An Update on RPR FOM 3

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ABSTRACT: *The purpose of the SISO Real-time Platform Reference FOM (RPR FOM) version 3 is to support real-time platform simulation, matching the capabilities of DIS 7. It will also address some issues in RPR FOM 2. RPR FOM 3 is expected to be completed during 2020. Experimental versions of several FOM modules already exist. This paper summarizes the current status, new and improved capabilities and provides some background and rationale.*

Some of the key new features relate to IFF (Identification Friend or Foe), Directed Energy Fire, Information Operations and Entity Appearance and Capabilities. For IFF, Mode 5 and Mode S are the most important additions. The IFF module has also been restructured to better represent the different modes of transponders and interrogators as well as the Interactive Mode. The new Information Operations module is very generic, using two interactions with an extendable set of Actions and Statuses and is expected to be useful for operations like electronic warfare, computer network operations, psychological operations, military deception, and operations security. For Entity Appearance and Entity Capabilities, a number of missing properties have been added, based both on DIS 6 and DIS 7.

One of the challenges in the FOM design is the DIS Attribute PDU, the question if or how to bridge the different basic principles for extending an information model in DIS versus HLA. Another challenge is the principles for transferring ownership. The representation of time stamps is yet another challenge, in particular for pure HLA federations, needing to use Time Management. This paper summarizes the approach taken, including pros and cons.

RPR FOM 3 will be a valuable step forward, particularly for use in federations that mix HLA and DIS based systems, as a migration path from DIS to HLA and as a starting point for further extension.

1. Introduction

1.1 Background

The Real-time Platform Reference FOM (RPR FOM)[1] is the most widely used Federation Object Model (FOM) for distributed simulation using the High Level Architecture (HLA)[2]. It is an open international standard through the Simulation Interoperability Standards Organization (SISO). It builds on the heritage of the SIMNET[3] project, the first known major distributed simulation, developed for the US Advanced Research Project Agency (ARPA), and its successor, Distributed Interactive Simulation (DIS)[4], standardized through IEEE Std 1278™.

Distributed simulation is a rapidly evolving technology and standards need to evolve accordingly. This paper intends to summarize the work with the upcoming RPR FOM version 3 and give some insight into both the process and the expected content. RPR FOM 3 is intended to include the new functionality of DIS version 7, as well as to add some missing details from DIS version 6. Note that the capabilities of the RPR FOM also continuously evolve based on new versions of the SISO Reference for Enumerations for Simulation Interoperability (SISO-REF-010)[5] that are included as a separate module.

1.2 Short history of the RPR FOM

The primary goal of the first RPR FOM standard was to provide a reference FOM that would facilitate the transition of DIS simulations to the new HLA standard. The initial work began in 1996, but the kickoff for the SISO RPR FOM Standards Development Group (SDG) did not occur until the fall of 1998. The initial RPR FOM, known as RPR FOM 1.0, was approved in 1999. This standard was based on the IEEE Std 1278.1-1995 version of the DIS standard.

With RPR FOM 1.0 complete, work began on RPR FOM 2.0 in order to include the many extensions added in IEEE Std 1278.1a-1998. In addition, the group considered ideas for improvements that came out of early use of RPR FOM 1.0. Seventeen draft revisions were created between 1999 and 2003, but development of the standard ceased before RPR FOM 2.0 could be finalized. As a result, for many years the only versions of RPR FOM 2.0 available were draft versions. Draft 17 became the most commonly used draft, despite several issues and without commonly agreed upon formats for HLA 1516-2000 or HLA 1516-2010.

In the spring of 2011 an effort was begun to revive RPR FOM 2.0 development. A product nomination was approved in 2012. This effort resulted in a standardized version of RPR FOM 2.0 that was published in 2015. This standard mostly maintained buffer compatibility with RPR FOM 2 draft 17 while resolving many issues, adding support for all three HLA versions (1.3, 1516-2000, and 1516-2010), and modularizing the FOM.

After the completion of RPR FOM 2.0, in an effort to prevent the RPR FOM from falling further behind the evolving DIS standard, it was decided to combine the RPR FOM Product Support Group (PSG) with the DIS Product Support Group and form the DIS / RPR FOM PSG. This combined PSG supports both standards and is designed to keep open lines of communication between the DIS and RPR FOM communities. In 2018 the PSG decided that a new RPR FOM Product Development Group (PDG) should be formed with the goal of developing RPR FOM 3.0 to support the latest DIS standard, IEEE Std 1278.1™-2012.

1.3 Earlier papers

When the final version of RPR FOM 2 was completed, a paper “RPR FOM 2.0: A Federation Object Model for Defense Simulations”[6] was published, summarizing the effort and updates made. Key aspects were the detailed specification of datatypes and the modularization, both of which were driven by the adaptation to newer standards versions, namely HLA IEEE 1516-2000 and HLA IEEE 1516-2010 (“HLA Evolved”). One goal of RPR FOM 2 was to cover the same scope (object and interaction classes), and to be buffer compatible with, RPR FOM 2 draft 17. This meant that some proposed changes that were discussed in the development group, had to be postponed, for example updates to data representation. These discussions were captured in the paper “Towards RPR FOM 3: Revisiting the Datatypes”[7].

1.4 Process and current state of the RPR FOM 3 development

The development of the RPR FOM follows the SISO Balloted Products Development and Support Process (BPDSP)[8]. It kicked off with the submission and approval of a Product Nomination in August 2018. After a first PDG meeting in November 2018, most of the technical work is carried out in a Drafting Group (DG) that produces Product / Change Requests (PCRs). A number of PCRs had already been developed as part of the DIS / RPR FOM PSG and were included in the effort as a starting point. The DG work is focused either on specific technical topics, or around reviews of selected chapters of the standard. PDG meetings are then held to approve which PCRs may be included into the next draft version of RPR FOM 3. The most recent draft of the FOM, as of December 2019 is Draft 2.2. All drafts, PCRs and DG and PDG meeting minutes are publicly available in the SISO Digital Library.

As of December 2019, 22 PCRs have been completed and several more are underway. Most of the technically complicated topics have been resolved, as further described in this paper. A lot of general review remains to be done. With the current pace, the PDG hopes to have a final draft available in mid 2020, which can then be balloted, possibly resulting in a published standard in 2021.

2. Major Revisions

2.1 Enumerations

The “Reference for Enumerations for Simulation Interoperability”, frequently referred to by its document number SISO-REF-010, is a document that specifies the numerical values and associated definitions for those fields that are identified as enumerations in SISO standards and in SISO-sponsored standards published by IEEE. Since the DIS standard references this document for its enumeration fields, this document is also relevant to the RPR FOM. For a complete HLA FOM, however, the definitions of enumerated datatypes will need to be included, not just referenced.

The starting point for the modularization of the RPR FOM 2.0 has been a draft version of the NATO Education and Training Network (NETN) FOM[9], developed by members of MSG-068. During the final drafting phases, it was decided to separate out the enumerations related to SISO-REF-010 in a dedicated Enumerations module. With the focus on “Draft 17” buffer compatibility, however, the existing enumerations were only updated with new enumerators from the latest SISO-REF-010.

Following the publication of the RPR FOM 2.0 standard, the eXtensible Stylesheet Language Transformations (XSLT) toolset used for updating the Enumerations module has been provided to the SAC Special Working Group (SWG) Reference for Enumerations for Simulation. This enabled the working group to continue delivering an up-to-date Enumerations module with every new release of SISO-REF-010. However, as the XSLTs were built to update the Enumerations module, it is fairly complex and the result is still not fully in line with the source SISO-REF-010.xml.

This triggered the change request PCR-RPR-007, proposing a complete regeneration of the Enumerations module from the SISO-REF-010 XML source file. By automatically regenerating the names for the enumeration datatypes as well as the enumerators, full correlation is established again, matching SISO-REF-010’s scope of applicability across multiple standards. Version B of the PCR has been approved for incorporation in RPR FOM 3.0 draft 2 in the PDG meeting on November 13, 2019. Upon completion of the RPR FOM 3.0, the new XSLT toolset will be provided to and maintained by the SWG Enumerations to ensure a continuous alignment of the RPR FOM Enumerations module and SISO-REF-010.

Since all enumerations are generated from their SISO-REF-010 names, some datatype names will change. This also applies to the enumerator names. However, since the semantics to the enumerator values in SISO-REF-010 typically do not change and the enumeration sizes are fixed by their definition in the DIS standard, in most cases the encoding does not change. For this part, this renders an alignment of federate code with the new names optional.

There are, however, a few enumeration representations in RPR FOM 1.0 and 2.0 that do not match the size as defined in SISO-REF-010.xml, for example because two or more enumerations were merged into one during the RPR FOM development. Consequently, this realignment of the Enumerations module with SISO-REF-010 triggers updates to a few classes and datatypes. Currently identified are necessary changes related to entity appearance (covered with PCR-RPR-006), synthetic environment appearance, radio related datatypes, and minefields (all with PCRs under development), and some simulation management (SIMAN) interaction parameters.

2.2 Appearance and capabilities

Unlike its title suggests, the SISO-REF-010 “Reference for Enumerations for Simulation Interoperability” does not only define enumerations. The DIS standard also deferred the definition of a few record structures to the reference document, providing the flexibility to add definitions at a later stage without the need to go through a time-consuming (IEEE) update process for the standard. However, in contrary to the update of the enumerations during the finalization of RPR FOM 2.0, none of the changes to the record structures since 2003 have been reflected thus far in the RPR FOM.

Two of the records that were updated significantly are the Entity Appearance record [UID 31-43] and the Entity Capabilities record [UID 55]. Consequently, although the latest SISO-REF-010 is also applicable to DIS v6, RPR FOM 2.0 has reduced expressiveness regarding entity appearance and capabilities. For example, appearance fields such as damage and power plant status and capability fields like ammunition and fuel supply were defined from the early days, and are therefore available as attributes in RPR FOM 2.0. But e.g. appearance fields as surrender state, added in 2002, or landing gear extended, added in 2013, or a capability as sling loadable, added in 2015, are currently not represented. In a mixed DIS/HLA exercise it is therefore not possible to translate all appearance and capabilities information from an Entity State PDU to a PhysicalEntity based object. This may lead to a loss of information even between DIS applications when RPR FOM is used as the backbone for distributed exercises.

The first version of PCR-RPR-006 proposed to replace the many individual RPR FOM 2.0 appearance and capability attributes by a single attribute for each record, matching the record definitions in SISO-REF-010. However, it also included a discussion section on options to translate the 32-bit DIS records to HLA fixed records, especially considering possible future updates to the definitions. In addition, the alternative of staying with the RPR FOM 1.0 and 2.0 design of individual attributes was also mentioned.

A. Two PhysicalEntity (or BaseEntity !?) attributes (Appearance, Capabilities)
   1. Only include fields currently defined in SISO-REF-010
      a. Regenerate fixed record when unused bit(s) are defined
      b. Append new fields when unused bit(s) are defined
   2. Includes ‘spares’ for undefined bits in the SISO-REF-010 records
      a. Use 8-bit datatypes, one ‘spare’ for each undefined bit
      b. Use datatypes of the same size as in the SISO-REF-010 records (1-bit, 2-bit, 3-bit, 4-bit)

B. Individual attributes for each of the appearances and capabilities
   1. Only for each of the leaf classes
   2. Common attributes for all leaf classes are generalized to the parent class
   3. Common attributes for two or more leaf classes are generalized to the parent class
   4. Mixture of attributes for PhysicalEntity, Platform, Lifeform, CulturalFeature, Munition, Sensor (RPR FOM v2.0)

Figure 1: Entity Appearance and Capabilities solutions options (PCR-RPR-006)

Subsequent discussions in the Drafting Group lead to the review and a theoretical analysis of eight alternatives for aligning the RPR FOM again with SISO-REF-010 with respect to the entity appearance and capabilities, see Figure 1. The characteristics analyzed included backward and forward compatibility, the ease of understanding and implementing the FOM, and memory footprint and network bandwidth. Figure 2 shows an example of the effects on the network bandwidth based on some typical, theoretical use cases of updates to an entity’s appearance. Following group review of that analysis, it was commonly agreed that solution B.2 overall provides most benefits with only limited drawbacks. This has been reflected in version C of the PCR, which was approved in the PDG meeting on November 13, 2019.

Although the RPR FOM 1.0 and 2.0 design to translate the appearance and capabilities fields to individual attributes will be kept, the RPR FOM 3.0 attributes will mostly not be backward compatible. First of all, all the attribute names have been regenerated from their field names in SISO-REF-010. Existing implementations will perceive this as a rename from the RPR FOM 2.0. Secondly, some fields that were merged into one attribute in the past, will now again be available as individual attributes as per the record definitions in SISO-REF-010. Thirdly, many appearance and capability attributes will move downward in the class hierarchy, to prevent these being available to objects to which they don’t apply. This also implies that attributes that do apply to multiple entity kinds or platform domains will be duplicated in several classes. And last but not least, federate implementations will need to add support for the appearance and capability properties that have been added after 2003.

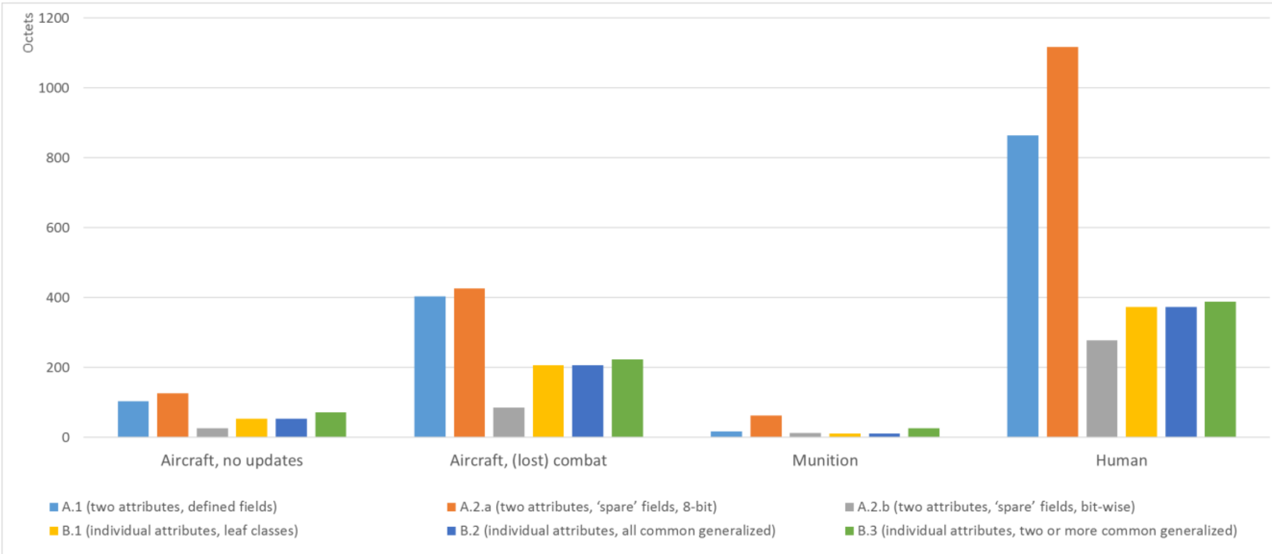

Figure 2: Theoretical network bandwidth analysis of six solution alternatives (PCR-RPR-006)

2.3 IFF

The capability for simulation applications to exchange the state of Identification Friend or Foe (IFF) and Air Traffic Control (ATC) beacon and transponder systems was introduced in DIS v6, and mapped to the current EmbeddedSystem IFF object class hierarchy in RPR FOM 2.0. While retaining backwards compatibility, DIS v7 added new capabilities such as the military Mode 5 and civilian Mode S to the IFF PDU. Furthermore, in addition to the mandatory regeneration mode, in which each recipient is responsible for maintaining a local model of the systems and recreation of the interrogation and reply environment, the optional interactive mode was added. This mode enables a higher fidelity representation of the interaction between an interrogator and a transponder, e.g. to activate visual or aural cues in correlation with the events in a distributed synthetic environment. Last but not least, DIS v7 includes a separate normative annex defining the information, issuance, and receipt rules for specific transponder and interrogator systems.

In preparation for specifying the changes necessary to add the new IFF capabilities to the RPR FOM, the annex has been analyzed in detail. One of the reasons to reflect on the RPR FOM 2.0 IFF class hierarchy was the now explicit definition of civil-only ATC interrogators and transponders. The grouping of the various PDU and record fields, as representation of distinct interfaces that IFF systems may implement, revealed that there is no single hierarchy possible satisfying both applicability of all attributes to each IFF object and a definition thereof at just one specific class. Subsequent review of the analysis and discussion was captured in PCR-RPR-022, proposing a new class hierarchy primarily reflecting the distinction between transponders and interrogators followed by a split into civil-only and military systems. Furthermore, it was preferred to try to minimize the cases where an attribute would not be applicable to a certain system, at the expense of duplicating attributes at multiple classes in the hierarchy.

During one of the subsequent Drafting Group (DG) teleconferences, this proposed class hierarchy for IFF was reflected upon by comparing the pros and cons of six alternatives. The one that attracted the most attention, and results in a significantly better balance between attribute applicability and preventing their duplication, is one in analogy to the publication of emitter systems and their beams. This object class tree is shown in Figure 5. The class diagram in Figure 3 shows the relationships between the two main IFF classes, through the IFFData attribute IFFSystemIdentifier, and the link from the IFF system to the entity.

Although the update of the PCR is still pending, this is the structure currently proposed by the PCR author and the regular participants of the RPR FOM DG meetings. To get a better understanding of the consequences of this change, to be able to compare it to the RPR FOM 2.0 design by attempting a migration of federate implementations, an experimental FOM has been created and published in the SISO Digital Library. Apart from the changes to the IFF, including the necessary additions to the Enumerations module, this experimental IFF FOM matches the RPR FOM 2.0 (i.e. it does not build on one of the RPR FOM 3.0 drafts). At the time of writing, a (public) report on experimentations with this FOM appears to be not (yet) available.

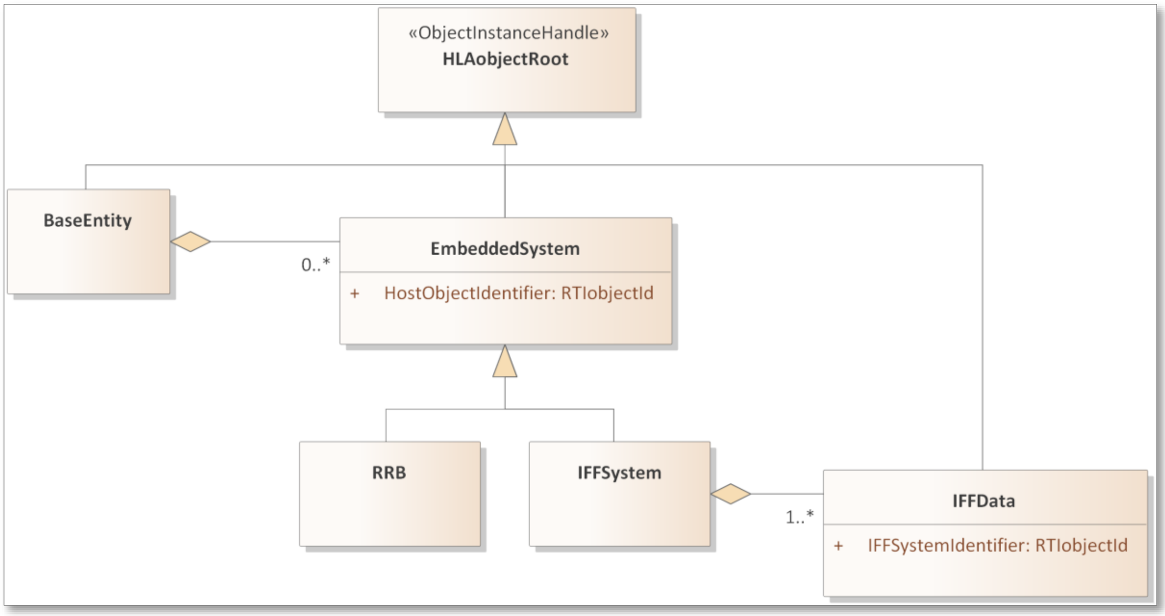

Figure 3: Experimental IFF object class relationships

In DIS there is only one IFF PDU for both the regeneration mode and the interactive mode. The transient nature of the interactive data exchange is indicated by a special flag in both the PDU header and in the IFF Change/Options record, and by publication of the data in a specific layer (5). Generally, publication of regeneration mode PDUs for the same IFF system continues, and even an interactive IFF PDU must contain regeneration mode data to support backward compatibility. Translating this design to the RPR FOM would lead to the appearance of the same IFF object switching modes and the addition and removal of attribute content depending on the regeneration/interactive mode.

In HLA, a more natural representation of transient data exchange between systems is through the usage of interactions. Hence, for RPR FOM 3.0 a separate IFF interaction class hierarchy is proposed in PCR-RPR-022 for the interactive mode, see Figure 4. Through the IFFEmission parameter IFFSystemIdentifier each interaction is linked to the object instance of the IFF system the emission originates from. This enables a federate to only include the data in the interaction that differs from the IFF system's and modes' states. Any other data relevant to the interactive emission can be retrieved from the already published objects attributes.

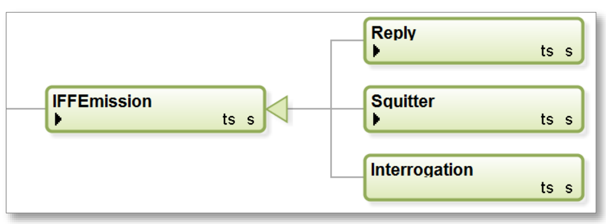

Figure 4: Experimental IFF DER module interaction class tree

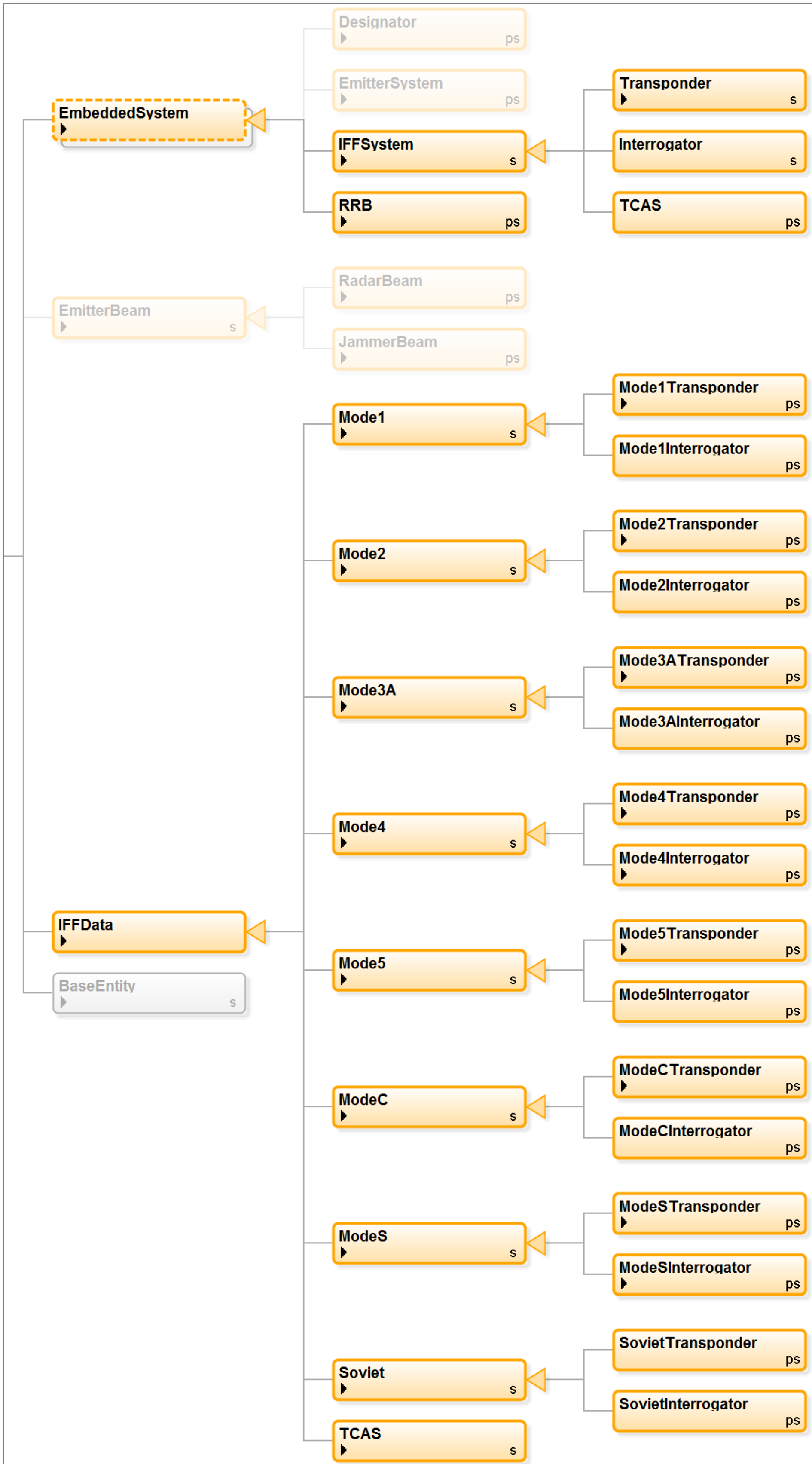

Figure 5: Experimental IFF DER module object class tree

The analysis of the IFF data exchange capabilities in DIS v7 also raised a series of questions regarding the interpretation of the standard. These questions have been included as part of the section Discussion in the PCR and have been raised on the SISO DIS / RPR FOM PSG discussion board. The subjects being:

- Alternate Mode 4 and Mode C Indicators
- Alternate Mode 4 Challenge/Reply for Mark XIIA Interrogator and Mode 5 Interrogator
- TCAS/ACAS Undefined Fundamental Operational Data Fields
- Mode 3/A record
- Transponder Location Error IFF Data for Mode S
- Squitter Aircraft ID Source and Movement Enumerations
- GICB Message Packing
- Mode 5 Message Formats for Interactive Squitter
- Purpose of Reporting Simulation

As most of these questions remained unanswered thus far, readers are encouraged to reach out to simulation application developers that implemented IFF using the DIS standard.

The PCR's Discussion section includes several other topics that may be considered in the IFF design for RPR FOM 3.0. Some are more generic in nature, also applicable to other mappings between DIS and RPR FOM or even to the nature of HLA in general. An example of the former is the question of how to deal with DIS fields that have not yet been assign a specific purpose. Should the RPR FOM include a representation of those, so that in case something is included by a DIS application a gateway is able to forward the information to RPR FOM based federates? Or should semantically empty attributes and parameters be avoided in the RPR FOM?

Another discussion regularly returning, and especially applicable to IFF due to the many records applicable, is whether to map DIS records to HLA fixed records, or model the fields as individual attributes. Separating loosely coupled data in individual attributes enables a federate to make maximum use of the HLA capability to minimize network traffic, as only changes to objects need to be published. However, with the division of certain system capabilities into individual attributes, the ease of building up the understanding of an object model suffers. In some cases the expected limited number of updates during federation execution may justify to group data in a fixed record and a single attribute.

In line with the decision for the entity appearance and capabilities, the IFF update proposal favors individual attributes. The object composition pattern, analogous to the emitter systems and beams, contributes to the understandability of the model and limits the number of attributes per class. The additional object bookkeeping overhead from this design is minimized by changing an on/off attribute for each of the modes, instead of adding and deleting objects.

2.4 Attribute PDU

With the Attribute PDU, DIS v7 introduced a generic extensibility capability that can be used to extend any another PDU with additional information as well as communicate information not associated with a specific PDU type. By specifying the information content of the Attribute PDU to be transported using one or more Standard Variable (SV) records, the PDU itself remains generic in nature, allowing for any current as well as future specification of SV record types.

In DIS v7 the following SV records have been explicitly defined:

- Damage Description records
    - Directed Energy Damage Description record
- Directed Energy (DE) records
    - DE Area Aimpoint record
    - DE Precision Aimpoint record
- EE Attribute records
    - Blanking Sector attribute record
    - Angle Deception attribute record
    - False Targets attribute record
- IO records
    - IO Communications Node record
    - IO Effect record

In addition, as the Attribute PDU itself is generic in nature, also a generic Attribute record has been defined. From the perspective of simulation applications exchanging information, this is also a template: the actual record structure will need to be agreed upon to be able to process the data. However, for simulation applications not involved in the data exchange the content remains opaque, as per the definition of the Attribute record; although the data type is specified by enumerator value, the content is merely an array of octets.

For most of the SV records mentioned above, new PDUs have been introduced in DIS v7 (Entity Damage Status, DE Fire, IO Action). In all those cases, a reference is made to the applicable SV records, but it is also explicitly noted that the corresponding field "*may contain other Standard Variable records*". For the EE PDU the extensibility has not been implemented by adding a field, but through the usage of Attribute PDUs. Actually, the Attribute PDU provides a generic extensibility capability to every PDU. Moreover, the Attribute PDU may be used to exchange any data unrelated to any other PDU type.

Consequently, DIS v7 provides simulations with the capability to exchange information beyond the data structures defined in the standard, be it associated to information already published or covering a new use case.

When it comes to data exchange capabilities clearly associated to a PDU, associating them with the equivalent object or interaction class in the RPR FOM supports its understandability. Consequently, the DE Damage Description is proposed to be made available through the new PhysicalEntity attribute ExtendedDamageStatus (PCR-RPR-018), the DE SV records with the new DirectedEnergyFire class (PCR-RPR-017, also see section 2.7), the EE SV records (probably) with the RadarBeam and JammerBeam classes (PCR pending), and the IO SV records with the new IO classes (PCR pending, also see section 2.5).

Regarding the extensibility, however, there are arguments in favor of different ways of dealing with it. One the one hand, one could argue that the HLA in principle provides extensibility through the ability to add attributes and parameters. A FOM can be modified, new data exchange capability added, without requiring existing federates to be modified. In addition, the RPR FOM is a reference FOM, i.e. it may be modified to support different use cases, including the need to add data exchange capabilities. From this perspective, there is no need to provide for "other SV records" or an equivalent of the Attribute PDU in the RPR FOM.

However, in contrast to the DIS standard, this would imply that the standard RPR FOM would need to be modified in case the usage of custom SV records is agreed upon for an exercise. Although HLA simulation federates that are not affected by such custom SV records would not need to be modified, a mixed DIS/HLA exercise would require the gateway federate(s) to be adapted to be able to forward the data, even though gateways specifically do not care about the data content, and thus are not that interested in the semantics of the FOM.

There might even be situations in which publishing the structure and semantics of datatypes is not desired, for example related to Information Operations. Having a generic capability to publish opaque data allows for a data exchange within the same exercise, using the same protocol, while only those participants that know how to decode the structure can understand it. The DIS standard provides this capability for targeted interoperability with the definition of the generic SV record structure while allowing the details of such custom SV records to be left to exercise agreements or limited distribution annexes thereof.

Similar thoughts and discussions have resulted in PCR-RPR-016, proposing to implement a generic SV record extensibility capability in the RPR FOM according to the following design "rules":

1. Known SV records, as specified in the DIS standard, are used for attributes/parameters of the object or interaction classes they are explicitly defined for.
2. Unknown SV records are encoded using a generic datatype, used by an attribute or parameter respectively of a generic object or interaction class. This pair of object class and interaction class provides a generic extensibility capability, which may be used for the exchange of additional information associated to any existing object or bundled with an interaction, as well as for unassociated data publication.
3. The extension capability of specific classes is limited to those SV record datatypes that are explicitly related to it. Any other SV record used to extend a specific object or interaction is to be published using the generic extensibility attribute or parameter.
4. The generic extensibility attribute and parameter only handle opaque data, their datatypes do not include a definition of specific SV records.

The proposed object and interaction class trees are shown in Figure 6 and Figure 7 (focusing on the change, therefore blending out most of the existing classes). Figure 8 shows the datatypes and their relationships used for the ExtensibilityAttribute and ExtensibilityParameter. The actual data is being published in an opaque array of octets.

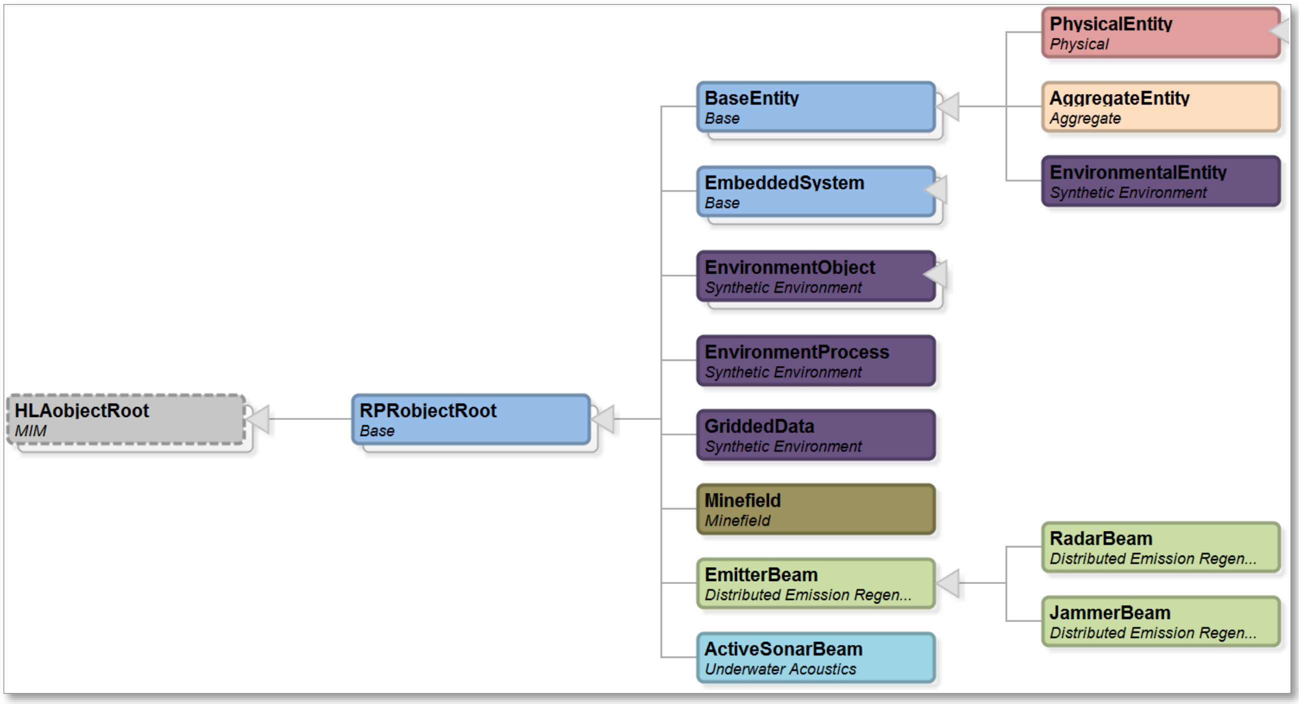

Figure 6: Partial object class tree with RPRobjectRoot

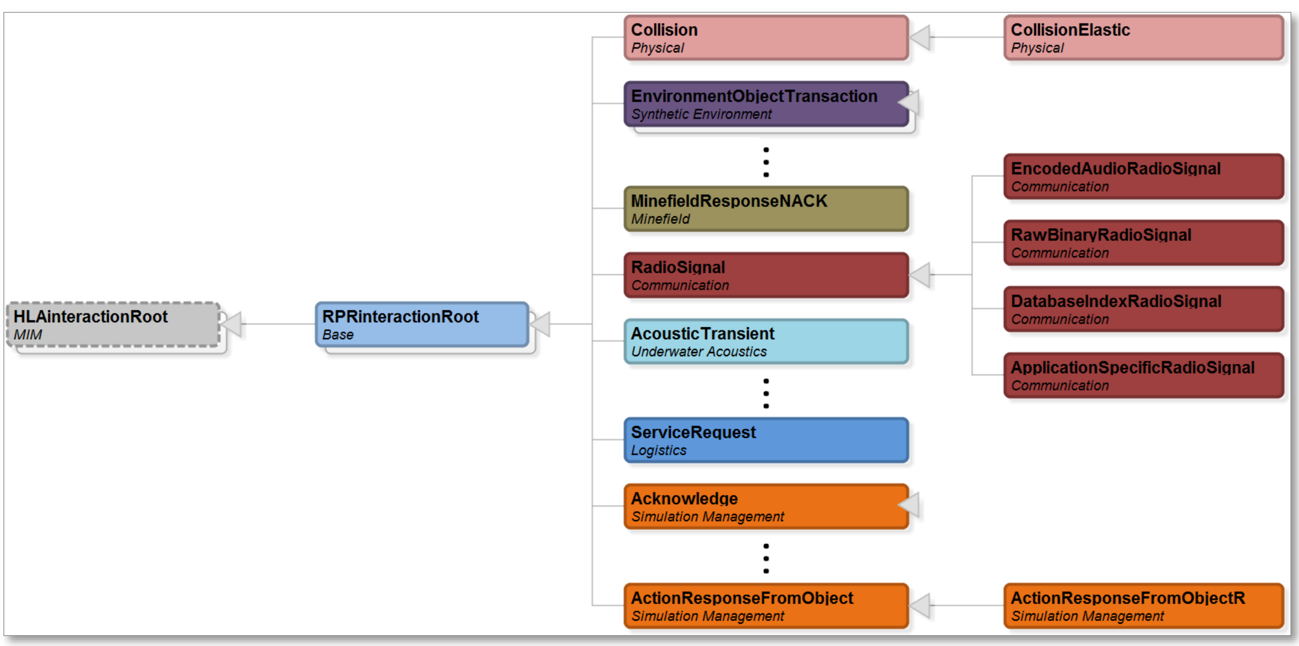

Figure 7: Partial interaction class tree with RPRinteractionRoot

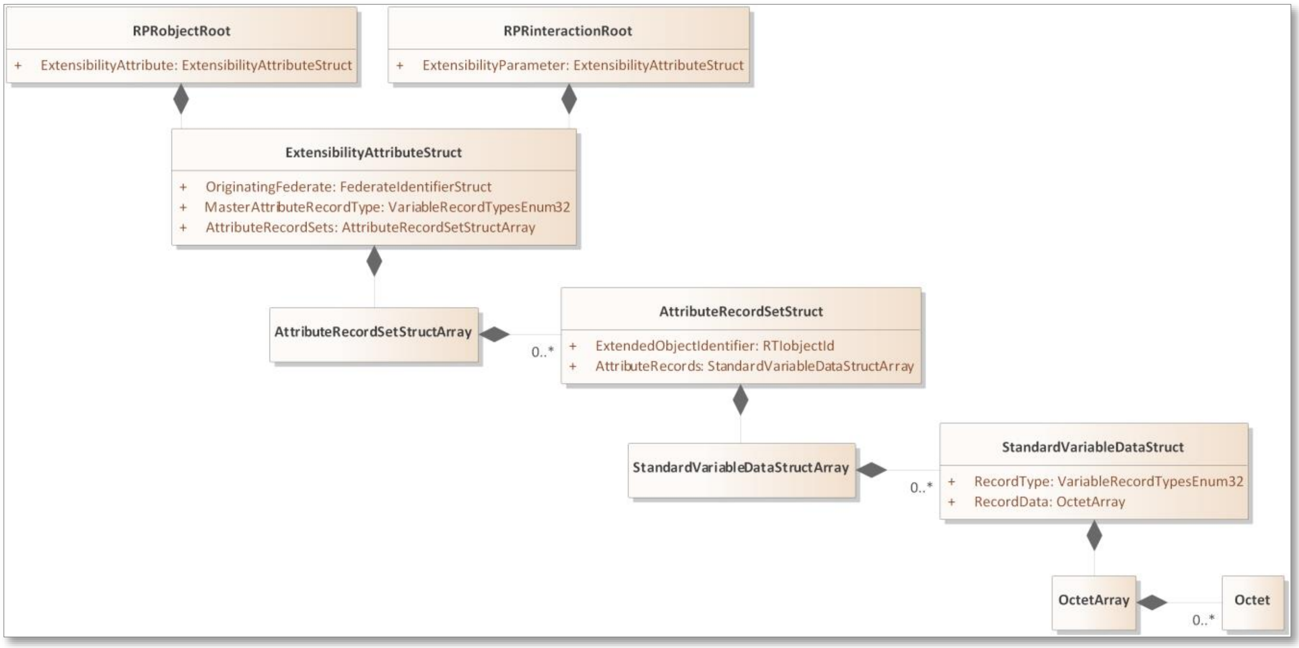

Figure 8: Extensibility datatypes

The PCR contains more details on the rationale for this solution, including

- a reflection on the DIS PDU bundling capability;
- the (im)possibilities of providing buffer compatibility between the DIS and RPR FOM SV record structures;
- the applicability and, if applicable, the mapping of DIS record fields to RPR FOM datatype fields;
- in which module to implement the new root classes;
- a discussion on the consequences of the DIS heartbeat rules, especially in light of one of the issuance rules of the Attribute PDU:

  "*It is not required that a particular Attribute record be included in every issuance of Attribute PDUs for its associated entity. At a minimum, an Attribute record shall be issued when its contents change or to satisfy the appropriate heartbeat requirement.*"

One of the topics not (yet) covered in the PCR is how a gateway should translate between DIS Attribute records and the new RPRobjectRoot ExtensibilityAttribute. The difficulty lies in understanding which DIS Attribute record should be mapped to which record within the RPR ExtensibilityAttribute. Since a gateway will not be able to understand every custom Attribute record a user might add, the goal would be for it to be able to generically copy the opaque data from the DIS PDU to the HLA attribute. The problem is that DIS has no unique identifiers for its Attribute records nor does it require all records be included in every update. While each record has a record type, that type only indicates the format and type of the data. It does not prohibit multiple records of that record type from being added. For example, a DIS entity could include multiple Attribute records defining articulated parts. Each record would have the same record type even though they referred to different parts. An application would have to know how to decode and understand the data in order to know which articulated part was being updated by a specific record. As a result, a gateway receiving a partial DIS Attribute PDU update will not be able to conclusively determine which records within the ExtensibilityAttribute should be updated. There is no clear solution to this issue that can be accomplished by a generic gateway. It may be required that gateways have knowledge of every Attribute record in order to properly translate them. In that case the benefit of the generic extensibility capability of the RPR FOM comes into question. It also makes translating between DIS extensions and RPR extensions difficult for users.

When the RPR FOM is modified according to the PCR, the fully qualified name of all object and interaction classes change. Consequently, existing RPR FOM 2 based federates will need to be updated. This may be as easy as a general search-and-replace of 'HLAobjectRoot.' by 'HLAobjectRoot.RPRobjectRoot.' and 'HLAinteractionRoot.' by 'HLAinteractionRoot. RPRinteractionRoot.'. However, since the inclusion of the HLA root classes is optional, it may also require some more work to find and update each class name.

2.5 Information Operations

DIS 7 adds a first level of support for information exchange about information operations (IO), such as electronic warfare (EW), computer network operations (CNO), psychological operations (PSYOP), military deception (MILDEC), and operations security (OPSEC). The capabilities are expected to develop as the capabilities of information operations simulations develop.

The information exchange follows the pattern that an attack is first carried out and effects are then reported. Two new PDUs are thus introduced in DIS 7, the IO Action PDU and the IO Report PDU. RPR FOM 3 will add a new module, called Information Operations, with two new interactions corresponding to these PDUs: IOaction and IOreport, as shown in Figure 9. A superclass, with common attributes, called IOinteraction, has also been added.

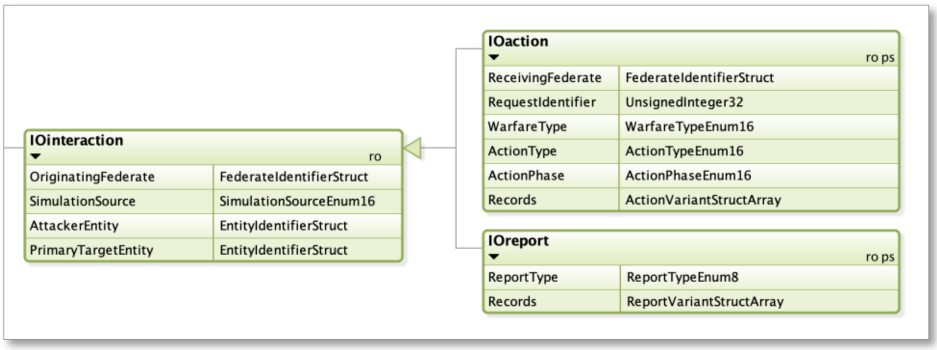

Figure 9: Preliminary interaction class hierarchy for Information Operations

These interactions are intended to be used as follows: The federate generating an attack sends an initial IOaction interaction, that specifies the simulation generating the attack, the target(s), the type of attack, the phase and additional attack profile data in a number of records. The simulation(s) responsible for simulating the effects on the target responds with an Acknowledge interaction. Subsequent IOactions can be sent if some of the profile data has changed since the initial attack. These shall also be acknowledged. Any federate simulating a target of an attack shall send an IOreport when the effects have been determined, be it from the initial IOaction interaction or an update in the profile data. There is no strict requirement on the timing between the IOaction and the IOreport. There is also no requirement for any federate to acknowledge IOreport interactions. The profile data for a specific type of IOaction or IOreport is specified in variable records, based on the two IO Standard Variable records defined in DIS 7 and using the IO enumerations as defined in the Enumerations module.

2.6 Fire and Detonation

The current RPR FOM equivalent of the DIS Fire and Detonation PDUs are named respectively WeaponFire and MunitionDetonation. This is in line with IEEE Std 1278.1™-1995, in which the PDUs are briefly introduced with "*The Fire PDU shall be used to communicate information associated with the firing of a weapon.*" and "*The Detonation PDU shall be used to communicate information associated with the impact or detonation of a munition.*". However, in the most recent version of the DIS standard, IEEE Std 1278.1™-2012, the usage of these PDUs has been extended respectively with "*or expendable*" and "*a non-munition explosion, or the burst or ignition of an expendable*".

PCR-RPR-015 proposes to clearly indicate this additional applicability to RPR FOM users by defining the interaction classes ExpendableFire, ExpendableBurst, and Explosion. And, as these classes share commonality based on their DIS PDU origin, reflect this in class hierarchies with Fire and Detonation as parent classes, see Figure 10. The majority of the parameters defined in the WeaponFire and MunitionDetonation classes in RPR FOM 2.0 will move to their new parent class. To represent the dedicated requirements for the different use cases, as provided in the DIS v7 standard, each of the derived classes will hold the parameters that only apply to the corresponding usage of the interaction.

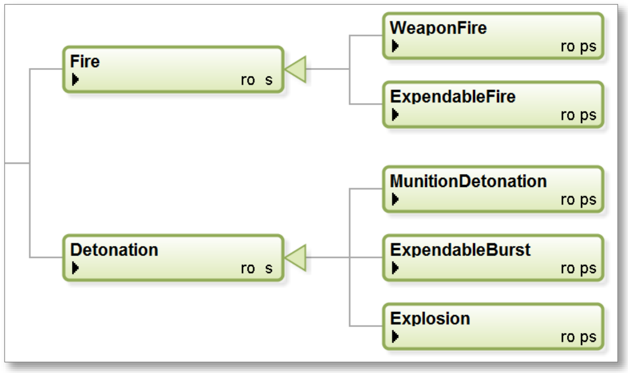

Figure 10: New Warfare module interaction class tree

As from the perspective of this PCR the parameter names and datatypes are not changed, existing implementations based on RPR FOM 2.0 need only to prepend the class name with the new base class to retain the ability to send WeaponFire and MunitionDetonation interactions. By keeping the existing class names, the proposed class hierarchy also enables federates that have not (yet) implemented the new capabilities to filter out the expendable effects and explosions. In case existing implementations have been using the RPR FOM 2.0 interaction classes for expendables and non-munition explosions as well, the new classes should be used and some of the parameters will have to be renamed.

2.7 Directed Energy Fire

DIS v7 also introduced a new type of weapon fire, Directed Energy (DE). In contrary to the typical firing of a weapon, such weapons are not characterized by one or several successive firing events, but a continuous emission of electromagnetic energy at a target for a period of time. Consequently, in DIS the PDU that communicates the information associated with the firing of a DE weapon has a heartbeat. For the RPR FOM, this translates to an object, in PCR-RPR-017 proposed with the class name DirectedEnergyFire.

This PCR also refers to PCR-RPR-016, primarily focused at the translation of the Attribute PDU capabilities. For the DE Fire PDU also includes the in DIS v7 introduced generic capability to extend a PDU using SV records. Currently, two records have been defined (in the DIS standard) specifically for the DE Fire PDU, the DE Area Aimpoint record and the DE Precision Aimpoint record. Although PCR-RPR-016 has not yet been scheduled for a vote in the PDG, the design of assigning specific SV records to their respective RPR FOM classes was approved for DirectedEnergyFire in the PDG meeting on November 13, 2019. Therefore, the RPR FOM 3.0 draft 2.1 only contains the capability to provide the equivalent of the mentioned DE SV records in the DirectedEnergyData attribute. Until PCR-RPR-016 is approved, or any other solution decided upon for the publication of SV records not defined in the DIS standard, early adopters of the RPR FOM 3.0 will need to add custom DE SV records to the DirectedEnergyDataVariantStruct.

2.8 Ownership

The latest DIS standard has clarified and improved the rules for transfer of ownership. Since one of the primary goals of RPR FOM 3.0 is to enable interoperability between DIS exercises and RPR FOM federations, we needed to update the Guidance, Rationale, and Interoperability Modalities (GRIM) procedure for ownership transfer to better align with the rules of IEEE Std 1278.1™-2012. As in other cases in the GRIM, the updated ownership transfer section refers to the DIS standard as much as possible, while also expanding on the DIS procedure to explain how this process should work in an HLA federation. The procedure follows the DIS standard very closely, substituting the corresponding RPR FOM interactions for each DIS PDU. The HLA ownership transfer services are then used once the divesting and acquiring applications have agreed to the transfer.

The goal of the Transfer Ownership section in the GRIM is to outline one possible procedure that could be used to achieve ownership transfer either among RPR FOM based federates or between a RPR FOM federate and a DIS application. This section is informative only. Ownership transfer is not a required part of the standard, and other ownership transfer procedures are equally valid. The GRIM only outlines a recommended procedure to follow when interoperating with DIS. When operating in an HLA-only exercise, other ownership transfer processes may be used, but they should be described in the federation agreement and be supported by all required federates.

The biggest difference between HLA and DIS ownership transfer is the level at which ownership is allowed to be transferred. In HLA, ownership can be transferred at the attribute level, meaning that the attributes of a single object could be owned by several different federates. In DIS this is not possible. If ownership is transferred in DIS, then the whole object must be transferred, not just selected attributes. Furthermore, DIS limits ownership transfer to entities and environmental processes, and does not allow transfer of aggregate entities. It also requires that the acquiring simulation take responsibility for any supplemental PDUs that are being published for the entity, such as IFF or emitter systems. In the RPR FOM, these are separate object classes that can be transferred separately using HLA ownership transfer. In order to allow interoperability between the standards, the GRIM ownership transfer procedure only supports whole-object transfer and also requires that any EmbeddedSystem objects associated with the object also be transferred.

Another difference in the DIS standard is that it defines a mechanism for sending additional data between the divesting and acquiring applications. Often an entity contains internal state that is not normally published but is necessary for maintaining proper behavior. By sending this data during transfer of ownership, DIS applications can ensure a more seamless transition. HLA does not have a defined mechanism for transferring this type of data, and as a result, HLA federations must build this into the object model. The recommended procedure in the GRIM follows the DIS standard and uses the RecordSetData parameter of the TransferOwnership interaction or separate SetRecord interactions to provide this data.

3. Minor Revisions

A number of minor revisions are also planned. This section summarizes some of the more important ones.

3.1 Intercom

IEEE Std 1278.1a-1998 added the Intercom Signal and Intercom Control PDUs, but corresponding interaction classes were not added to RPR FOM 2.0. Intercom communications can be simulated using two different methods in DIS: the Simple Intercom Method or the Intercom Method. The Simple Intercom Method uses the Transmitter and Signal PDUs, just as is done for radio communications. The Intercom Method is more complicated and uses the Intercom Signal and Intercom Control PDUs. RPR FOM 2.0 only supported the Simple Intercom Method. Since the Intercom Signal and Intercom Control PDUs were retained in IEEE Std 1278.1™-2012, the RPR FOM 3.0 drafting group considered adding interactions to support this method as well. However, there were no requests for this capability from the RPR FOM community, and after talking to other members of the DIS / RPR FOM PSG we discovered that these PDUs were planned to be removed from the next version of DIS due to lack of interest. So, the drafting group made the decision to leave the more complicated method out of RPR FOM 3.0 as well.

3.2 CommentR, EventReportR

The Comment-R and Event Report-R PDUs have existed in DIS since IEEE Std 1278.1a-1998 version of the standard. Despite this they were left out of RPR FOM 2.0. In order to better support translation between the DIS and RPR FOM standards, new interaction classes will be added to RPR FOM 3.0 to represent these PDUs. The RPR FOM already supports many of the DIS reliable simulation management PDUs, so the new CommentR and EventReportR PDUs follow the same design. They are subclasses of the Comment and EventReport interaction classes, respectively, that only change the transportation type from HLAbestEffort to HLAreliable.

3.3 Spatial – Dead Reckoning Other Parameters

DIS v5 (and v6) included the possibility to include "Other Parameters" as part of the Entity State PDU's Dead Reckoning Parameters, referring to Annex B. However, since no usage of this field was mentioned in Annex B, and therefore not standardized for interoperability, RPR FOM 1.0 and 2.0 did not contain an equivalent field for these 120 bits. In DIS v7, however, two record structures have been defined for the "Other Parameters", one for local Euler angles and one for world orientation quaternion parameters. Therefore, this capability has been added in RPR FOM 3.0 to each of the spatial fixed record structures as proposed in PCR-RPR-010.

3.4 HLA Time Management

It has been proposed to add an informative appendix in the RPR FOM 3 that specifies a design for using HLA Time Management together with the RPR FOM. The use of Time Management in a federation would be optional. HLA Time Management has several useful features for platform simulation. It enables federations to run as-fast-as-possible and facilitates faster/slower than real-time execution, while guaranteeing correct and repeatable results. The main mechanisms in HLA enabling this are:

- Reliable, time-stamped ordered delivery of messages and
- Coordinated time advance, where federates are guaranteed not to get messages in their past logical (scenario) time.

There is no corresponding mechanism in DIS, where data is exchanged using best effort transportation and delivered in receive order, except for some PDUs for coordinated time advance.

Most current RPR FOM federations and all DIS federations run in real-time, without HLA Time Management. Some HLA federations use HLA Time Management together with a modified RPR FOM for example for Monte Carlo simulation. An appendix about HLA Time Management for the RPR FOM standard would capture best-practices and enable a priori interoperability. It would mainly benefit RPR FOM federations where there are no DIS systems connected through a gateway. There is currently no decision if such an appendix is to be included in the RPR FOM 3 standard. The RPR FOM PDG encourages the user community to get involved for further discussions.

4. Conclusions

The development of RPR FOM version 3, that reflects DIS version 7, is well under way. A complete draft, ready for balloting, is expected to be available during 2020. The new version contains large and small updates, the most important ones being:

- Improved support for all entity appearances and capabilities in DIS
- Improved support for IFF, in particular Mode 5 and Mode S
- Added support for information operations
- Improved support for expendable fire and non-munition detonations
- Added support for directed energy fire

Draft versions of RPR FOM 3 are publicly available in the SISO Digital Library for early review and testing. An experimental version of IFF is also available. Current users of RPR FOM 2 are invited to join the PDG and share their experiences of RPR FOM 2 as well as thoughts on the next version.

RPR FOM 3 will be a valuable step forward, in particular for use in federations that mix HLA and DIS based systems, as a migration path from DIS to HLA and as a starting point for further extension.

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