HLA Federation Design / Development and Federation Implementation Process Model

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ABSTRACT: *The need exists for guidance on all phases of HLA operations, including the Federation Design / Development and Implementation Processes currently manifest in the FEDEP Model v1.0. Derived initially from a priori expectations and the experiences of early HLA federation prototyping, the current model is suggestive; but it is neither sufficiently detailed nor sufficiently general to serve as guidance to the diverse family of expected practitioners. In particular, the scope of the FEDEP Model which spans the activities of federation design and development admit to significant and fruitful elaboration.*

This paper investigates the requirements for the next generation of FEDEP Model, indicates the sources of additional operational lessons-learned and prospective guidance, consider alternative forms of specification of such process models, and provides a draft recommendation for the next version of process model for HLA federation design and development. Particular attention is given to identifying clearly process-model component activities, necessary resources, completion criteria, and intermediate products. Issues associated with establishing standard practices are identified and explored.

1. Introduction

The need exists for guidance on all phases of HLA operations, including the federation development process, currently manifest in the HLA Federation Development and Execution Process Model (FEDEP Model) v1.0. This paper is the second of three companion papers intended to address the full scope of process activity identified in the HLA FEDEP Model v1.0, namely: 1) Objectives Development and Conceptual Design, 2) Federation Design / Development and Federation Implementation, and 3) Federation Execution, and Results and Feedback. The original HLA FEDEP Model with these three domains discriminated is depicted in the illustration of Figure 1-1 below.

This paper addresses the specification of a 'next generation' HLA FEDEP Model for federation design, development, and implementation. The paper explores the need and opportunity to improve the existing HLA federation development and execution process for federation life-cycle management in general; and it provides detailed recommendations for the specification of the Federation Design / Development and Federation Implementation phases in particular.

Three goals were adopted by the authors in preparing the paper. We intend to establish requirements for a process model which provides useful guidance while avoiding levying unnecessary constraints upon future federation developers. We try to leverage significant experience and lessons-learned in order to derive an articulate and self-consistent process-model specification. Finally, while respecting the necessity to tailor prospective HLA federations to the needs of their intended use, we try to address in a constructive way several issues which exist for standardization of HLA federation design and development, for which reasonable working strategies are available.

1.1 Outline of Exposition

In the exposition which follows, we first establish the *context* of the improvement of the existing HLA FEDEP Version 1.0, introducing in turn: 1) the need for improvement of the existing model, 2) opportunities for improving the model offered by prevailing circumstances, 3) strategies offered to facilitate the FEDEP Model improvement process, and 4) assumptions and hypotheses which have been elected in the preparation of this paper. Next, proposed *requirements* pertaining to the evolution of a second generation FEDEP Model are briefly delineated. Desired attributes of the prospective model are proffered

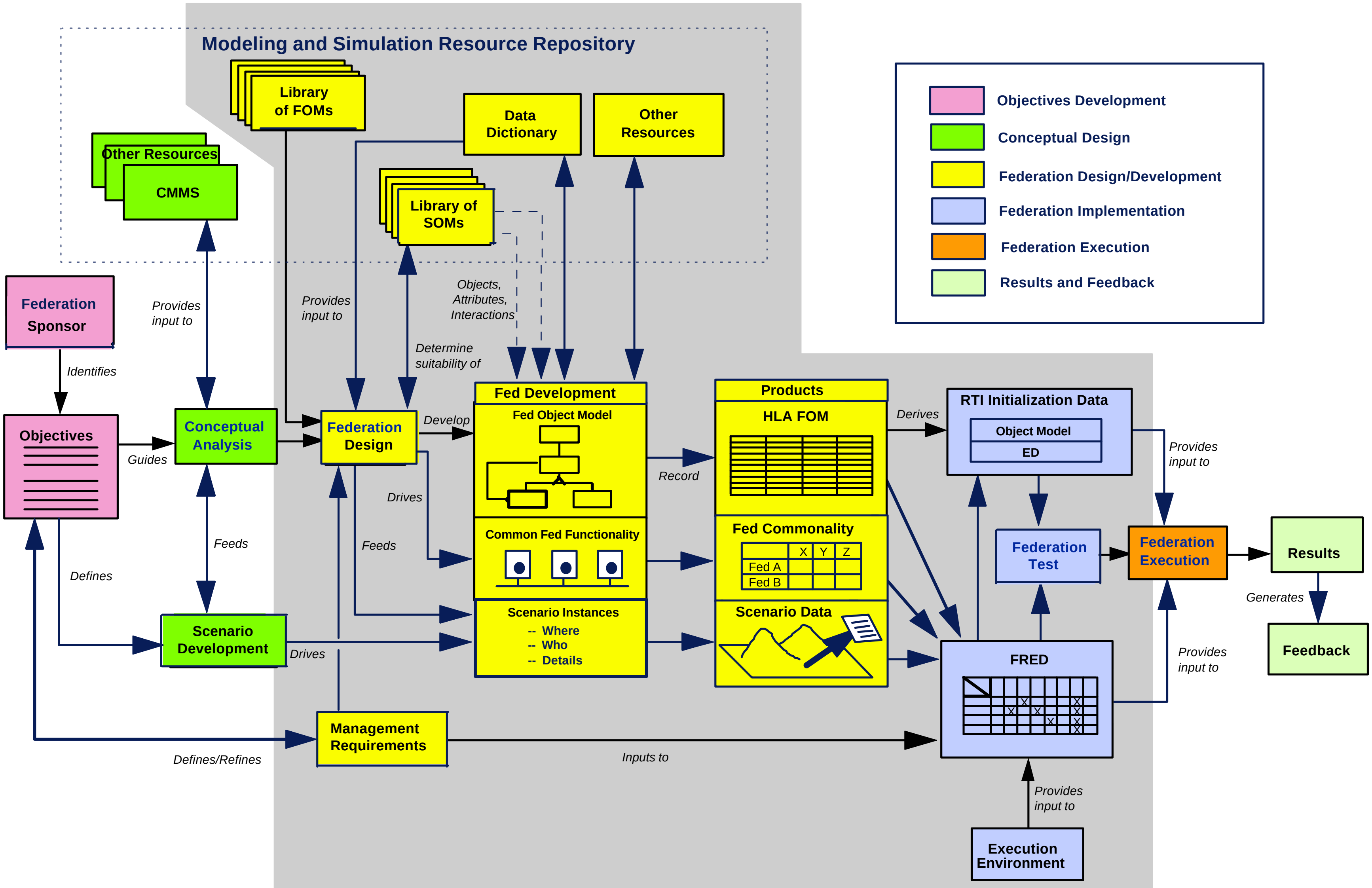

Figure 1-1. HLA FEDEP Model illustrating the general area of process activity which is the subject of this paper.

as evaluation / exit criteria which might be applied to potential reference models and associated recommended practice guidance standards. In this context, the concept of federation development as a systems engineering enterprise is raised, and the question of alternative model representation schema is addressed. Finally, a *candidate process model* is detailed covering the Federation Design / Development and Federation Implementation portion of the complete FEDEP Model scope, and conclusory comments and recommendations are provided.

1.2 Need

The need for reasonable guidance for the design and development of HLA-compliant federations stems from the relative novelty of the HLA and its associated processes and practices as well as the interest on all sides for efficient and effective operations. Particular dimensions of the need for exploring alternative practices and establishing suitably qualified normalizing guidance include: 1) stimulating and initializing the definition of robust and flexible standard practice, 2) improving shortfalls of the existing FEDEP Models and existing specifications of such recommended practice, and most importantly, 3) contributing to the economy and security of operations of the community of HLA users.

1.2.1 StimulatingDiscussion and Convergence on Standard Practices

The Simulation Interoperability Standards Organization (SISO) provides an administrative mechanism for the management of standards development. This paper is intended to stimulate debate within that forum on federation design and development practice. We hope to provide an explicit visualization of a fiducial process model, complete with its motivational rationalization, which can serve as the basis for the next iteration of community consensus on recommended, standard practice for HLA federation life-cycle management. This paper is intended to speak to the topic of *how* process model specifications may be established and captured in general, and *what* process model is desirable for the Federation Design / Development and Federation Implementation components of the overall process in particular.

1.2.2 Improvement of the Existing Process Specification

Derived initially from *a priori* expectations and the experiences of early HLA federation prototyping, the current Version 1.0 FEDEP Model is suggestive; but it admits to considerable improvement in serving as guidance to the diverse family of expected HLA practitioners. This comes as no surprise to those familiar with the evolution of expressions of standard practice for systems engineering and software development which has occurred over the last two decades. Such process modeling is essentially hard-to-do for a variety of reasons and the good news is that there exists a wealth of paradigms, tools, and lessons-learned already available from those antecedent ventures which should be useful in the current context.

Without being unnecessarily critical, a few observations may serve to suggest opportunities for improvement of the HLA FEDEP, and provide a basis for requirements and evaluation criteria for prospective standard practices as discussed briefly below. In *scope*, the existing FEDEP Model is generally adequate; and we assume that the set of papers of which this is one should suffice to span the domain of interest. On *detail*, there is room for improvement. The existing FEDEP Model is certainly not sufficiently detailed as to be operationally concrete, notwithstanding references to qualifying documentation and pertinent experience. Further, any substantive revision of the FEDEP toward the consensus on a Version 2.0 and concomitant publication of associated recommended practice standards should be formulated and populated in such a way that pushing toward procedural detail is gracefully accommodated. With respect to *completeness*, while Version 1.0 of the HLA FEDEP is noticeably in-explicit in completely identifying pertinent activities, actor-agents, information, and artifacts, such errors are easily redressed. As to *consistency*, several opportunities for improvement exist. A clearer discrimination among activities (what one does), actor-agents (who performs activities) and artifacts (the products of the execution of activities, e.g. data, report products, etc.), in subsequent FEDEP specifications would be useful. Precise distinction between information flow and control flow in FEDEP Model specification (as in software specifications) is illuminating both to the process designer and to its user. And, finally, consistency in the detail of abstraction (e.g. activities described at comparable levels of detail being visible together) aids modularization of specification in development and comprehension in use.

This paper is intended to address one portion of the FEDEP proposed process model in such a way as to be responsive to any such global opportunities for improvement with the existing FEDEP Model at large.

1.2.3 Economy of Operations

Finally, just as the HLA and the common technical framework themselves are intended to improve the economy and efficacy of simulation practice, so to is the improvement of federation development process specification. The end-user of the FEDEP is the HLA federation systems engineer and the wider federation enterprise team for any given HLA federation life-cycle operation. The need exists for a FEDEP Model and associated recommended practice standards which are explicit, understandable, comprehensive, tailorable, and useful to the end-user. The proof-of-the-pudding for any prospective FEDEP and associated standards is that they facilitate regularization of practice and result in more efficient and prompt convergence on HLA federation designs which are appropriate for their intended use(s).

1.3 Opportunity

Coincident with the need for a second-generation federation design and development process model is the opportunity to develop a model sufficient to serve as the basis of establishment of recommended practice standards and to support standard practice across the HLA community. The combination of an evocative (if imperfect) first-order model in the Version 1.0 FEDEP, reasonably diverse recent experience, and the mechanism of the SISO for establishing standard guidance are propitious circumstances. Together, they provide a sound basis for prompt evolution of HLA federation development and exercise process specification.

The existing V1.0 FEDEP has been publicly available for some time (having been reported in considerable detail at the 14th DIS Workshop), it has been extensively reviewed, and it is generally understood and appreciated by the community. Its availability for use as a common reference and baseline for subsequent improvement is a significant advantage.

Concrete, recent experience, available as an empirical basis of estimation of how the job is (or should be) done, is ever-more extensive. Some of the experience base which is drawn upon, albeit incompletely, for this paper includes not only the original series of Proto-federation exercises managed by the Architecture Management Group (AMG), but subsequent technology experiments (e.g. the DMSO C2 experiment), tool and component development efforts (e.g. Object Model Development Tool and Federation Management Control component), and developmental programs (e.g. JSIMS and its affiliated programs, Wargame 2000, Space and Missile Defense Battle Lab, etc.). Of particular concern, of course, is making any standards for recommended practice sufficiently comprehensive to embrace the universe of prospective user domains.

Finally, the establishment of the SISO as the administrative infrastructure for the management of a variety of standards-types development activities provides the ideal mechanism for capturing, maturing, codifying, and evolving comprehensive user-focused FEDEP Models and associated standards.

1.4 Strategy

In preparing this paper, and in proceeding with reconciliation, revision and integration of recommendations for the complete FEDEP Model, it seems that a few strategies need to be made explicit. Particular candidates which are introduced here have to do with: a) adopting a preferred point-of-view of an HLA federation, b) emphasizing field experience as the best ‘driver’ for process model regularization, and c) conducting the current cycle of FEDEP Model maturation with the intent to facilitate continued evolutionary clarification, completion, and convergence.

1.4.1 Federation-as-System

Having one point of view respecting HLA federations and the development thereof is important insofar as it influences the choice of process model components, tools, and exit criteria. If an HLA federation is conceived of as software, one set of practices, tools, etc. might be appropriate; but, if it is conceived of as a hardware ensemble, another may be preferred. Our positions that either of these views is of itself too limited, and consequently, the view adopted herein is that an HLA federation is a set of hardware, software, data, and humans (operators, participant role-players, etc.) which constitutes a system.[1] We further hold that much of the development and use of an HLA federation may be constructively treated as a problem in system life-cycle evolution management. This strategic elective in point-of-view will be seen to affect the identification of process activities and artifacts introduced below. In addition, we note that some of the process activities’ artifacts and agents indicated below are peculiar to HLA, while others are virtually independent of the HLA context, and some are pertinent to both the general systems engineering and to the details of HLA. In order to develop the HLA FEDEP Model in context of the federation-as-system point-of-view, we elect to assume the extra burden of addressing topics somewhat outside the range intimately related to HLA in order to provide the reader and participants in the subsequent standards development activity a more comprehensive and useful frame of reference.

1.4.2 Leverage Experience and Lessons-Learned

A second strategic position is to emphasize user's experience as the best 'driver' for process model regularization. Users and uses (whether actual, potential, or hypothetical use-cases) are the best determinant of requirements for a FEDEP process - any uncertainty or ambiguity in actual or prospective practice suggests requirements for process specification scope, detail, consistency, or clarity. The experience of users is the best predictor of necessary and sufficient component activities and their interrelations within a prospective process specification. The results of user's trials are the best evidence of the efficacy of proposed process model components. And, finally, the needs of users and their preferences for guidance are the best basis for evaluation- (and exit-) criteria for a truly useful FEDEP Model specification.

1.4.3 Graceful Extension

The third and last recommended strategic elective is to conduct the development of a FEDEP Model in such a way that its improvement or extension is likely to be evolutionary rather than revolutionary. In any event, one must 'do what it takes' to establish a practical Model, but the preference is to develop, capture, and mature the FEDEP Model and associated practice guidance standards systematically. Two practical implications follow. The first implication is that the form of capture and representation of the process model must be acceptable for long-term use by the whole community. Manifestations of this strategic decision are reflected in the discussion of process model specification form below. The second implication is that concurrently evolving the design-requirements / desiderata for the process model itself (e.g. what we want in a process model) along with its actual expression will keep up on-track for the long haul, controlling expectation, and continually reconciling subsequent versions of the FEDEP Model to the demands of its intended use. Manifestations of this strategic decision are reflected in the discussion of evaluation criteria below.

1.5 Assumptions

As in any analysis, synthesis, and exposition, the confession of (known) assumptions is preferred. A few such explicit assumptions and working hypotheses are indicated here.

1.5.1 Existing Model is the Baseline

The HLA FEDEP Model Version 1.0 is assumed to be a useful baseline for this analysis, although if push-come-to-shove, a too rigorous adherence to previous specifications is considered unnecessarily limiting. The existing model is generally available, familiar, and correct insofar as it is explicit. We assume that all the elements which are explicit in the existing model (activities, agents, artifacts, relationships) are significant, and should be retained in one form or another in successor versions. This is, in any event, the conservative position given that errors of omission are often more egregious and hard to correct than errors of commission, which are at least guaranteed visibility. We further assume that the form of representation of the existing Model (e.g. mixed object and activity block diagram with data / control flow relationships) is at least acceptable for general discussion. Notwithstanding this assumption, however, we will recommend a considerably more formal specification form for any Version 2.0 integrated model.

1.5.2 Input from Upstream Model Activity is Available

Since this paper addresses the second of three segments of the FEDEP Model, we are obliged to assume that any of the activities, artifacts, and relationships associated with the precursor segment (e.g. Objectives Development and Conceptual Design) are conceptually available as input to the Federation Design / Development and Federation Implementation segments. If they are found in fact not to be proposed in the logically antecedent sister paper their identification herein as 'input' will serve as requirements for the model reconciliation effort expected to follow delivery and discussion of all three papers.

1.5.3 Pool Data, Standards, Tools, and Operational Capabilities are Available

Aside from precursor model activities, all necessary input information from data pools, control, tools, and associated operational capabilities were assumed to be available. In this respect, we are trying to design the preferred FEDEP Model, relatively unconstrained by the temporary unavailability of physical or intellectual assets. This is somewhat optimistic, but the development of such enabling resources is proceeding, this assumption is consistent with the strategy of designing for the future, and in any event it has the precedent of a similar presupposition (e.g. eventual availability of the Modeling and Simulation Resource Repository) in the Version 1.0 Model. Any temporary accommodation for less-than-perfect resource availability is expected to be a reasonable excursion from the standard process.

1.5.4 Information First, Form Later

A final assumption is that if we capture in this paper and in subsequent discussion the requisite information *content* defining HLA FEDEP Model components (identification of process model components, structure, etc.), then the *form* of their exposition is negotiable, or better, variable. The form of expression is important for a number for reasons discussed below. This assumption is intended to defer determination of form(s) of expression of standard model representations and focus debate on the completeness, consistency, scope, detail and functional utility of the information content of the model in much the same way that the information content of the HLA OMT specification was established in anticipation of determination of alternative and interchangeable forms.

2. Process Points-of-View, Specification, and Evaluation

In the sections which follow, we discuss in somewhat more detail the subjects of conceptual point-of-view, specification schema alternatives, and evaluation criteria for evolving FEDEP Models and standards, which were introduced in the context of strategy and assumptions above. In each case, we intend to acknowledge the significant body of existing practice and to draw therefrom the elements which are most fit-for-use in the present context.

2.1 FEDEP Relation to Systems Engineering Process

Having elected to view HLA federations as systems composed of hardware, software, data, human controllers and, possibly, human role-players, and including by definition and by inference simulations (hardware-software-data aggregates), there are a few implications which affect federation design, development, and implementation.

In the first place, there exist several schools of systems engineering whose paradigms, tools, practices, and processes are suggestive for FEDEP Modeling. The table of Figure 2.1-1 indicates a few such perspectives along with their discriminating attributes. It seems evident that each perspective has value, and that any can support successful system life-cycle management, but that it is impractical for us to employ all such perspectives concurrently in FEDEP Model specification. Therefore, we will avoid the fact or appearance of adopting any particular school and its attendant biases and deficiencies, while using such alternative perspectives as sanity-checking opportunities for evaluation of the process as recommend.

Related to such approaches to systems engineering professional practice are a few general life-cycle schemas which may be elected more or less independently from the details of any given school. In particular, waterfall or linear process schemas are still popular, although modern trends favor spiral models which converge progressively through successive cycles of design and development from rough prototypes toward finished products or builds. Open-ended versions of spiral models which admit to an unspecified number of successive builds, for instance, are typical of software system development. As in the space of points-of-view, it is possible that any life-cycle schema will do, although it is clear that some are superior in one respect or another. It is equally clear, however, that all cannot be incorporated explicitly into a unified FEDEP Model. The tactical accommodation to this limitation is to proceed to detail one traverse of the FEDEP Model as though a federation could be so developed, and leave the degree and scope of recursion in system engineering to be determined by the process-tailoring peculiar to each particular program.

The identification (and subsequent specification) of the activities which comprise a given process model in any of the preceding paradigms is expected to provide a

PERSPECTIVE	ATTRIBUTES
DoD[2]	Military systems as unit-under-development, emphasis on documentation
Traditional / Systems[3]	Physical system as unit-under-development, hybrid components, multiple-views
Traditional / Programs[4]	Program as unit-under-development, CPM, Gantt process views
Traditional / Software[5]	Software as unit-under-development, deliberate process specification, multiple user defined views
Object-Oriented[6]	Object-Oriented perspective, standard abstract language, executable CASE support
Pattern-Based[7]	Compositional via component and process pattern re-use and instantiation

Figure 2.1-1. Several schools of systems engineering process management provide suggestions for the HLAFEDEP Model structure and content.

conceptual inventory of components for the desired FEDEP Model.[8]

These identifications of activities, artifacts, and actor-agents may not necessarily be either complete or unique (i.e. orthogonal) as they are introduced here, but they certainly provide an inventory for the laying down of components for a second-generation FEDEP Model as employed below. The intention in any case is to elect the use of generally useful baseline set of Model components, with the expectation that the eventual Version 2.0 FEDEP Model will be tailored in its application, as is usual, to the circumstantial needs and constraints of the particular development program.

2.2 Process Model Evaluation

Pursuant to the strategic elective to conduct the development of a FEDEP Model in such a way that its improvement or extension is likely to evolve gracefully, we have proposed to concurrently mature the design-requirements / desiderata for the process model with its actual expression. In order to initialize this tactic, some considerations are introduced here regarding design / evaluation criteria for the FEDEP Model itself. Evaluation of the evolving FEDEP Model in areas of process specification quality, utility, and universality are considered.

2.2.1 Process Model Quality

Any development activity requires evaluation of the prospective product quality and the development of the FEDEP Model is no exception. In this case, we have elected to nominate in advance evaluation criteria for the entire FEDEP Model definition enterprise and apply it to the portion of the Model which is treated within the scope of this paper. As with software and systems evaluation, typical evaluation categories include completeness, consistency, correctness, extensibility, robustness, and the like. Some general recommendations are provided in the paragraphs which follow.

On *completeness*, it is important that continuing efforts to detail and refine the FEDEP Model be particularly sensitive to deficiencies in completeness. Hard to detect and particularly irritating to prospective users of the process model, errors of omission translate to unplanned and unfunded effort, and consequent program risk. A complete process model must be comprehensive with respect to the scope of the set of activities of which the process is comprised. It must provide informative guidance in all significant areas associated with the designated activities, indicating at least the who, what, where, how, when, why of activity execution. Associated artifacts (standards, tools, information) need to be identified, characterized, and related to correlative activities sufficiently well that their use is evident to the prospective federation developer. Finally, a useful process model needs to provide enough detail of specification of the process that the federation developer can proceed to design for himself (or choose from a growing stock of recommended practices) those procedures by which the process is ultimately executed.

On *consistency*, reference points exist within the scope of a given analysis, across the entire FEDEP Model, and with external references defining the High Level Architecture and its practice. Self consistency includes the regularity of expression of the components of the process and their interrelationship. Similarity of detail and of form of representational specification are particularly desired. To this kind of consistency are added lack of redundancy or indeterminacy with respect other parts of the FEDEP Model. Finally, there are at least four domains outside the FEDEP itself with which consistency is desired, even if it is not entirely within the command of the FEDEP Model architect. First, the FEDEP must be consistent with HLA reference specifications and associated standards. Specifications and DIFs need to be invoked and respected. The FEDEP needs to be constrained as necessary to achieve this end. The FEDEP needs to be consistent with such collateral resources as the MSRR, and Federation Workbook artifacts. In this case, concurrent development and common oversight is desired. And, the FEDEP should be consistent with recommend practice as evinced in HLA training in general and in the standards in such fields a VV&A. The FEDEP and such recommended practice should be collaboratively derived so as to be mutually self-consistent.

As to *correctness*, the FEDEP Model should be such that: if a federation developer uses the process model in the spirit in which it is offered, employing it with aggressive good-sense, and tailoring and detailing the process as necessary and appropriate in accordance with the circumstances of the enterprise; then a well-behaved, HLA-compliant federation will result. This says nothing about cost-effectiveness or operational efficiency, but to the majority of the HLA community who are following rather than designing such guidance, the assurance of correctness of the FEDEP will be welcome.

2.2.2 Process Model Universality

A significant virtue of a FEDEP Model is its universality with respect to the variety of technical disciplines, application domains, and professional experience which characterize the SISO and HLA community. Acceptance, appreciation, employment, and progressive evolution of the FEDEP Model will improve monotonically in the degree that the model is universally comprehensible and consistent with the majority of community practice. Of particular significance is the form of specification of the process model and the degree to which it is intuitively clear, expressive, and familiar.

2.2.3 Process Model Utility

Finally, the *raison d etre* of a FEDEP Model is that it provide useful guidance to prospective developers and associated actor-agents in managing HLA federations over the span of their development life-cycle. The utility of such a model may be realized in its facilitating: a) preconception and appreciation of the enterprise, b) communication among the actor-agents involved, c) execution of the set of activities which constitute the process, and d) management of the enterprise at large for acceptable risk, cost, schedule, and product. While the prospective utility of the FEDEP Model is not a sufficient attribute, it is necessary - literally the bottom line for FEDEP Model evaluation.

2.3 Process Specification Representation Schema

Our final assumption was that capturing requisite information defining HLA FEDEP Model components and relationships (identification of process model components, structure, etc.) would suffice, pending establishing the form(s) of their exposition which are preferred by the community. There is, nevertheless, the need for *some* relatively catholic form of representation of the FEDEP Model which is systematic, generally familiar and acceptable, and which does not evoke particular schemas not generally acceptable in context of the preconceptions of the diverse SISO and HLA user communities.[9]

In the text which follows, we review briefly some of the existing domains of schema, practice, process, and tools for process specification; comment on the significant features of each; and discuss the opportunities for concurrent alternate and interchangeable canonical representations of the FEDEP Model. Finally, we introduce the generic schema which will be used subsequently to express the candidate model.

2.3.1 Alternative Operational Domains of Schema, Practice, Processes, and Tools

Several alternative professional domains exist wherein representational schemas for process specification are well established. A few such schemas are described briefly here to illustrate alternative candidates and to establish the context for a generic specification formulation for use for the FEDEP Model.

2.3.1.1 Program Process Specification

In the domain of traditional programs, the scope of process representation is the range of activities constituting the program. This domain is naturally process-oriented, and the common schemas are those in which activities are the essential entities. Typical forms are Gantt Charts (bar-chart schedules), Critical Path Method (CPM) networks, and associated data as supported by such tools as Microsoft Project and other more sophisticates members of the same family. Activity identity and control flow are particularly explicit. Information flow, products, contingency, and entity state are generally inexplicit. The graphical formulation of activity-flow and concomitant activity execution sequency adopted from this domain are reasonable candidates for re-use in FEDEP Model specification.

2.3.1.2 Physical Systems Process Specification

In the domain of traditional systems, the scope of process specification is typically the constitution and operational behaviors of the physical system under development. This domain is typically a hybrid of object-entities (particularly constituent components) and their functional behaviors. Common representational schemas include: a) those which are themselves hybrid and address the issues of requirements and system specification audit traceability and are manifest in such schemas as propounded by Hatley-Pirbhai[10]; b) those which are essentially process-oriented and manifest in such forms as IDEF0[11], and c) those which are essentially object-oriented and manifest in such evolving representational schemas as the Unified Modeling Language (UML)[12]. Formalisms for representation are reasonably well established which cover both the process- and object-oriented ends of the spectrum. Process-descriptive forms may be useful in adding rigor to the FEDEP Model once its contents are accepted by consensus within the SISO / HLA community.

2.3.1.3 Software Systems Process Specification

In the domain of software systems, the scope of process specification includes both the developmental activity itself and the actions and operations of the software components and systems. At the administrative level, Humphrey[13] and others emphasize the significance of an aggressively explicit process model, leaving both the substance of the practice and the form of its specification to the discretion of the practitioner. At the level of the software system itself, both entities and their behaviors are important. Representation evolution has progressed form predominantly process-oriented perspectives with data-flow views predominating as in DeMarco;[14] through the current spate of object-oriented schemas,[15] views[16] and tools;[17] toward re-usable software patterns.[18] Data-flow views, use-cases, and the textual description of patterns are suggestive for next-generation FEDEP Model specification

2.3.2 Activity Specification Analysis

Observation of schemas from several domains reveals that many items of information occur commonly as attributes of process activities. A collation and reconciliation of these activity-information-attributes provide a common list which is not dissimilar in its form from the enumerated characteristic of services in the HLA Interface Specification or the enumeration of pattern attributes. Elements in this activity-characterization list can be generalized to remove the accidental vestiges of their particular lineage, and specialized somewhat (particularly in the enumeration of types of classification of activities) to the HLA federation development environment. Finally, the resulting activity-information-elements are organized into a template which is self consist, relatively complete, reasonably universal across domains, and plausibly effective in expressing what prospective Model users may need to know by way of guidance in executing process constituent activities. The results of this analysis serve as a basis or kernel of the recommended specification FEDEP Model detailed below.

2.3.3 Recommended Specification Formulation

As the FEDEP is first and foremost a process model, the identification and description of *activities* which constitute the overall process is recommended as the basis for a FEDEP representation schema.

2.3.3.1 Activity - Description Template

The scope of specification-content recommended for the FEDEP Model is indicated in Figure 2.3.3.1-1, along with the information content of each part of the Model and the suggested form of specification of each component individually.

2.3.3.2 Activity Taxonomy and Enumeration

Commensurate with the Activity characteristics template above, the table of the Figure 2.3.3.2-1 which follows

ACTIVITY CHARACTERISTIC	INFORMATION	SPECIFICATION
Activity identity		
• Activity Name and aliases	Activity denotation	Character string
Activity description		
• Activity Rationale / Need / Motivation	Purpose of activity execution	Text description
• Activity Classification	'Kind' of activity	Enumerated hierarchy
Activity method		
• Activity Procedure	How the activity may be performed	Text or schematic procedure or algorithm
Activity Uses		
• Previous uses	Familiar uses which illustrate the activity	Text description or pointer to available documentation
• Prospective Applications	Future ways the activity may be applied	Text description or pointer to available documentation
Inter activity relationships		
• Activity sequency and control-flow	Contingency or precedence constraints on activity execution	Text description, graphic, or CASE specification
• Activity information flow	Message passing among activities	Text, graphic, argument list or CASE tool
Associated Entities		
• Tools	Applications or components which facilitate activity execution	Character String denotator text description identified of tool or component
• Actor-agents	People, roles, or institutions which perform activities	Character String denotator, Text description, or pointer
• Information pools	Pertinent sources and sinks of information for the activity	Character String denotator, Text Data Item Description (DID) , or pointer
• Product-objects / artifacts	Persistent compilations of values resulting from the execution of the activity	Character String denotator, Text Data Item Description (DID), or pointer
Problem Management		
• Problem Identification	Likely issues or difficulties associated with activity execution	Text description
• Problem Amelioration	Approaches to mitigating the effects of problems encountered	Text description
Completion		
• Exit Criteria	How to determine that an activity has been successfully completed	Text description

Figure 2.3.3.1-1. This specification is recommended for the FEDEP Model activity identification with the suggested information content and form of specification

ACTIVITY CLASS	ACTIVITY
ConceptualDesign	
	Develop Use-Case Scenarios
	Federation System Composition ID
	FOM Draft
Detailed Design	Draft Federation Execution Plans Notebook
	Federation System Architecture Specification
	Develop Design-to Scenarios
	FOM Negotiation and Reconciliation
	Federation Federate Component Design
Development	Federation Component Procurement
	Federation Component Development
	Federation Modification
	Federate Compliance Testing
	Federate Design-to Requirement Audit (FCA)
Integration	- Asset Accumulation and Installation
	Federation Interconnection Debugging
	Federation Integration Debugging
Testing	Federation Compliance Testing
	Federation Functional Testing

Figure 2.3.3.2-1. The hierarchical organization and denotation of executable activities for the FEDEP is finite but extensible.

indicates the classes of activities which are considered to be necessary and sufficient for the specification of the Federation Design / Development and Federation Implementation portions of the FEDEP process. Extension of the specification herein to encompass the entire scope of the FEDEP requires the extension of the table accordingly.

2.3.3.3 Associated EntityTaxonomy and Enumeration

A wide variety of candidate associated entities is available for election in federation development at the discretion of the program manager. While the particular candidate items, classified by type, which appear in the table of Figure 2.3.3.3-1 are suggestive, they are assumed to be incomplete, even for the specification of the Federation Design / Development and Federation Implementation portions of the FEDEP. Naturally, extension of the specification herein to encompass the entire scope of the FEDEP requires the extension of the table accordingly.

2.3.3.4 Process Model Specification Capstone View

A global context for capstone representation of FEDEP constituent activities is suggested in Figure 2.3.3.4-1. FEDEP activities are related primarily via. activity-flow, with agents indicated in association with each activity. An activity's respective input information and output products related by information flow, extends the overall structure. Auxiliary specification of individual activities and related entities completes the Model.

2.3.4 Canonical Representations

Respecting future, more formal FEDEP Model specifications, we expect that the opportunity exists for concurrent, equivalent, alternative-and-interchangeable, canonical representations of FEDEP Model activities and their characteristics and relationships.

Further, we imagine that with requisite care in specifying the information content of the FEDEP Model, information-preserving transform operators may be defined so that users may elect their representation of choice with no lack of generality or communicability with others interested in the same federation system.

ENTITY-TYPES	PARTICULAR ENTITIES
Enterprise Support Tools	
	Project / Program Management support tools
	CASE system / software design tool
	Configuration Management support tool
	Issues / Trouble Report tracking mechanism
	T&E / Certification support tools
	VV&A support tool
Related Agents	
	Federation Sponsor / Customer
	Executing Agent
	Development Agent
	Program Manager
	Federate Custodian
	System Integration Agent
	HLA Compliance Certification Agent
	Federation O&M Agent
	Federation User
	MSRR Custodian
Report / Data Products	
	Program Plan
	Federation Execution Planner's Notebook
	Design Specification
	Federation Object Model FOM)
	Simulation Object model(s) (SOM)
	Integration plan
	RTI Initialization data
	FRED
	Test plan/ data collection plan
	Test Report
Information Pool Assets	
	Issues
	Requirements specification
	Data Dictionary
	CMMS
	Library of SOMs
	Library of FOMs
	Scenarios
	Scenario data
	Execution environment
	Simulation data

Figure 2.3.3.3-1. A variety of entities of a few general types are associated with those activities which comprise the HLA FEDEP Design / Development and Implementation process model.

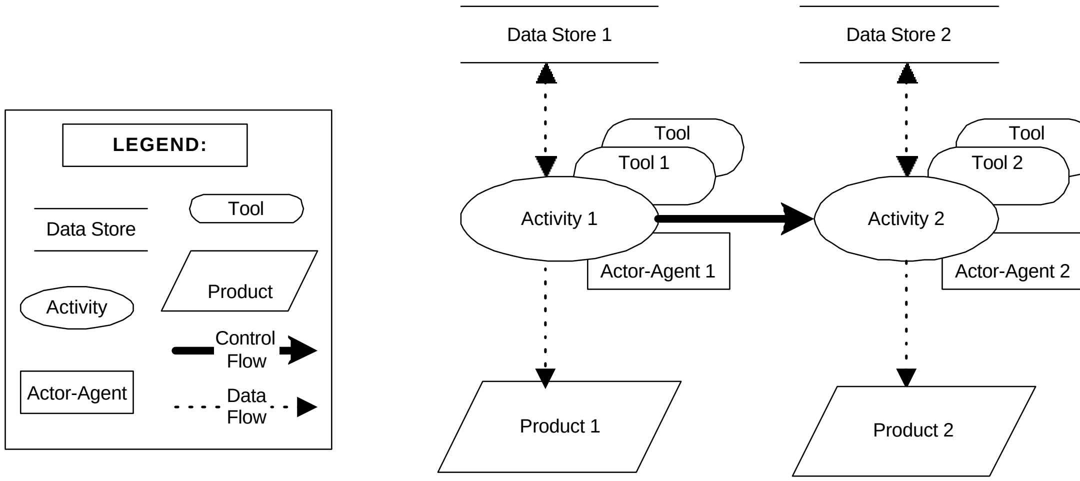

Figure 2.3.3.4-1. The diagrammatic template provides a suggested baseline graphical representation for indication of activities and their relationships with other entities in the FEDEP Model.

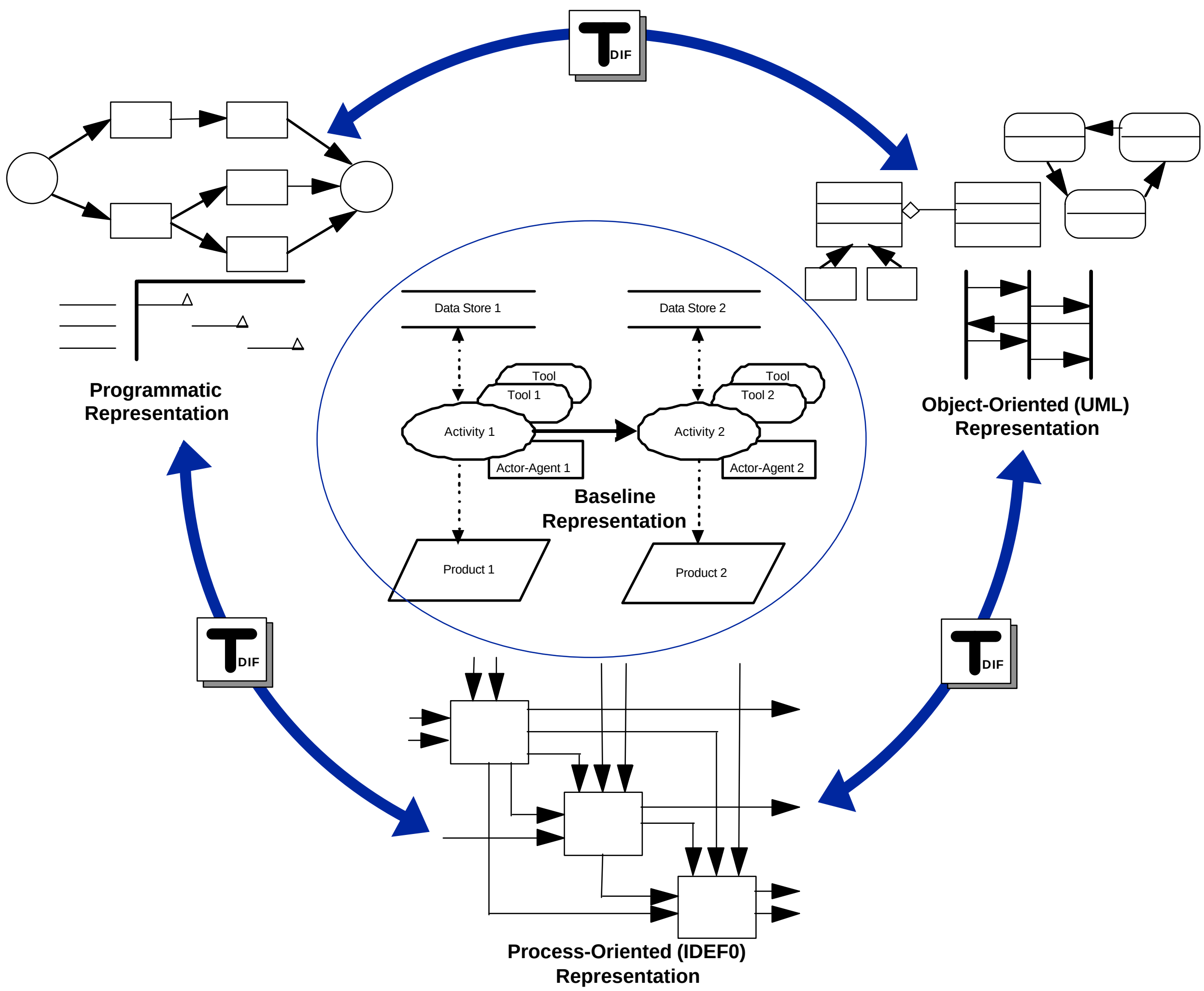

Figure 2.3.4-1. Alternative canonical views with information-preserving transform operations are possible, facilitating use of CASE-supported native representations and guaranteed information sharing

3. PROCESS MODEL

The process model for HLA federation design / development and implementation provided herein is a draft version submitted to the SISO in order to seed the process of establishing standards for recommended practice. It is assumed that this portion of the total FEDEP Model will need to be reconciled with similar portions provided for the remaining domains of FEDEP scope, and that the result will be suggestive of draft recommended practice standards.

The partial model which is discussed here is considered to be responsive to the needs for a more detailed and systematic successor to the Version 1.0 FEDEP Model. It is intended to be consistent with the strategies and assumptions, and to conform favorably to the requirements and associated evaluation criteria introduced above. Nevertheless, it is expected that there is room for considerable improvement in both the structure and content of the model specification which is begun in the text which follows, and that the subsequent SISO-administered standards process will provide ample opportunity for just such evolution in due course.

3.1 Federation Design / Development and Federation Implementation Model Overview

An overview of the recommended Federation Design / Development and Federation Implementation process model is provided in the activity flow diagram of Figure 3.1-1. This figure is composed in accordance with the scope of activities indicated in the table of Figure 2.3.3.2. - 1 and the baseline specification format defined in Figure 2.3.3.4 - 1 above. In this figure, particular activities in each of five general activity classes are shown in control-flow (or activity-flow) relation to one another, where it is assumed that all preceding activities need to be completed (at least in part) before a succeeding activity can be initiated.

Activities which are largely administrative in nature are discriminated from those which are principally technical in nature. Data pools are indicated from which information is provided as input to activities. Products are indicated which are seen as the result of the execution of activities and which are related to those activities by directed information-flows. Actor-agents and tools associated with the execution of each activity, although indicated in the legend, are not populated onto the drawing in the interest of legibility.

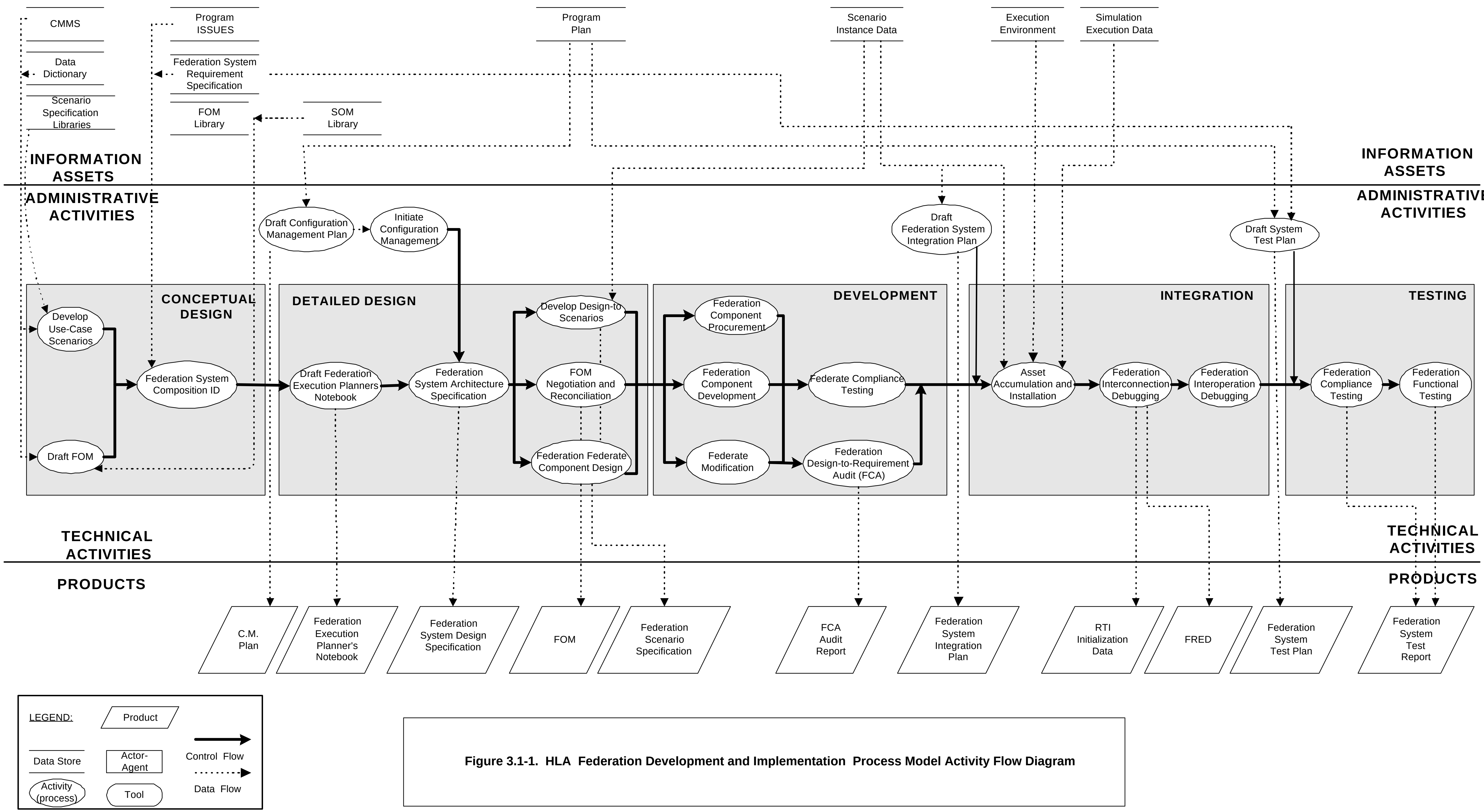

Figure 3.1-1. HLA Federation Development and Implementation Process Model Activity Flow Diagram

3.2 Federation Design Activity Descriptions

In the following sections, several activities with in the recommended FEDEP Model are discussed. A complete specification in the same form and at the same level of detail will be provided at the SISO meeting for review and discussion. For each selected activity, we comment on the particular significance or interest in the activity selected. We provide an instantiated activity attribute specification template as specified in Figure 2.3.3.1 - 1., indicating the nature of the activity and its relation to other activities and to associated entities (information, products, actor agents, and tools). Finally we comment in some cases upon special consideration associated either with a) executing the activity or b) establishing guidance and recommended standard practice for activity execution.

3.2.1 CONCEPTUAL DESIGN / Draft FOM

Development of the FOM is crucial to the HLA federation life-cycle process. The FOM is effectively the contract by which the federates interoperate, and the efficiency, effectiveness, and quality of its design influence several successive activities.
Drafting the FOM is a relatively easy activity with which to start HLA federation development from the purely mechanical point of view - tools and information are generally available, and the activity in itself is not particularly labor intensive. It is, however, and activity which is intimately related with the culturalization of the federation development team which is necessary for federation development operations. Developing procedural specifications for FOM development is facilitated by available materials and experience.

ACTIVITY CHARACTERISTIC	INFORMATION
Activity identity	
• Activity Name and aliases	[Develop] Federation Object Model Draft
Activity description	
• Activity Rationale / Need / Motivation	Establish conceptual object model specification for subsequent federation development, consistent with HLA OMT specification
• Activity Classification	Conceptual Design
Activity method	
• Activity Procedure	See HLA OMT, HLA Integrated Training materials, SISO technical papers, lessons-learned reports from preceding enterprises, and associated documentation
Activity Uses	
• Previous uses	Refer to any preceding enterprise (protofederations, C2 Experiment, JSIMS, etc.)
• Prospective Applications	Every prospective HLA federation
Inter-activity relationships	
• Activity sequency and control-flow	Typically conducted concurrently with generation of prospective federation use-case scenarios (with emphasis on simulation representation) as initial activities in conceptual design. Precedes Federation System Composition ID.
• Activity information flow	Input includes information from CMMS, Data Dictionary and FOM /SOM Libraries
Associated Entities	
• Tools	OO CASE tools, Object Model Development Tool (OMDT)
• Actor-agents	Federate custodians, System Integration Agent participate as Federation development team.
• Information pools	CMMS, Data Dictionary and FOM /SOM Libraries
• Product-object-artifacts	Draft Federation Object Model (FOM)
Problem Management	
• Problem Identification	Efficient compilation from available information sources, Establishment of consistent view of the federation representation schema, Reconciling disparate federate preferences consistent with federation design objectives
• Problem Amelioration	Informed use of tested tools, Effective team-building, identifying federate constraints and opportunities for FOM reconciliation
Completion	
• Exit Criteria	HLA compliant FOM, Consistency with Use-Case Scenarios

3.2.2 DETAILED DESIGN / Draft Federation System Architecture Specification

Consistent with the point-of-view adopted earlier that the prospective HLA federation is a system, some form of system architecture specification is necessary. Capturing the overall system design and establishing context for the artifacts which are particularly related to the HLA, and specifying federation system architecture admits to considerable invention and leveraging of existing systems engineering practice.

Note that much of this activity is not HLA specific, but depends for its particular procedures instead on the style of systems engineering and associated procedures and support tools which the federation development team elects. HLA specific procedures and artifacts (e.g. FOM development, and the HLA OMT) should be found to fit gracefully into almost any such systems engineering paradigm. Execution of the activity should be no more complex nor difficult than any comparable activity in a non-HLA

ACTIVITY CHARACTERISTIC	INFORMATION
Activity identity	
• Activity Name and aliases	Federation System Architecture Specification
Activity description	
• Activity Rationale / Need / Motivation	Establish a persistent, visible concrete specification of the system which will constitute the prospective federation to support life-cycle systems engineering
• Activity Classification	Detailed Design
Activity method	
• Activity Procedure	A wide variety of mainstream systems engineering practice is available for adoption. See Figure 2.1-1
Activity Uses	
• Previous uses	Engineering, JTF Protofederations
• Prospective Applications	TBD
Inter activity relationships	
• Activity sequency and control-flow	Succeeds drafting the Federation Execution Plans Notebook and the initiation of Configuration Management. Precedes and serves as the basis of capture of the detailed design activities of developing Design-to-Scenarios, negotiating and reconciling the FOM and conducting federate component designs.
• Activity information flow	No specific input from information pools, receiving only information-product results of preceding activities
Associated Entities	
• Tools	Depends on Procedure, see above
• Actor-agents	Activity executed by System Integration agent
• Information pools	None
• Product-object-artifacts	Output is the Federation System Design Specification document, the basis of system description over the life-cycle.
Problem Management	
• Problem Identification	Selection of a systems engineering approach and system specification schema which is consistent with the prospective life of the federation and the practices of the participating federate custodians is necessary. Specification forms which are sufficient to capture the system and track its evolution without generating too burdensome overhead are necessary.
• Problem Amelioration	Prudent choices of system specification schema by the System Integration Agent, and cooperation by the federation development team to implement a ‘sufficient’ system architecture specification.
Completion	
• Exit Criteria	Consensus of the federation development team. Sufficiency and consistency with the Configuration Management Plan Process.

circumstance, and, in fact, should be facilitated by the existence of well specified HLA-specific elements. Detailed specification of this activity, contingent as it is on paradigm, will be difficult to establish in detailed standard practices, and some level of abstraction may need to be accepted instead.

3.2.3 DEVELOPMENT / Federate Modification

Federation development often will require the modification of member federates. Whereas the High Level Architecture will facilitate simulation interconnectivity and interoperability, the circumstance of completely alternative and interchangeable (A&I) plug-and-play of simulations is an unsupported expectation. Given that some federate modification should be expected, given that many characteristics of such modification (e.g. need for modification, types of modification, cost-estimating relationships, dependency on degree of previous investment in interoperability, etc.) are contingent on the circumstantial nature of the particular federation, and given that the cost of such activities are of considerable concern to federate custodians and

ACTIVITY CHARACTERISTIC	INFORMATION
Activity identity	
• Activity Name and aliases	Federate Modification
Activity description	
• Activity Rationale / Need / Motivation	Modify, extend, or tailor federate for its role in prospective federation
• Activity Classification	Development
Activity method	
• Activity Procedure	Several kinds of federate modification may be considered in response to circumstantial needs. Prospective needs / modifications include: RTI interface implementation, syntactic conformance to FOM/MOM conventions, semantic accommodation to other federates, support for federation control operations (save and restore, etc.), support for federation operations (experiment preparation and analysis), etc.
Activity Uses	
• Previous uses	Each of the protofederation exercises provide multiple examples. AMG briefings address the topic, and the DMSO C2 Experiment provides further examples.
• Prospective Applications	TBD
Inter activity relationships	
• Activity sequency and control-flow	Federate modification logically follows completion of FOM Negotiation and Reconciliation and Federate Design activities. It precedes Federate compliance Testing and Federation Design-to-Requirements Audit (FCA)
• Activity information flow	No particular information input from other activities exists aside from information naturally available from execution of precursor activities.
Associated Entities	
• Tools	CASE system and software development and software configuration management support tools
• Actor-agents	Federate custodians
• Information pools	None
• Product-object-artifacts	Executable components available for unit testing and subsequent integration are the typical products.
Problem Management	
• Problem Identification	Uncertainty in scope of modifications and implications for cost to the Federate Custodians and schedule to the Federation Integration Agent needs to be addressed.
• Problem Amelioration	Clear and current Federation Development program plans and design process and regular systems engineering practice within the team.
Completion	
• Exit Criteria	Federate is determined ready for testing...apparently meets design criteria, executes against appropriate test drivers, etc.

ACTIVITY CHARACTERISTIC	INFORMATION
Activity identity	
• Activity Name and aliases	Federation Interoperation Debugging
Activity description	
• Activity Rationale / Need / Motivation	This activity explicitly addresses the functional interoperability which is the primary attribute of HLA federation systems
• Activity Classification	Integration
Activity method	
• Activity Procedure	Candidate procedures include: focused interaction audits, representation scenario results review, alternative-exhaustion trials, etc.
Activity Uses	
• Previous uses	Protofederations, C2 Experiment, etc.
• Prospective Applications	TBD
Inter activity relationships	
• Activity sequency and control-flow	Interoperation Debugging naturally follows Interconnectivity Debugging and proceeds formal testing activities.
• Activity information flow	None
Associated Entities	
• Tools	Test components and data collection tools, scenario generation assets
• Actor-agents	Federate Custodians in cooperation with Federation System Integration Agent
• Information pools	N/A
• Product-object-artifacts	N/A
Problem Management	
• Problem Identification	A significant difficulty is achieving a sufficiently complete state of interoperability, since any residual incompleteness is assumed to produce semantic errors in federation simulation-domain results.
• Problem Amelioration	Explicit deriving Federation Interoperation Debugging activity exercises from the CMMS, Program Issues, and Federation System Requirements Specification will ensure the best investment of effort.
Completion	
• Exit Criteria	Interoperability functionality trials completed as planned.

federation developers and custodians alike, standards specification for this activity needs particular attention.

Maturation of design and development practice, the consistent implementation of HLA compliance in new-build federates, and the specification of dependable cost-estimating-relationships (CERs) should improve the environment for Federate Development.

3.2.4 INTEGRATION / Federation Interoperation Debugging

HLA standards and practices are intended to facilitate true simulation interoperation. Interoperation presumes interconnection and syntactic consistency, but requires in addition semantic consistency between the interconnected member federates. Whereas HLA compliance cannot of itself guarantee interoperation, an explicit Federation Interoperation Debugging activity within the FEDEP should support achieving interoperational functionality.

3.2.5 TESTING / Federation Functional Testing

Given the demonstrated compliance of the federation to HLA standards, the final and decisive evaluation activity in the FEDEP is Federation Functional Testing. Guided by the Federation System Test Plan, which incorporates information from the system mission, CMMS, FOM / SOMs, and technical requirements, the Federation Functional Testing activity guarantees that the federation under development is demonstrably fit for its intended use.

ACTIVITY CHARACTERISTIC	INFORMATION
Activity identity	
• Activity Name and aliases	Federation Functional Testing
Activity description	
• Activity Rationale / Need / Motivation	Demonstrate that the subject federation is fit for its intended use to within the scope of the functional testing plan.
• Activity Classification	Testing
Activity method	
• Activity Procedure	A variety of functional exercises of the federation system which emulate the prospective uses and demonstrate the achievement of functional requirements.
Activity Uses	
• Previous uses	Engineering and JTF protofederations, C2 Experiment
• Prospective Applications	TBD
Inter activity relationships	
• Activity sequency and control-flow	Presumes Federation Compliance Testing successfully completed. No successor
• Activity information flow	Implicit information via System Test Plan
Associated Entities	
• Tools	Scenario generation, data collection tools
• Actor-agents	System Integration-Test Agent
• Information pools	N/A
• Product-object-artifacts	Federation System test Report activity
Problem Management	
• Problem Identification	Robust system functional testing requires an effective test plan. Coordination of Functional Testing with other components of a comprehensive VV&A Program
• Problem Amelioration	Test Plan which propagates system requirements into evocative test exercises. Deliberate coordination of Test and Evaluation with M&S VV&A.
Completion	
• Exit Criteria	Tests criteria met or exceptions established.

As with other activities which are adopted from general systems engineering practice, the guidance which can be provided in contest of SISO practice standards is limited and some generalization of recommended process details may be necessary.

4. CONCLUSION

By way of conclusion, summary observations derived from the preceding discussion and recommendations for pursuing HLA FEDEP Model specification in the context of the SISO administrative process are compiled in the sections which follow.

4.1 SummaryObservations

- There is a clear *need* for improved guidance and recommended-practice standards for the federation development process.
- The *opportunity* for prompt evolution of the HLA FEDEP Model and associated standards is indicated by: a) the existing Version 1.0 FEDEP Model, 2) reasonably diverse recent experience, 3) the ready availability of tools and process

components, and 4) the existing administrative mechanisms of the SISO.

4.2 Recommendations

- Establish design / evaluation *criteria* for a prospective FEDEP Model and recommended practice standards.
- Adopt *strategies* for FEDEP-standardization including: a) adopting a federation-as-systems point-of-view of HLA federations, b) emphasizing field experience as the best 'driver' for process model regularization, and c) conducting the current cycle of FEDEP Model maturation with the intent to facilitate continued evolutionary clarification, completion, and convergence
- Emphasize the identification and description of *activities* which constitute the overall process as the basis for a FEDEP representation schema.
- Capture in SISO deliberations the requisite information *content* of FEDEP Model and then establish the canonical *form* of exposition the exposition of that Model.
- dopt *formal generic standards forms* introduced herein including: Activity-Description Template, Activity Taxonomy and Enumeration Table, Associated-Entity and Enumeration Table, comprehensive, augmented activity-flow relationship diagrams.
- Identify *alternative canonical representations* and transform operations (DIFs) for use at the convenience of the community.
  - Identify *requirements for tools and components* which are desired to support the recommended standard process.

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[1] Note that we wish to distinguish this operational point-of-view of a federation from the formal definition of an HLA Federation as 'a named set of simulations, a common federation object model, and supporting runtime infrastructure, that rare used as a whole to achieve some specific purpose'; although the two are considered to be self-consistent.

[2] 'DoD' systems engineering guidance is illustrated (but not exhausted) by the following sources:
- MIL-STD-973. *Military Standard: Configuration Management* . DoD, 17 Apr 1992.
- MIL-STD-SDD (Draft). *Military Standard: Software Development and Documentation.* DoD, 22 Dec 1992.
- MIL-STD-1521 B (USAF). *Military Standard: Technical Reviews and Audits for Systems, Equipments, and Computer Software* . DoD, 4 Jun 1985.

[3] 'Traditional Systems' systems engineering guidance is illustrated (but not exhausted) by the following sources:
- Rechtin, Eberhardt, *Systems Architecting - Creating and Building Complex Systems* , Prentice Hall, Englewood Cliffs, 1991.
- Hatley, D. and Pirbhai, I. *Strategies for Real-Time System Specification* . New York, NY: Dorset House, 1988.

[4] 'Traditional Programs' systems engineering guidance is illustrated (but not exhausted) by the following sources:
- Kerzner, H. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling* , 5 ed. Boston, MA: Van Nostrand Reinhold, 1995.
- Rosenau, M. *Successful Project Management: A Step-be-Step Approach with Practical Examples* , 2 ed. Boston, MA: Van Nostrand Reinhold, 1992.

[5] 'Traditional / Software' systems engineering guidance is illustrated (but not exhausted) by the following sources:
- Humphrey, W. *Managing the Software Process* . Reading, MA: Addison-Wesley, 1989.

[6] 'Object Oriented' systems engineering guidance is illustrated (but not exhausted) by the following sources:
- Rumbaugh, J., Blaha, M., Premerlani, W., Eddy, F., and Lorensen, W. *Object-Oriented Modeling and Design*. Englewood Cliffs, NJ: Prentice-Hall, 1991.
- Booch, G. *Object-Oriented Analysis and Design with Application* ; 2 ed. Santa Clara, CA: Benjamin/Cummings Publishing, 1994.
- Jacobson, I., Ericson, E., and Jacobson, A. *The Object Advantage: Business Process Reengineering with Object Technology* . Reading, MA: ACM Press, 1995.
- Martin, J. and Odell, J. *Object-Oriented Analysis and Design* . Englewood, NJ: Prentice-Hall, 1992.
- Schlaer S. and Mellor S. *Object Lifecycles: Modeling the World in the States* : Englewood Cliffs, CA: Prentice-Hall, 1992.
- Coleman, D., Arnold, P., Bodoff, S., Dollin, C., Gilchrist, H., Hayes, F., and Jeremaes, P. *Object-Oriented Development: The Fusion Method* . Englewood, CA: Prentice-Hall, 1994.

[7] 'Pattern Based' systems engineering guidance is illustrated (but not exhausted) by the following sources:
- Gamma, E., Helm, R., Johnson, R., and Vlissides, J. *Design Patterns: Elements of Reusable Object-Oriented Software* . Reading, MA: Addison-Wesley, 1995.
- Fowler, M. *Analysis Patterns: Reusable Object Models*. Reading, MA: Addison-Wesley, 1997.

- Pree, W. *Design Patterns for Object-Oriented Software Development*. Reading, MA: ACM Press, reprint 1995.

[8] A compilation of a variety of entities which are considered candidates for use in the FEDEP Model are contained in working papers associated with the development of this paper and are available from the authors on request.

[9] Note that a similar circumstance existed for the development of the HLA Object Model Template and the federate-to-RTI Interface Specification(s). The strategy suggested here is modeled on that relatively successful experience.

[10] Hatley, D. and Pirbhai, I. *Strategies for Real-Time System Specification*. New York, NY: Dorset House, 1988.

[11] For IDEF0 specifications, see http://nemo.ncsl.nist.gov/idef/standsp/idef0.html.

[12] For UML specifications, see http://www.rational.com.

[13] Humphrey, W. *Managing the Software Process*. Reading, MA: Addison-Wesley, 1989.

[14] Demarco, Thomas. *Structured Analysis and System Specification*. Englewood Cliffs, NJ: Prentice-Hall, 1979.

[15] UML, *ibid*.

[16] Object Class, State transition, Event trace, Use-case and executable views

[17] Rational ROSE, PARADIGM Plus, OMT, Object Time ..., etc.

[18] Pattern specifications and taxonomic classification are introduced clearly in Gamma, ibid.