant Record Data Table
  - Record Name, Encoding, Semantics, Discriminant-{Name, Type, Semantics}*, Alternative--{Name,Type,Semantics}*

Notes Table

- Named annotations may be attached to any OMT entry
- A set of name/value pairs
- Value is free form explanatory text
- Name uniquely identifies the corresponding explanatory text
- Notes may be referenced multiple times

FOM/SOM Lexicon

- Name/Value pairs
- Dictionary tables associating every class, attribute, interaction, parameter, etc (by name) with a free form text description (value)

For Next Time …

- A deeper look at the RTI

References (1)

- IEEE Std 1516-2000, IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) - Framework and Rules.
- IEEE Std 1516.1-2000, IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) - Federate Interface Specification
- IEEE Std 1516.2-2000, IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) - Object Model Template (OMT) Specification.

References (2)

- Roy Crosbie and John Zenor, “High Level Architecture, Module 1 – Basic Concepts, Parts 1-6.” California State University, Chico. http://www.ecst.csuchico.edu/~hla
- <Steffen Strassburger's text>