RIM-Recasted, Value-Added Efficiency Interpolation in the HL7 Development Paradigm

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ABSTRACT

The Medical fraternity and the healthcare service sector have long acknowledged the need for smart, IT-based healthcare systems, operating globally. Semantic Interoperability is key, which is the regulated and meaningful exchange of valued healthcare information with homogenous understanding amongst participating healthcare service providers. Health Level Seven (HL7) is the predominant interoperability-related global healthcare standard in operation today. Introduced in 1987, the standard has evolved to its current version 3 and has been embraced by the National Health Services of the most developed economies in Europe, North and South America, and Australasia.

However, the standard is not without issues. Version v3 has been found to be difficult to implement and maintain. A principle component of the HL7 v3 development paradigm is the Reference Information Model (RIM) which defines the complete language and vocabulary schema used in the three v3 paradigms of Messages, Clinical Document Architecture, and Services, and indeed in all v3 implementations. This study determined that the RIM itself has many documented issues which ultimately affect implementation. Thus, true global semantic interoperability which is the germinal goal of the HL7 standard is still an illusion.

This study focuses on the belief that the achievement of true global interoperability is rooted at the labyrinths of specifications development and its associated foundational paradigms. This study focused on the Reference Information Model (RIM), the foundational semantic and lexical reference structure which affords vocabulary derivation to be used in all v3 system implementations. Infusing sequencing and temporal dimensions to the RIM structure and operation would promote and afford enhanced analytic, design, semantic interoperability, and two-way traceability, which in turn would suffuse to high-calibre specifications generation and true global International Interoperability in operation. In addition, multi-faceted interoperability interpolation in these core processes would promote and enhance numerous allied activities as well, from domain requirements cross-checking, audit, and consensus, to kindred system development verification and validation.

This research therefore analyzed many of the prevalent RIM issues indepth, and effected smart, delicate, and prudent recasting of this encyclopedic vocabulary and language reference structure, to derive optimal efficiencies in specifications development and implementation.

Keywords: *Act, Health Level 7, Object-Orientation, Reference Information Model, Relationship, Role, Semantic Interoperability.*

I.   INTRODUCTION

The *Reference Information Model* (RIM) constitutes the encyclopedia of all healthcare-related terminology utilized in *HL7-based, IT-driven* Healthcare Information Systems.

- Release 1 in 2003, ISO certification in 2005 – 2007.
- Release 2 released in 2010.

It is a *Reference Ontology* consisting of six core classes, ie., four *Generic* classes and two *Helper* classes namely *Entity, Role, Participation, Act, Role Relationship*, and *Act Relationship* [1].

The *RIM* expresses a diverse, expansive space of information content, within a unified framework. It affords consistent meaning to all usable healthcare-domain related terminology, beyond all local contexts. This comprehensive source of pertinent system vocabulary covers the spectrum of possible *HL7* specifications, promoting overarching *Semantic Interoperability* amongst all domains. Indeed, *RIM* is the source from which all

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HL7 v3 Information Models are derived. eg.. *Domain Information Models* (DIMs). It defines the healthcare grammar in any environment.
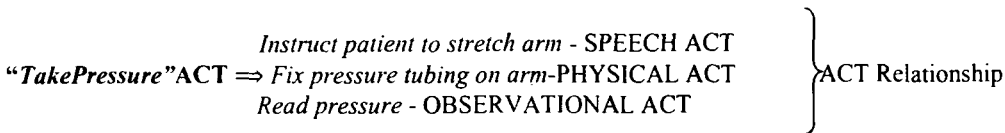
However. according to [2], the *RIM* has many logical and ontological flaws. placing severe obstacles to efficient, *RIM-compliant* system implementations. It is incoherent and inconsistent in places, leading to ambiguity. These flaws ripple to other kindred components or phases in the *HL7 v3* specifications development continuum. such as the paradigmic *Messages*. *Clinical Document Architecture* (CDA), and *Services*. These deficiencies permeate beyond the generated finalized specifications to actualized system implementation affecting our principle goal of *International Interoperability* (II) and *inclusive* network efficiency. Some of the documented *RIM-related* issues are presented in the next section.

II.   RIM ISSUES

1.   NULL and NULL flavoured attributes should be handled with more clarity [3].
NULL attribute – modelled by a missing attribute.
NULL Flavour – modelled using a placeholder.
Greater Semantic identifiability desired.

2.   *RIM Object-Orientation* (OO) violates sacred *OO* principles [4].

3. *RIM* does not provide distinction between an *Information Model* (IM) and a *Reference Ontology* (RO) [2][4]. This is not exactly true; indeed the *RIM* is clearly a *Domain Ontology* from which the specific domain environment vocabulary is derived, and the allied *Information Model* represents the data and information annotated to the *RIM-derived* information structure. The reference ontology defines the world in structure and bound. and the information model fills in its instantiated attribute values. However, a clearer demarcation between the two viewpoints is desirable.

Egs., i. *"person is a human being"* in *RO* versus person record object of demographic   information in *IM*.
        ii. *"checkPressure"* in *RO*   versus record pressure reading in *IM*, or
        iii. (existing real-world analysis) *versus* (class-objects based information system design)

The *RO* versus *IM* confusion can also be more complex. as shown below.

Instruct patient to stretch arm - SPEECH ACT

"TakePressure"ACT ⟹ *Fix pressure tubing on arm*-PHYSICAL ACT   ⟩ACT Relationship

Read pressure - OBSERVATIONAL ACT

Above signifies RIM as a REFERENCE ONTOLOGY (RO)

⬇

Record Pressure reading
RIM-driven Information Model (IM)

4.   ENTITY component not precisely defined in *RIM*. Information recorded about an ENTITY and the ENTITY itself not distinctly identified, eg., the *RIM* class *LivingSubject* contains *person, dog, plant, mammal*, etc., versus information about such entities. Both bundled together due to *Object-Orientation*, but clearly deficient in exuding *RIM-related* structural, space, and informational benefits during specification generation.

5. ACT component has similar issues. Information about an ACT (recorded) not clearly distinguished from the ACT itself (occurred).e.g.,

Instance of patientEncounter (subclass of ACT) versus ACTion *itself* (Physical, Speech or Observation ACT). Presently *RIM* switches back-and-forth between the two; thus ambiguity ripples through related processes.

6.   *Object-Orientation* of *RIM* objects cause consistency issues, eg., Consider *person* instantiations such as John Silva, Mary Perera. Justin Alwis, and so on. Currently, object record of John Silva holds his demographic and medical information. There could be many John Smiths; how can we converge on required John Smith object record? Use of unique record identifiers like *National Identification Card* (NIC) or *Social Security Number* are recommended in such situations for precision target binding. Obvious distinction between instantiated *person* (Reference Ontology) and the record of his/her demographic information (Information System) is desired, but the object record does not indicate this.

7.   Antiquatedness of current *HL7 v3* message-driven methodologies is another issue. In keeping with current trends, web-centric, service-based technology is preferred; the *RIM* should be recast accordingly [2].

8. *RIM* expanse is strictly scoped to cover healthcare-related vocabulary; ancillary terminology not directly affined to core healthcare processes are not included in *RIM*. To what extent can the *RIM* be applied for coherent interoperability in such situations.

9. Currently, the *RIM* structure consists of a flat representation of six core classes, ranging from *static classes* (ENTITY), *static relationships* (ROLE, ROLE RELATIONSHIPS), to *dynamic, action-related representations* (ACT, PARTICIPATION, ACT RELATIONSHIP). Check the relationships given below.

   ROLE ←→ ROLE RELATIONSHIP: dependency-type link, static as defined at creation
   (NOT dynamic or mutative), e.g., accountability, subordinate, peer, etc.

   ROLE ←→ PARTICIPATION ←→ ACT: dynamic, created on-the-fly.
   PARTICIPATION binds pending ACTs to ROLEs (ENTITIES-IN-ROLES).

   ACT ←→ ACT RELATIONSHIP: totally dynamic.

   Presently the *RIM* structure possesses components which vary from *statically-defined* and *statically-related*, to *fully-fledged dynamically defined and dynamically related*, in the same diagram and space. Thus, ambiguity abounds; part processing and part instantiations lead to incoherent, incongruous, and inconsistent *RIM-based* domain structures. The chance of in-process verification, validation, and traceability is low, and the finalized, static snapshot of the *RIM* is required for further processing. This terminal snapshot defines any domain-related *RIM* vocabulary with any resulting ambiguity and inconsistency rippling down to subsequent phases of the specifications development continuum. Clearly, a distinctive demarcation of the static and dynamic facets of the *RIM* is desired in order to eliminate ambiguity. Further, *sequencing* and *temporal* injection into inherent *RIM* processes would enable *score boarding* of valuable sub-process data which occur ahead of the terminal snapshot, affording much desired verification, validation and traceability.

10. *International Interoperability*, a significant enhancement and a principle goal of this research and study, needs to be infused into the *RIM Ontology*.

11. In conclusion, the above issues lend enough ambiguity to the original *RIM* description in [2] as a "*credible, clear, comprehensive, concise, consistent, universally applicable, and extremely stable*" referential structure.

III.   PROPOSED RIM *REFACTORING* SOLUTION

The *HL7-based RIM* (Reference Information Model) is *Reference Ontology* consisting of six core classes, ie., four *Generic* classes and two *Helper* classes. They are [1] :

Entity: Static, *library-data*. Physical things and beings, eg., person, organization, creatures, devices, animals, etc.

Role: Instantiations of ENTITY in healthcare environments, eg., patient, doctor, investigator, nurse, CEO(Entity-in-a-Role).Captures *competency, capability, certification* (3 C's).

Participation: context or scoping for an ACT, e.g., who, when, where it was done, e.g., practitioner, giver, recipient.

Act: an action meaning actual performance, e.g., procedure, observation.

Role Relationship: relationship between ROLES, e.g. dependency relationships, e.g., *client-of, reporting-to, assistant-to*.

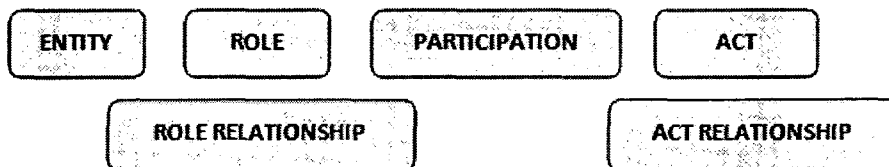**Act Relationship**: relationship between ACTs.

Figure 1 Present RIM Structure

The solution approach was two-phased. Firstly, the current *Reference Information Model* (RIM) was analysed and *delicately recrafted* in three aspects; injection of *International Interoperability* (II) the principle goal of our research, infusion of a temporal dimension to the hitherto *placid RIM* with a view to interpolating automation in the *RIM-related* processes such as *harmonization*, access, adoption, and finally the promotion of expansive *RIM*

applicability and usage as deemed necessary. in allied and ancillary processes of the core healthcare domain. The last option is afforded herein but optional during implementation given the requirement of *RIM conciseness*. Secondly, the present *XML-based* (Extended Markup Language) *RIM* representation was remodelled using the proposed *Unified Data Atom* (UDA) language accruing abounding intra and inter-process merits from the *RIM* harmonization, access, and adoption processes.

The recrafted *RIM Ontology* is given below in Figure 2, so termed since the figure gives some semblance of component constituents and inter-relationships.

Core: Current core healthcare-process related ENTITY items. eg.. *person, disease, organization. animals. mammals. etc.*

Ancillary: Valuable additions in keeping with principle goals, such as the following.

1. Newly infused terminology related to *International Interoperability* (II), eg., Continent, Country, Service Provider, Application. Database/Cloud, Patient, UID, OID, etc. Some overlap of terminology with CORE ENTITY exists.

2. Useful terminology extraneous to core healthcare processes, their scope, extent. and even adoption dependant on client and implementor, e.g., agent, medical representative, distributor, drug-substitute, etc. An open-source ANCILLARY component befits this requirement.

Entity: Now a blend of CORE and ANCILLARY, also incorporating infused temporal and sequencing aspects (as indicated by the *). Each new propogation via the ENTITY component with respect to RIM harmonization, access, or adoption is sequenced and time-stamped enabling sub-process verification, validation, and traceability between refinements. Indeed, this also affords seamless automation of these RIM processes ensuring greater governance and overall consistency of the RIM. Each successive time-stamping veritably captures a successor phase in the overall RIM processing workflow. This can even be transcribed onto a timeline of phased activity. Presently, there is no explicit time-relatedness in RIM. All current time-related attributes are deeply embedded in relevant class structures presenting little or no value; only the final snapshot of any domain-related RIM being used for further processing.
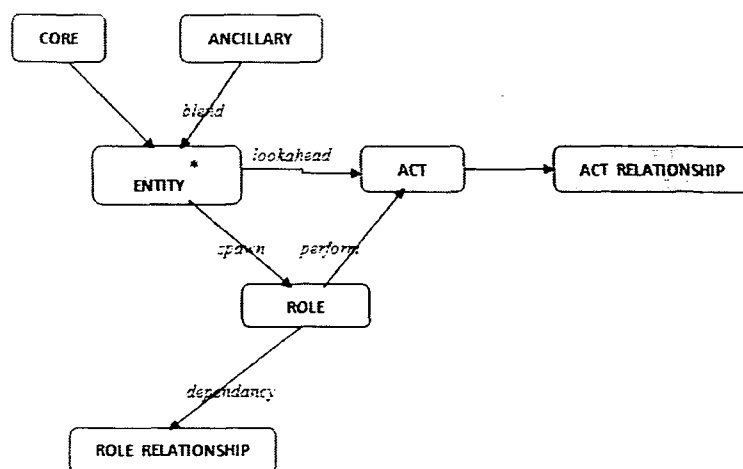

Figure 2 Proposed RIM Ontology

Act, Act Relationship, Role, Role Relationship are as present.

Participation component was found to be superfluous, often under-used and sparse (few entries) and thus was dropped for brevity's sake. This is significant in order to maintain RIM conciseness because of the two new components CORE and ANCILLARY (convergent on ENTITY) inserted into the arrangement.
Look ahead on required/pending ACT/s is needed before the ENTITY component can spawn the relevant ROLE subset (*Entities-in-Roles*) which would perform these ACT/s. Apparent disassociation between the ROLE and ACT components until ultimately bound by the PARTICIPATION component has been rectified. This present process is *semantically flawed*; it is not possible for the ENTITY component to spawn a pertinent ROLE subset without knowledge of the pending ACT/s. otherwise an un scoped, infinitely expansive ROLE *set* would result. Further, sequencing and temporal refinement of the current flat RIM structure has been proposed (as shown in the diagram below), in order to infuse future automation to native RIM processes; indeed validation and traceability of inherent sub processes is another derived bonus.

IV. SOLUTION METHODOLOGY

1. NULL/NULL flavour: handled through NULL value entry in attribute or NULL demarcator (2 distinct options - *Induced Semantics*). The NULL demarcator supplants the previous "*absence of attribute*" option infusing clearly defined semantics to the *RIM* structure.

2. *Object-Oriented* principles not relevant anymore (most logical/ontological flaws due to *OO* representation). The proposed *UDA* representation is clearly a departure, indeed an significant enhancement on present *OO* representation, and avoids and eliminates known, inherent demerits.
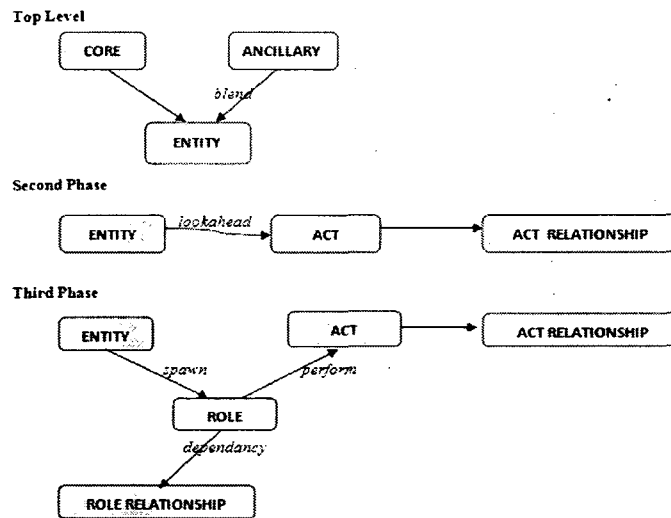

Figure 3 Temporal Phase-wise RIM Refinement

3. Proposed *UDA* vocabulary models *Ontologies* (the world) and *Information* (about the world) with equal adeptness. *RO* and *IM* handled individually and distinctly. No concept of record objects or classes which cause the ambiguity. Indeed, the proposed *UDA* representation models *RIM* objects more closely with greater refinement and precision.

4. ENTITY component of *RIM* now precisionly defined in *UDA* representation. ENTITY versus information recorded about an ENTITY now distinctly identified. eg., the *RIM* classes such as *LivingSubject* modelled by *Demarcators*, whilst information about such entities actualized by regular *DataAtoms*. Similar modelling strategy used for ROLES.

5. No confusion in representing ACTs. Report/record of performed ACT (DataAtomised) separately identified from ACT itself (Demarcated). Actual ACT is not a propositional comment anymore, Eg., Actual ACT (not its record) versus patientEncounter (instance of ACT), now stable, distinguishable. With proposed solution representation, *RIM* stays consistent and stable as defined, without switching back and forth (Issue No. 5.)

6. *Object-Orientation* of *RIM* objects causes consistency issues, eg., *person* instantiations such as John Silva, Mary Perera, Justin Alwis, and so on. Currently, object record of John Silva holds his demographic and medical information. The obvious distinction afforded between instantiated *person* (Reference Ontology) and record of his/her demographic information (Information System) by the proposed *UDA* language, in addition to the inherent uniqueness of its data storage eliminates all consistency issues. Further, unique record identifiers like *NIC* are used in dealing with *Syntactic Synonyms*, eg., identically-named *person* instantiations.

7. Indeed, *commensurate* with current technology, *web-centric*, *service-based* technology is recommended, and the *RIM* should be recast accordingly. The current *HL7 v3* message-driven methodology is *antiquated* and *decrepit* and it is advisable that it should be discontinued.

8. Presently, the RIM scope covers only *healthcare-related* vocabulary; however, it is proposed that ancillary terminology affined to allied processes and objects (outside the core healthcare periphery) be also available, if not directly incorporated in the *RIM*. An open-source approach can be used for this ANCILLARY component, and the client/implementor allowed discretion on its inclusion. This valued insertion to the *RIM ontology* would afford enhanced *international* interoperability and interphase cohesion in the HL7 specifications development continuum.

9. Presently the RIM structure possesses components which vary from statically defined and statically related, to fully-fledged dynamically defined and dynamically related, in the same diagram and space. Thus,

ambiguity abounds: part processing and instantiations lead to incoherent. incongruous. and inconsistent *RIM-based* domain structures. The proposed, recast *RIM ontology* annotates *dynamic, temporal. lookahead*, and *sequencing* features thereby accurately and closely modelling the actual RIM an its many evolutions.

This enhanced. fine-grained *RIM actualization* exudes the following merits:

- The chance of in-process verification, validation. and traceability, instead of the terminal, static snapshot of the RIM: presently the mix of *passive* and *active* domain features on the same RIM diagram results in ambiguity and inconsistency rippling to subsequent phases of the specifications development continuum. The new RIM ontology provides a distinctive demarcation of the static and dynamics related facets of the *RIM*, which eliminates ambiguity.

- The *lookahead* used on the ACT component enables a convergent, concise, and pertinent ROLE set to be spawned. Otherwise a divergent, inordinate ROLE set would result.

- *Temporal* and *sequencing* injection into inherent *RIM* processes would enable *scoreboarding* of valuable sub-process data which occur ahead of the terminal snapshot, affording much desired validation and traceability.

10. *Interoperability*, a significant enhancement and principle goal of this research and study, is infused into the RIM *ontology* via the ANCILLARY component.

11. The proposed *RIM-related* structural enhancements and representational vocabulary promotes, enhances, and re-articulates the original *RIM* description in [2] as *credible, clear, comprehensive, concise, consistent, universally applicable*, and *extremely stable*.

V. SOLUTION FORMALISM

The *UDA* vocabulary formalism is presented below. The *Necessary* condition for transformation T_R^{X-U} (meaning *RIM* transformation from *XML* to *UDA*) is stated as follows :

If U signifies the set of transliterated, target *DataAtoms* $\{u_1, u_2, u_3, u_4, \ldots\ldots\ldots, u_k\}$ as a result of the *Complete Transformation* T_R^{X-U} acting on the source *XML*-based *RIM* schema X where $\{d_1, d_2, d_3, \ldots\ldots, d_l\}$ $\in U$ represent *source RIM* elements, then

$$T_R^{X-U}: X \longrightarrow U \quad X \subseteq X \quad \text{and} \quad U \subseteq \overset{\circ}{U} \text{ where}$$
X - Problem domain *RIM-related XML* super schema, and
$\overset{\circ}{U}$ - Problem-related target *UDA* super schema

$U \subset U(u_i \longleftrightarrow u_j)$ where $\{i, j, = 1, 2, 3, , \ldots, k\}$
where U : set of spawned target DataAtoms
$\mathbf{U}$: union of bidirectionally inter-connected, target *DataAtom* pairings (all-over, complete connectivity, all pairings) as defined by the *UDA* structure definition. (i : index of u_i, $1 \leq i \leq k$, j : index of u_j, $1 \leq j \leq k$)

It was proved that the mapping $T_R^{X-U}: X \longrightarrow U$ denotes a *Complete Transformation*, meaning the result of the transformation T_R^{X-U} is a *necessary and sufficient* target *set* U in relation to the source set X. This would also satisfy the *necessary* condition for the $X \longrightarrow U$ mapping. By definition,

Injection of T_R^{X-U} : $\exists$ 1:1 mapping T_R^{X-U} of elements from domain X to codomain U
$\forall d_i \in X \land \forall u_j \in U, \quad i \in N \land j \in N \quad (d_i \text{ are } RIM \text{ elements})$

Surjection of T_R^{X-U} : $\forall u_j \in U$ there exists $d_i \in X$ such that $T_R^{X-U}(d_i) = u_j$
In other words, $T_R^{X-U}: X \longrightarrow U$ is an "*onto*" relationship.
Thus, every member u_j of target co-domain U *is mapped onto* by at exactly one $d_i \in X$. There are no unmapped elements in either X or U.

Hence, $T_R^{X-U}: X \longrightarrow U$ represents a ***Complete and Sound Transformation***.

The following were also proved in this study for the *XML* to *UDA* transformation or mapping (T_R^{X-U} in this case).

1. *Equivalence.*
2. *Completeness and Exhaustiveness.*

3. *Syntactic Completeness and Validity.*
4. *Semantic Validity.*
5. *Preservation of XML source precedence and nested ordering.*

VI. RESULTS

The table below illustrates the modality of the T_R^{X-U} transformation. Indeed this exercise is extrapolatable to all *RIM* structures.

Table 1: RIM_{XML} to *UDA* Transformation and Syntax Mapping [6]

RIM Element	XML Representation	Example	Target *UDA* (Syntax Mapping-Satisfied by T_R^{X-U})
Generic Class *Helper Class* *Sub-Class* *Attribute* *Inter-Class* *Multiplicity/ Cardinality* *Inter-Class Association Label*	*Class* *Class* *Sub-Class* *Attribute* *Inter-Class* *Multiplicity/ Cardinality* *Inter-Class Association Label*	*CORE, ANCILLARY, ENTITY, ACT, ROLE ACT RELATIONSHIP, ROLE RELATIONSHIP* *Patient, Country, UID* *Attribute* *Inter-Class* *Multiplicity/Cardinality* *Inter-Class Association Label*	*RIM Structure Demarcator (yes)* *RIM Structure Demarcator (yes)* *Dataset Demarcator* *LabelDataAtom, (yes) ValueDataAtom (yes)* *Property Demarcator (Value and Name)(yes)*
General Constraint - DataType *Vocabulary Constraint Relationship*	*General Constraint - DataType* *Vocabulary Constraint Relationship*	*General Constraint - DataType* *Vocabulary Constraint client-of,peer-of, practitioner, instance*	*Intrinsic DataAtom DataType (yes)* *Restriction Demarcator (yes)* *Property Demarcator (Value field indicates direction of relationship) (yes)*

VII. DISCUSSION

Thus, the proposed structural enhancements of the *RIM*, including the much-sought *International Interoperability* and the optional *ancillary* information related enhancements, *look ahead, temporal,* and *sequencing* injections at the head **ENTITY** component, all blended with the fine-grained, enhancing, more appropriate *UDA-modelled* internal representation, derive optimum benefits and facilitate high-calibre specifications development. Further, **ENTITY** and **ROLE** components were often found to have identical tags, e.g., *patient, surgeon* etc., although used in the *passive* (**ENTITY** value is static) and active (**ENTITY-IN-A-ROLE** is dynamic), thus creating unwarranted ambiguity. This has been resolved in the new, proposed *RIM Ontology*. In addition, the PARTICIPATION class was found to be relatively sparse, often consisting of repetitive entries. Since it was determined that no undesirable effects would accrue, this component was removed in the new proposed *RIM ontology*. The semantics of the **ROLE–ACT** relationship can still be maintained with the *UDA link* component, thus avoiding any loss of information and ensuring the desired structural brevity.

Hence, the revamped, recast *RIM ontology* affords and facilitates high-calibre specifications generation, promoting true, network-wide *International Interoperability* and *inclusive efficiency* (our principle goals) during system implementation and operation.

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