SBA / SeBA
- Implementing the Inevitable -

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ABSTRACT: *The recent maturation of simulation technology together with its relative cost-effectiveness and ubiquity of application is precipitating a new form of systems-life-cycle business practice – namely Simulation Based Acquisition (SBA) / Synthetic environment Based Acquisition (SeBA). This practice involves the intimate and deliberate use of simulation and associated synthetic environments throughout the objective system life-cycle. SBA / SeBA is characterized by forms of distributed, collaborative enterprise among stakeholders which heretofore have been impossible and which hereafter will become commonplace. In this paper, we analyze the simulation technologies, simulation practices, and modeling and simulation industry business operational environment, which make SBA / SeBA practically possible and virtually inevitable.*

1 Introduction

1.1 Context

Faced with the specter / opportunity of defense acquisition reform in the United States [1], the prospect of having to perform in accordance with recently implemented reforms in the UK [2], [3], and the implications for the World of the re-alignment of national security interests subsequent to the dissolution of the Soviet Union, there is certainly the feeling of excitement in the domain of defense procurement practice. Similarly, serious and systematic consideration of economic incentives for liquidity and return-on-investment by commercial interests in the military-industrial complex, perceived opportunities by governments to leverage commercial technologies, and the general need to maintain capacity-to-perform in the face of extremely competitive and fluid labor and technology markets, will no doubt make the next decade of defense procurement 'interesting'.

Into this turbulent socio-economic context, comes a particular form of business practice denoted Simulation Based Acquisition (SBA, in the US) [4], [5], and [6] and Synthetic Environments Based Acquisition (SeBA in the UK) [7], [8]. Characterized by: emphasis on shared representations of objective systems through simulation and data, physically distributed but operationally collaborative operations among disparate participating agents, and synoptic cohesion and integrity of the virtually continuous evolution of objective systems out of nascent needs; these eagerly awaited business practices have much in common. The 'vision', as phrased in the somewhat proscribed vernacular of the US DoD context is that of "…an acquisition process in which DoD and Industry are enabled by robust, collaborative use of simulation technology that is integrated across acquisition phases and programs". Similar sentiments are present in the U. S Army's Simulation and Modeling for Analysis, Requirements and Training (SMART) [9] Program, and in NASA's (currently unfunded) Intelligent Synthesis Environment (ISE) [10] initiative.

Not surprisingly, with concepts of such broad significance and potential influence, there is considerable debate about what precisely is intended for any particular implementation program, what degree of readiness-for-adoption exists in the subject constituencies, and what forms of 'enablement' [11] are necessary and sufficient to introduce such practices to good individual and collective effect. Nevertheless, it is our position that the question is not whether, but whither SBA – not *whether* we will move into SBA / SeBA-like business practices, but *how* we will choose do so. [12]

1.2 THESIS - SeBA/SBA is ready for prime time!

Fundamentally, SBA / SeBA, along with their various *doppelganger* manifest 'an idea whose time has come'.

The recent maturation of simulation technology coupled with its relative cost-effectiveness and ubiquity of application is precipitating a new form of systems-life-cycle business practice. This emerging practice involves the intimate and deliberate use of simulation and associated synthetic environments throughout the objective system life-cycle. This practice is characterized by forms of distributed, collaborative enterprise among stakeholders which heretofore have been impossible and which hereafter will become commonplace as the basis of significant competitive advantage for those who can successfully execute SBA / SeBA operations.

Before we proceed to justify our position on the 'readiness' of SBA / SeBA for successful implementation, let us consider briefly the necessary and sufficient conditions of readiness, the apparent state of perception of such readiness, and the degree to which we hold that it is prudent to proceed with SBA / SeBA practices.

SBA / SeBA are significant works-in-progress whose evolution have been pursued deliberately by government and private sector teams for some time. In that context, evolutionary tactics and factors affecting successful implementation have been explicitly investigated and published, and the particular set of factors identified thereby is indicated in the Table of Figure 1.2-1.

Enabler Category
Policy and law changes
Process Changes
Authoritative sources for all information
Data interchange standards
Capable re-usable software
VV&A for information and software
Means to identify, obtain and protect reusable resources
Tools and methods to manage collaboration
Business Case
Education of the work force
Motivation of the work force
Competency of the workforce

Figure 1.2-1 – Necessary enablers derived from the definition of SBA provide a basis for investing in the implementation of the practice.

Naturally, unqualified guarantees of success are not to be expected for SBA / SeBA any more than for any such evolving business practice. Still, given the current circumstances of procurement efficacy, *any* significant improvement could serve as the criterion of acceptability of SBA / SeBA practice. In fact, we suggest that *immediate* universality of appreciation and acceptance is not necessary for the success of SBA / SeBA - only the sure and intelligent conviction of those who choose to pursue such strategies. SBA / SeBA doesn't have to be mature enough to work *all* the time *every*where to justify implementation and to provide value, only *some*time, *some*where.

It is widely held that some form of cultural change of 'sea state' must accompany full adoption of SBA / SeBA. In the US, for instance, NASA has been particularly sensitive to this perceived need for cultural evolution. The need for such pervasive attitudinal and behavioral change may well characterize the desired end-state, but we assert that it is by no means necessary for early adoption and practically immediate recovery of utility from SBA / SeBA practices. It is in this spirit that we strongly recommend concrete implementation both for the immediate value recovered and by way of facilitating more widespread use of SBA / SeBA techniques.

The tenor of this paper, then, is to consider implementing SBA / SeBA practices *now*. We proceed to discuss the implications of the current state of demonstrable readiness of technology, economy, and business practice whereby *'early' implementation*, by individuals and organizations who will 'find a way' to capitalize on SBA / SeBA strategies, *will succeed*.

1.3 Outline of Exposition

In the sections that follow, we will address in turn the state of simulation technology, the economics of modeling and simulation, and the effective application of modeling and simulation. In each case, we consider the degree to which readiness exists today for implementing SBA / SeBA practices in earnest, on real programs, with reasonable prospects of success. Certainly, neither an exhaustive analysis nor a fully convincing panegyric for SBA / SeBA is possible here; but we hope to establish a basis of justification whereby implementation of SBA / SeBA in 'early adopter' [13] programs may be conveniently established. Finally, we provide a summary net assessment of SBA / SeBA's being truly 'ready for prime time'.

2 Simulation Technology

Simulation technology [14] is an enormous domain, consisting of the application of the body of knowledge of modeling and simulation. Closely related to – but different from – the technologies of computer software and systems engineering, 'simulation technology' implies considerably more scope than can be addressed reasonably here. We have elected, therefore to focus on three perspectives of simulation technology from which several circumstances are discussed that we consider most significant to SBA / SeBA. These perspectives are: standards, processes, and techniques.

2.1 Standards

The state of evolution of standards [15] in the domain of modeling and simulation is interesting on its own merits as an indication of the degree of maturity that exists in the simulation industry. It is significant here as a perspective on the degree of readiness of the simulation industry to support such systematic application strategies as SBA / SeBA.

2.1.1 Standards Rationale

Standards provide the degree of 'order' necessary for effective cooperation across the simulation and systems engineering communities. They are the specification of 'etiquette' whereby stakeholder agents and simulation assets can dependably operate (and interoperate). The establishment of standards is an investment in the industry-wide 'corporate enterprise' within which simulation-based systems engineering can be conducted successfully.

Standards, in and of themselves, will not be sufficient to support so complex and far-reaching changes in practice as SBA / SeBA imply – no amount of enforced prescriptive guidance could be. Our position is, rather, that the present level of standards evolution is appropriate and sufficient to facilitate that requisite order and degree of cooperation among simulation and systems engineering communities which is necessary for SBA / SeBA.

2.1.2 Standards Instances

Of the considerations which from the perspective of SBA / SeBA seem most relevant to standards, we consider both standards themselves, together with the institutional infrastructure whereby standards and standards–related practices and processes are developed.

One relatively recent and important structural or system-architectural standard, the High Level Architecture (HLA) [16], was originally developed for the U.S. DoD, but has since been adopted and used significantly more widely. Accepted now by the US DoD, NATO, OMG, IEEE, and ANSI, the High Level Architecture provides guidance *via* Object Model Templates, Interface Specifications, and Rules for the composition of inhomogeneous simulation applications, real-world components, and associated operational assets into useful ensembles. HLA has been demonstrated to be extremely stable, versatile, easy to employ, and effective in enabling interoperability of composite, albeit intrinsically dissimilar, simulation systems. While one set of standards does not an industry make, HLA exemplifies the kind of standard which affords very considerable regularity of practice, including in the best case supporting both syntactic intercommunication *and* semantic interoperability of simulation artifacts. It provides an architectural basis for composing a whole class of entities (potentially much broader than only simulation instances); and it serves, in fact, as a potential basis of communication, cooperation, and interoperation within the acquisition enterprise.

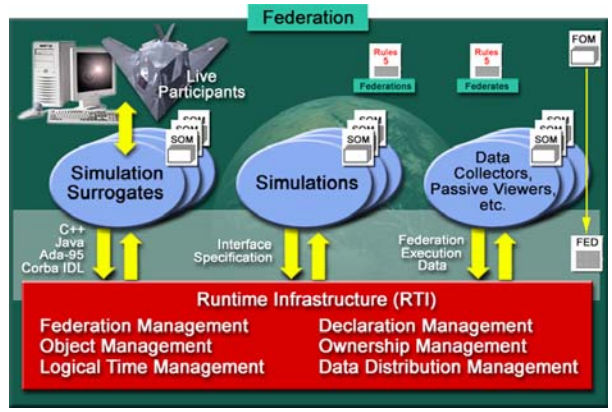

Figure 2.1.2-1 – The High Level Architecture (HLA) standard provides effective guidance for the interoperation of dissimilar simulations and associated artifacts.

Other similar enterprise-level standards include the Common Object Request Broker Architecture (CORBA) [17] established by the industrial consortium the Object Management Group (OMG), and the Standard Content Object Reference Model (SCORM) [18] being established by and for the Advanced Distributed Learning (ADL) community-of-interest. In both these cases, as in HLA, architectural standards offer regularity of practice in composing complex, open, extensible, information systems, without constraining to any great degree the information types and content of the individual components. That this form of standard is both extremely effective in affording orderly systems specification and extremely tolerant of the informational content of such systems is indeed auspicious for the prospect of SBA / SeBA implementation.

Powerful schemas, notations and associated processes have become established in several other related fields that allow concurrent simulation use, extension, and integration. In each case, regardless of the original domain of inception, such standards, when successful, invariably invite extension to scopes of applicability of interest to SBA / SeBA practice evolution.

In the domain of software programming, the Microsoft Common Object Module (COM) and Distributed Common Object Model (DCOM) standards [19], [20] provide for the software industry the kind of flexibility and design-level compositional capability which linked-libraries afforded a previous generation.

Other notations and associated functional capabilities for inter-component interface implementation have been developed primarily in context of software engineering, but admit to broader interpretation and use. They include:

Integrated Development Environments (IDE), Data Interchange File Formats (DIFs), and Application Programmers Interfaces (APIs). In each case, a 'type' of standard (or specification of structure) arose out of the need to establish regularity of design in collaborative operational environments and to facilitate re-use and interoperability and then was promptly generalized to levels beyond its original domain of applicability.

A similar dynamic is seen in association with Extensible Markup Language (XML), a notation that allows the generation of self-referential *de facto* standards for display specification. Stimulated by the need to provide flexible, user-defined display formats, XML and its progeny have progressively grown in both power and generality in relation to their predecessors. Microsoft's .NET [21], offered as the next generation of standard for online applications, has yet to be tested and judged by the marketplace.

In the database domain, design specification notations and associated practices as exemplified by the set of IEEE Standards for Functional Modeling Language - Syntax and Semantics for IDEF0, and IEEE Standard for Conceptual Modeling Language Syntax and Semantics for IDEF1X97 (IDEFobject) standards [22] – some predicated upon process perspectives and others object-oriented.

In the regime of software languages, the venerable Backus-Naur Form (BNF) [23] continues to support meta-level specification of operators, operands and expressions from which extremely powerful notations and operational implementation may be derived.

For simulations, the Discrete Event Simulation System (DEVS) notation [24] provides a higher-order abstraction language that supports the specification of simulation systems in ways which are demonstrably self-consistent with the HLA standard schema. In a similar vein, the WAVE-WP notation [25] is being advanced to serve as a comprehensive specification notation system for dynamic distributed systems.

At a level of even higher abstraction, notations intended for general systems theoretic scope are being refined. Originally developed within the software development community to provide denotative capacity for object-oriented software conceptual specification, the Unified Modeling Language (UML) [26] has proved to be promptly and effectively applicable to the universe of domains admitting to analysis in accordance with OO precepts [27].

The application of standards of various types at selected points in the simulation-systems development and operations life cycle, enable consistent system development processes to be used. This causes better, more maintainable SBA / SeBA system architectures to be produced.

2.1.3 Standards Evolution

Perhaps more significant for SBA / SeBA than any of these particular standards, is the status and process of standards evolution in the industry today. The effect of such standards on the software, simulation, and (to a lesser extent) the systems engineering industries is accelerating and broadening. The receptiveness of those industries to standards is consequently high, when the standards themselves are stable and their value to the user is evident.

In some fundamental ways, the evolution of new notations and processes appropriate and available for use as standards in SBA / SeBA is not accidental. First, it is clear that the development and use of technical standards is intentional – not particularly for SBA alone, of course – but for the sake of the regularity of practice and product that they facilitate. Secondly, the relevance of standards arising in software and simulation industries and in enterprise domains is logically related to the needs of SBA / SeBA in expected ways. SBA / SeBA certainly benefits with respect to standards from its consanguinity to such technical fields as software development, and systems engineering. Perception of the need for and prospective utility of technical standards which exist in those fields is appreciated by practitioners who are involved in the SBA / SeBA enterprise. Consequently, particular standards trends and instances which find favor and succeed in those fields may generally be useful to SBA / SeBA owing to the relatively short 'step' in generalization or tailoring which is necessary to adapt those standards to the needs of the SBA / SeBA community.

The infrastructure for the establishment and administration of standards for SBA / SeBA is largely already in place and can, if desired, serve to provide the venues and coordination mechanisms necessary to formalize required standards. In addition to the organizations already cited, the Simulation Interoperability Standards Organization (SISO) is moving to provide focused support to the SBA / SeBA community with the establishment of new Fora on simulation business practice and systems acquisition, which are specifically intended to address the needs of the SBA / SeBA community.

2.2 Process

Simulation technology process [28] - the 'verbal' or active consequence of standards guidance and community behavioral commonality - is at the core of SBA / SeBA (which is itself a form of enterprise process). Process is what we do (and to a considerable extent how we do it), and as such, is of primary concern in addressing the opportunity associated with SBA / SeBA.

2.2.1 Process Rationale

Like standards, one effect of clarity and consistency of process is regularity of practice. Another, more significant consequence however, is efficient and effective performance.

A variety of forms of regularity of technical and business-practice operations are significant for SBA. The first class includes those processes which are executed in relation to SBA itself and which, being antecedent-to and used-by SBA are prerequisite conditions to it. Three such SBA / SeBA process instances are discussed below.

Another perspective on SBA process is to consider that SBA / SeBA is itself a process whose constituent elements, their intrinsic 'methods' (e.g. what is done) and their interrelationships, must be defined, accepted by consensus, learned, and practiced in self-consistent ways. It is with respect to this second sense of SBA / SeBA process that there seems to exist considerable anxiety in the defense acquisition community.

In fact, formal, and operationally concrete definitions of SBA / SeBA seem to be hard to come by. This is evident in the United States in the failure to achieve acceptance of either of the two defining documents proffered to date. There is, consequently, a good deal of discussion and specification of 'what-it-is and what-it-ain't' (a kind of implicit definition by domain-whittling) that has been helpful at least in clarifying the domain of discourse, thereby avoiding some potential misunderstandings.

It is felt by some that, until the SBA / SeBA operational process is defined fully, it is at best imprudent or at worst impossible to proceed. Holding that there is precious little overt progress evident, many in the community are wary. ("If we don't know precisely what SBA is and what all of its potential implications are, then how can we be asked to risk 'changing horses amid stream'"?) Given this conservative attitude, practical trials and progressive achievement of some form of sufficient progress is inhibited. ("You're not going to do business-process-reengineering experimentation on my watch"!) There are, of course, no surprises here, only role players doing what they think best under somewhat uncertain and trying circumstances. Program Managers hold their charters and prerogative dear (and for good reason). Defense procurement executives in both government and industry (with a few rare exceptions) do not understand or appreciate the details of simulation technology and its untapped power to support systems-engineering business practices. Conversely, of course, simulation technologists (however enamored of their industry and its declared benefits) have not been able to articulate these opportunities convincingly.

This Catch 22 situation is, in our view, unnecessary. We propose, on the contrary, that SBA / SeBA may be safely considered to be a future state of practice toward which we are already migrating under the impetus of technical, economic, and enterprise motivations, and at which we will arrive in due course. We suggest that there is fundamentally no need to define *a priori* the future state of the SBA / SeBA process before taking the 'next' steps toward implementation. Instead, we suggest that the more realistic view is to consider that 'the ship is sailing' and that without undue haste (or risk) we may safely 'get aboard' and see to well ordered progress by helping to 'make way'.

2.2.2 Process Instances

A few specific processes warrant discussion owing to their special relevance to the near-term implementation of SBA / SeBA practices. These are instances of the kinds of processes which, as adopted and adapted, will be a significant part of fully realizing SBA / SeBA. In particular, we address: 1) the Federation Execution Development Process (FEDEP) - the 'process' complement of the HLA structural (architectural) standard; 2) Verification, Validation, and Accreditation (VV&A) – the determination of credibility and appropriateness for intended use of simulation components and systems; and 3) the systems engineering process(es) relevant to the development of objective systems in context of SBA techniques.

2.2.2.1 Federation Execution Development Process (FEDEP)

The Federation Execution Development Process (FEDEP), associated with the HLA, is one whose specification and adoption within the simulation community is contributing materially to the evolution of shared practices for implementing distributed and interoperable simulation systems. Fundamentally a tailoring of generally accepted systems-engineering practice, the FEDEP provides guidance for the life-cycle management of distributed simulation systems, indicates opportunities for automated support, and provides the basis for specification of associated processes such as information security management and Verification, Validation, and Accreditation (VV&A).

The similarity of the FEDEP to recognized systems engineering practice is not incidental. Derived originally from concrete experiences in federation prototyping during HLA standards evolution, the FEDEP has evolved into a familiar, stable, well-accepted process for integrating simulations and other assets, in accordance with the HLA standard, into a successfully interoperating ensemble. As its definition and specification proceed to mature, leveraging more general systems engineering practices should be expected, even as the specialization of the FEDEP particularly for distributed interoperable simulations proceeds.

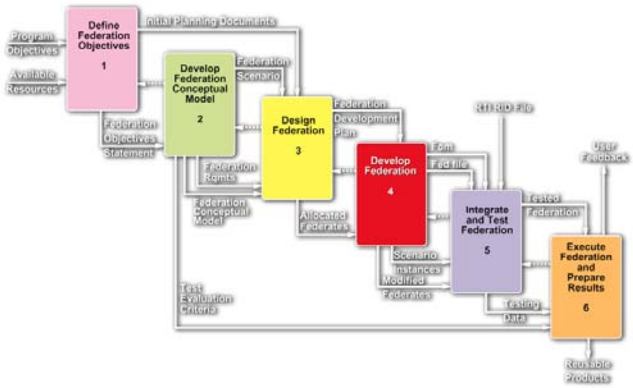

Figure 2.2.2.1-1 – The Federation Execution Development Process (FEDEP) provides guidance for the composition of simulations into distributed systems

The FEDEP is significant to SBA / SeBA insofar as it provides a clear and effective prescription of the simulation integration process which is essential to any reasonable expectation of use of simulations together with other assets (people as operators or trainees along with data, software, and hardware components) in an SBA / SeBA ensemble.

2.2.2.2 Verification, Validation, and Accreditation (VV&A)

Simulation VV&A (or in the UK, V&V) denotes the set of activities whereby various factors of the quality of models and simulations are determined. According to the US DoD, verification is "the process of determining that a model implementation accurately represents the developer's conceptual description and specification". [29] Generally: 'Is the simulation what it was intended to be?' Similarly, validation is "the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model". Generally: 'How good is the simulation?' This terminology is consistent in the US, UK, and NATO. Accreditation is handled somewhat differently. In the US, accreditation is "the official certification that a model or simulation is accepted for use for a specific application"; while in the UK, accreditation is only implicit in the determination to use the simulation, no formal accreditation certification being required or recognized. In either case, the fundamental question is: 'Is the simulation good enough for my use?'

While not by any means reduced to algorithmic precision, the body of recommended practice for VV&A is reasonably well-known and accepted by consensus among US and UK simulationists. In fact, typical VV&A meta-processes, practices, and techniques are documented by way of providing an inventory of elective guidance for practitioners. [30]

The relevance of simulation VV&A to SBA / SeBA is twofold. In the first place, VV&A practice as-is is appropriate for establishing confidence in SBA / SeBA simulation assets. The rationale for this assertion runs as follows: We do VV&A successfully now. It works to establish requisite quality of simulation assets in a given context of intended use. Existing VV&A practice is applicable to SBA / SeBA simulation components and ensembles. Therefore, SBA / SeBA assets can be evaluated in context of their intended use and be certified in terms well-enough appreciated that confidence in their use may be justified.

In addition, these VV&A processes are precursors (and quite possibly progenitors) of the processes which will be necessary to establish the contingent credibility of a wide range of SBA / SeBA assets (including for instance, models, simulations, software, data, etc.). There will certainly need to be a more comprehensive set of practices whereby the full suite of SBA / SeBA assets is evaluated. Existing modeling and simulation VV&A practices are such however, that their extension to apply to other kinds of assets is relatively straight forward. Particularly important in this regard is the concept of maintaining relevance of evaluation with respect to intended uses through preservation of audit traceability of V&V evaluation activity criteria from requirements for confidence in unit-under-test element.

In any event, the availability of useful and extensible simulation VV&A process and practices yields considerable value in establishing correlative SBA / SeBA process.

2.2.2.3 Systems Engineering

The fundamental systems engineering of the objective-system is an extremely important component of process context for SBA / SeBA. Serving as the meta environment within which SBA / SeBA is implemented, the characteristics of the systems engineering practice constitute a kind of operational constraint to which SBA / SeBA must conform.

Too extensive to detail here, the regularization of distributed systems engineering practice as evidenced in initiatives such as the US DoD's Joint Distributed Engineering Plant (JDEP) [31], are proceeding in ways which are intentionally consistent with SBA / SeBA. Explicit coordination through common management authority are likely to guarantee mutually supportive processes for systems engineering and SBA / SeBA, providing in effect two complementary views on the same reality.

2.2.3 Process Evolution

In each of the three process domains indicated – standards, VV&A, and systems engineering - there is significant process evolution underway which will serve only to improve the already considerable utility of existing processes for SBA / SeBA.

In the area of standards, the increasing acceptance and extension of domain of applicability of the UML notation is quite remarkable. That standard was cultivated in an open-source atmosphere, converged to stability within a few years, and has seen rapid extension of application well beyond its original intention to support object oriented software development. COM and .NET standards have arisen relatively recently and the degree to which they are widely adopted remains to be seen, but that similar related standards are evolving and coming into use more rapidly than in previous decades is clear. VV&A best practices are continuing to be explored under government sponsorship by means of the US Defense Modeling and Simulation Office's (DMSO's) revision of VV&A recommended practices, and the continued debate within the SISO on the proper relationship of VV&A to the HLA FEDEP process. Systems engineering process specification, likewise is being pursued within the US Government in context of systems interoperability initiatives, and the JDEP, and in a variety of professional engineering venues.

All-in-all, lack of vigorous evolution of processes supportive of SBA / SeBA seems unlikely.

2.3 Techniques

2.3.1 Techniques Rationale

Simulation techniques [32] are generally sufficiently explicit, available, and powerful that they are affecting the (correct) perception of simulation as an effective tool to support whole life-cycle systems engineering. Narrower in their scope of applicability and more specific in their prescriptive guidance than processes, techniques of various sorts offer the welcome prospect of successful accomplishment of a range of tasks which are either especially common or particularly thorny.

2.3.2 Techniques Instances

Two particular techniques are addressed here whose application within SBA / SeBA will be critical. The tasks to which these techniques apply are: 'objective-system abstraction and conceptual modeling' and 'simulation-system architecture management'.

2.3.2.1 Objective System Abstraction and Conceptual Modeling

As with other elements of practice, conceptual modeling in M&S development is very similar to the conceptual modeling which serves in early phases of objective system evolution when nothing exists of the objective system but its concept - that is its representation in terms of the self-consistent set of attributes which characterize the system in prospectus. The same relationship (conveniently) applies in software engineering, for the same reason – namely that the software objective system is only provisionally defined in the early phases of its life-cycle.

The technologies associated with the abstraction [33] and specification of conceptual models [34] from real- (or imagined-) worlds has become significantly more systematic and mutually comprehensible in recent years; although significant examples exist where the failure to *perform* abstraction and conceptual modeling tasks has apparently inhibited the progress of SBA / SeBA-like enterprises.

Abstraction and conceptual modeling for M&S occur within SBA / SeBA processes anytime a new or alternative representation is established – as for instance when new components of the objective system are introduced, or when a more detailed model is developed, or when alternative representations of the same proposed system is made manifest via alternative schemas (e.g. data / model / simulation). The efficacy of conceptual modeling processes (in terms of our ability to develop persistent and well-documented conceptual models) and their quality (in terms of model completeness-of-scope, consistency, correctness, and requisite detail) are crucial for SBA / SeBA. Simulation-based business practices can succeed only insofar as conceptual models are developed, captured, maintained, and used successfully. Of particular concern, obviously, is the self-consistency among conceptual models and consequently their manifestations in model, simulation and data representations which afford the semantic interoperability of the component entities (models / simulations / data bases / hardware / software / people) which generate, store, and receive information in SBA / SeBA operational environments.

In general, there is *no inherent shortfall in available techniques* whereby conceptual modeling may be conducted. Unfortunately, there are abundant examples in major simulation-system procurements of the last decade where the practical application of these techniques, under circumstances of programmatic (budget and schedule) pressure, variety of stakeholder perspectives, and failure on the part of senior managers to appreciate the potential influence of successful (or unsuccessful) conceptual modeling upon program and product outcomes, has been less than impressive.

Nevertheless, some recent programs show more effective use of conceptual modeling as a tool to establish that shared 'worldview' which is so necessary to SBA / SeBA.

In the end, while abstraction and conceptual modeling techniques are critical and challenging, there is no fundamental impediment, even here, to the effective initiation of SBA / SeBA practice.

2.3.2.2 Simulation System Architecture Management

Simulation-system architecture management [35], [36] refers to the development and control, at the coarse but comprehensive level, of the system of assets which support SBA / SeBA practice. Systems which are expected to exist in SBA / SeBA environments comprise models, data, simulations, hardware and software artifacts, and sometimes, people. These systems are the essential infrastructure that complements the evolution of the objective system and whereby knowledge is accrued and decisions are facilitated.

Consideration of simulation-system architectures may arise in any of a variety of circumstances, which a few examples may serve to illustrate. Typically, for instance, at any given stage of development of the objective system, not all the parts of the system may be available to interact for purposes of validation of objective system's internal and external interoperability. At such times, using simulation to represent some components while other components 'represent themselves' as hardware, software or man-in-the loop is common practice. Realizable as an HLA federation for instance, this simulation system has its own architecture complementary to but fundamentally different from that of the objective system. In a similar vein, it may be convenient to establish and maintain over the life of objective system evolution an ensemble of SBA / SeBA assets (simulations databases, models with alternative but complementary schemas) with its own distinctive architectural qualities.

The management of such infrastructure architectures can be challenging - inviting as it might the confounding of infrastructure and objective system and containing as it does its own forms of technical complexity. Nevertheless, simulation architectures and frameworks are common nowadays which correctly discriminate between software and data relevant to the representation of simulation entities (airplanes flying) and the software and data relevant to the simulation executive functions (event queues popping), and which provide to the developer and user alike suitable interfaces and operational support infrastructure. [37]

Contained within such frameworks are simulation compute engines which execute complex processes expressly suited for Parallel Discrete Event Simulation (PDES), Continuous System Simulation (CSS), Finite Element Analysis, and others. Typically included with the simulation system is an interface and the wherewithal for automated control and management of the simulation infrastructure.

As with conceptual modeling (and considering the close relationship between SBA / SeBA infrastructures and software and systems engineering as a virtue), we see *no fundamental impediment* in the domain of SBA / SeBA infrastructure management techniques to the immediate employment of SBA / SeBA practices.

2.3.3 Techniques Evolution

The evolution of techniques supportive of SBA / SeBA is being pursued with reasonable intensity. Too, SBA / SeBA benefits from the growing appreciation of the prospect of technique re-use as techniques in one or another of a set of related fields (e.g. simulation / software / systems engineering) mature and as the similarities among those domains continues to be ever better appreciated.

3 Economics

SBA / SeBA are fundamentally forms of business or enterprise practice. They require for their success a community of interrelated constituencies co-operating in systematic ways according to shared precepts for the benefit of the individual and the common good in environments where scarce resources must be allocated to best advantage.

The economics of modeling and simulation, while only partially appreciated, are the fundamental motivation for M&S practice. Notwithstanding that the costs and benefits of M&S are imperfectly known even in retrospect, that the products and services in the M&S market place are not widely known, that the identity of buyers and sellers is sometimes difficult to ascertain, and that the mechanisms which govern price and availability of M&S products and services are confounded at least in the defense industry by government procurement practices; nevertheless, the only rational motivation for the use of modeling and simulation is that it can bring systems to the user better, faster, cheaper. Insofar as economics is the study of how society manages its scarce resources, management of quality, time and money are certainly economic (or at least programmatic) concerns.

The dynamic state of evolution of the modeling and simulation industry (and consequently of the simulation economic market), together with the economic pressure in technical R&D, system development, training, and operations, provides incentives for modeling and simulation to be employed more pervasively. The increasing cost-effectiveness of advanced simulation technologies is accelerating that trend. With opportunity comes responsibility, however, and we note that the advent of more and more visible and expensive modeling and simulation assets and enterprises invites explicit consideration of cost and of consequent value of return-on-investment (ROI) in the narrowest terms and, more broadly, of the economics of modeling and simulation as a market sector. Managers and senior executives have every reason to cry: "Show me the money!"

Pursuant to the need for managers and decision-makers to appreciate the economic implications of investment in and use of modeling and simulation, the perception of the need for some appreciable set of relatively systematic expressions of the 'business case' for simulation is becoming well established. In particular, agreement and facility for expression of the business case for simulation in context of SBA is included as one of the significant 'enablers' indicated above.

"If wishes were horses, beggars would ride", however, and significant effort seems to be required to establish the economic basis for simulation investment and use. The degree of uncertainty in appreciation of these matters and the progress of concrete efforts to pursue a shared appreciation of the economics of modeling and simulation in ways supportive of SBA / SeBA are described briefly in the sections that follow.

3.1 Operational Uncertainty

Modeling and simulation has always had an economic aspect. Simulation was perceived as being 'worth doing', and we did it. Being something of an underground industry, however, there has not been much need or effort to rationalize the economics associated with modeling and simulation. In this respect, simulation has been like many other supporting technologies such as on-the-job development of software development support tools – you did it when you needed to, but you may not have accounted for it explicitly.

However, "…the times, they are a changin'". There is no free lunch, and simulation is not particularly cheap at present let alone free, however cost-effective it may be. The need to justify the cost of M&S in the context of simultaneously increasing economic pressure and opportunity is something many of us feel. Any such goal-oriented perspectives, however, can best be pursued from the position of truly understanding the economics of modeling and simulation. On that basis, a wide variety of economic practices may be addressed systematically and constructively.

What do we know? The state of our collective appreciation of the economics of modeling and simulation is certainly varied and is somewhat a matter of debate.

There are some things about the economics of M&S that we know with confidence. Our 'sure' knowledge is typically that which is derived from our personal or institutional operational experience. It relates to questions that we have found prudent or convenient to pose and to answer intentionally. For instance, there is considerable concrete information in-hand about the costs and at least the 'kinds' of benefits of M&S, and a generally consistent appreciation of the nature of the market (e.g. who buyers are, who sellers are, what the goods and services are).

There are some things though, about which we are much less certain. Normally these tend to relate to matters that are outside our individual domain of perception or concern. For instance: What do certain M&S practices really 'cost'? Where are the cost-estimating-relationships (CERs) upon which we may depend in generating *a priori* expectation of M&S activity costs? What is the substitution-value of M&S compared to other forms of technology in supporting system development and evaluation? There is at least some justification for the judgment that this knowledge is fragmentary, unsystematic, and not generally available, and thereby less than fully useful.

Finally, there are things that we might reasonably agree we do not know much about at all. These topics include the comprehensive appreciation of M&S markets worldwide and across applications domains, market dynamics, and the evolution of M&S economic practices. Generally, these are questions for which there has been no perception of need or opportunity to have asked about before.

While economic market analysis deserves attention, it seems at times remote from the day-to-day practice of modeling and simulation. In its simplest form, however, the economics of modeling and simulation is about deciding what any of us will do with our 'next marginal dollar'. This is something that, regardless of our role in the industry, we can all appreciate.

There are a variety of particular reasons to be concerned about the economics of modeling and simulation. First and foremost, economic considerations affect what we do in conducting the business of M&S. Economic factors influence our estimation of the prospective value of investment in simulation development or in the use of simulation assets. Similarly, economics is a determinant of many critical decisions. Shall we pay the price (cost) to invest in M&S or not? Sellers, for instance, invest in bringing products and services to market in order to make a profit. Buyers invest in product and service assets to get best value. Users invest in procuring and employing simulation assets for improved operational efficiency (e.g. the do-your-mission 'faster, better, cheaper, or only way' point-of-view)

At a slightly more abstract level, understanding market-related behaviors (e.g. standards, shared resources, collaborative operations, pricing, substitution for alternative goods and services, product evolution, generally accepted accounting principles, and M&S cost and value reporting formats) is important too. For instance, conventions made to account for the cost and value of M&S and reporting these findings in ways, which facilitate comparing like systems, would be immediately valuable. This understanding would help us build a more broadly shared simulation market constituency, it can provide us with the opportunity to operate more globally, leading to increased opportunities and hence larger markets and increased profitability.

There are many different views and experiences, and these need to be captured and investigated so that the 'best way forward' can be determined, to ensure that all the 'lessons learnt' are made available to the widest possible audience. This of course may be perceived to conflict with commercial advantage – no one likes giving up how they can beat their competitors. We assert, nevertheless, that the current state of adoption of M&S is such that it is best for each and for all that the economics of M&S be appreciated more widely so that the industry as a whole benefits and each of its participants with it – in effect that better understanding the economics of M&S is Pareto optimal [38]

The bottom line is that what we know (and do) about the economics of simulation matters - it influences how well we do the SBA / SeBA business of M&S.

Figure 3.1-1 – Understanding the M&S market is an investment in the industry and in SBA/SeBA practice.

3.2 Collegial Initiative on 'The Economics of Modeling and Simulation'

With the express intention to establish a shared appreciation of the modeling and simulation market-place, the "Initiative on the Economics of Modeling and Simulation" was initiated in the Summer of 1998. This initiative was conceived to be an opportunistic, collegial exploration of the nature of the economic aspects of modeling and simulation.

The initiative includes as its domain of interest anything having to do with "The Economics of Modeling and Simulation", including, identification and explication of markets, market mechanisms, metrics of cost and value, and other economic issues of potential significance to the M&S community.

This program, still underway and involving more than 200 registered participants, is intended to be a grass-roots discovery process across the widest appropriate domain-of-interest at a suitably abstract level so as to be both accessible and useful to the entire M&S community. In conducting this exploration, we expect to crystallize our understanding of the current state of M&S economics. We should generate products capturing current wisdom, lessons-learned, and prospective action. And finally, we should derive value in understanding M&S economics and in being better able to operate as informed players in the M&S market.

As a practical matter, we have established some strategic guidance for the initiative. We have emphasized eliciting from M&S practitioners expressions of their perceived needs for information about the economics of M&S by way of focusing the agenda of the imitative and of economizing effort. As a largely un-funded *pro bono publico* enterprise, leveraging the auspices of established government, educational, commercial, and professional institutions seemed prudent.

In particular, we are introducing the initiative into the agendas of several existing organizations, events and operational forums. Societies that have been involved are the Society for Computer Simulation (SCS), Simulation Interoperability Standards Organization (SISO), National Training Systems Association (NTSA), and the International Test and Evaluation Association (ITEA). Particular events include the SCS' Summer Computer Simulation Conference (SCSC), SISO's Simulation Interoperability Workshop (SIW), NTSA's Interservice / Industry Training, Simulation and Education Conference (I/ITSEC), and ITEA's Simulation Conference. Persistent working groups include SCS's Technical Chapter on the Economics of Modeling and Simulation and the SIW's Working Group on the Economics of Simulation. Finally, we have been careful to capture such knowledge as is extant and to make it as broadly available to the community of interest as possible by way of investing in the most widely shared appreciation possible of both the subject matter and of our state of understanding of it.

There are four analysis activities underway which are intended to 'shed light' on the economics of modeling and simulation. In each case, an effort is being made to enlist the widest possible range of 'stakeholders' to participate in the initial studies and to share the benefit of any preliminary findings. These topics include:

- M&S Economics Glossary – Draft terminology and taxonomy of concepts
- M&S Market Models – Capture relevant models of the M&S Market

- M&S Cost / Benefit Evidence – Compile and disseminate readily available empirical data
- M&S Business Case - Document business cases

A next step is to establish a persistent, accessible, self-documenting web-based 'open-source' environment for the administration of the initiative.

3.3 Getting Down to Cases

By way of focusing interest in the economics of modeling and simulation in the present context, we note the particular relevance of the 'business case' as a form of process-instance specification and as enabler of SBA / SeBA. A business case is a form of expression of the plausibility of one or another business practice, action, or transaction. Naturally, the successful business case requires that the anticipated process or course-of-action be clearly appreciated by the variety of stakeholders. The business case, then, provides the basis of expression and communication, of advocacy, of deliberation, of perception and judgment, and, last and not least, of the establishment of the *commitment-to-act* by SBA / SeBA stakeholders. A business case is by its nature hypothetical, and it is contingent for its success on the validity of its premises, the relevance of its implications, and the effectiveness of its expression. In short, the expression of a 'business case' rationalization for SBA / SeBA is a practical precondition for its widespread acceptance.

4 Making Simulation Work

At the end of the day, the purpose of simulation is to provide efficient and effective support to some significant programmatic endeavor. In that spirit, 'making simulation work' is an absolutely essential part of SBA / SeBA.

We have discussed the practical preconditions and feasibility for SBA / SeBA in terms of simulation technology, process, and economics. There remains, however to elicit 'proof-of-principle' evidence that SBA / SeBA may be pursued with commitment to good effect. Therefore we turn to the challenge of making simulation work for SBA / SeBA – illustrating how simulations can readily be made to work in SBA / SeBA configurations and how such simulations can work effectively to support the user's needs in SBA / SeBA configurations. In fact, several convincing demonstrations of the use of simulation technology in context of SBA / SeBA operations already exist.

4.1 Techniques in Practice

In December of 1999, a flexible, extensible and low-cost simulation system was developed and publicly demonstrated by an *ad hoc* team expressly to illustrate the *prima facie* feasibility of SBA / SeBA operations using present day technology. That self-declared SBA / SeBA asset included virtual, constructive and hardware-in-the-loop simulation assets together with systems engineering meta-tools, composed as an HLA federation. The development and use of that asset in conducting prototypical systems engineering studies constituted both a demonstration of capability and a challenge to the industry to pursue SBA / SeBA with similarly concrete implementation. [39]

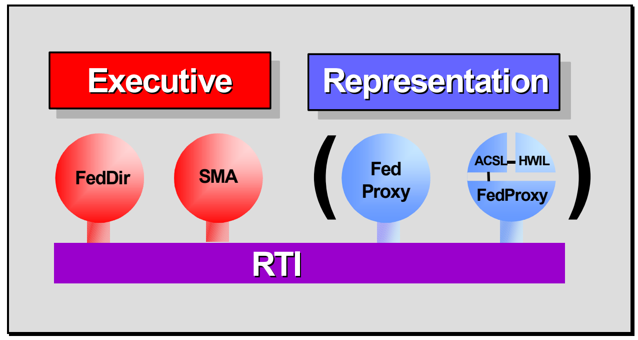

Figure 4.1 - 1 – Physical extension of the HLA structure provides meta extension of SBA operations.

Appreciating that a virtual "dual" exists between the functional, control relationship which is desired in simulation based systems engineering assets and the structural relationship which exists in the construction of an HLA federation, AEgis Technologies and Boeing Corporation combined engineering level analysis simulations and engineering analysis workstations in a proof-of-principle demonstration of SBA concepts of operations.

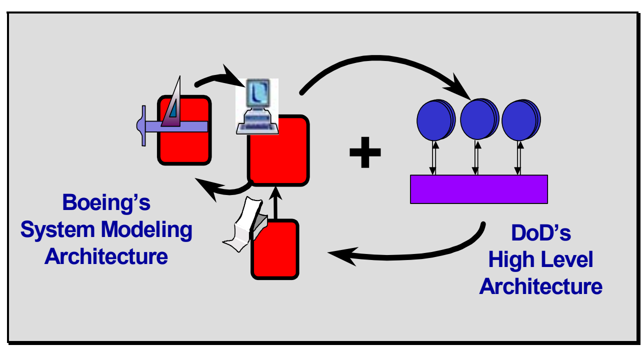

Figure 4.1 - 2 – Some SBA infrastructure assets may be readily composed using available technologies.

The resulting simulation system achieved embedding an 'intelligent agent' systems engineering environment into an HLA simulation architecture. It supported the interrogation of simulations and the subsequent analysis of results attained there from. And, it provided a significant improvement in the system engineer's capability to conduct studies and analysis in common operating and data environments.

While not *all* of SBA, this technology demonstration illustrated the relative ease with which *some* of SBA / SeBA infrastructure can be achieved.

4.2 Technical Architectures

Beyond the simulation system architecture illustrated above, there are operational architectures of significant concern for the establishment of successful SBA / SeBA practice.

One such architecture has been developed that includes facilities and communications, enterprise infrastructure, simulation representation, and engineering analysis layers. It utilizes the versatility of HLA as demonstrated in earlier technology exploration; and it provides a comprehensive, flexible, and extensible infrastructure sufficient to support any of a range of forms of SBA / SeBA practice.

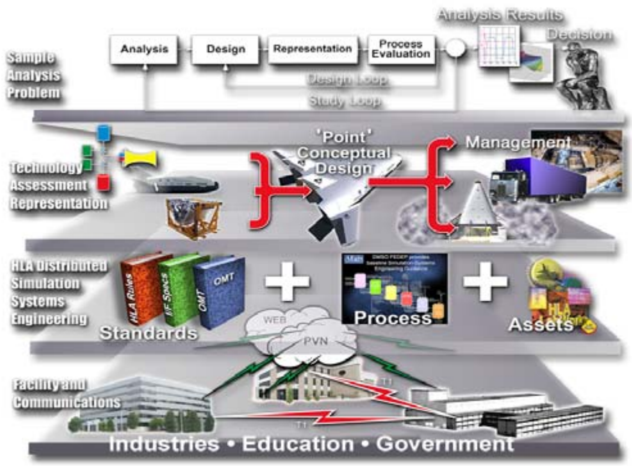

Figure 4.2 - 1 – Serious efforts are being made to instantiate SBA / SeBA enterprise in the context of mainstream procurement programs – this SBA-based enterprise model was proffered in support of the U.S. next-generation space launch system development program

Naturally, myriad such architectural constructs can be conceived. Any of a wide variety of characteristic values may be selected for each of its significant features, including: component modularization guidance and implementation support, communications layer topologies, simulation interface standards, data management strategies, application invocation, and so on. Given this intrinsic unconstrained opportunity together with the relatively benign requirement for architectural consistency only within the enterprise, it is hard to imagine that any fundamental inhibition to SBA / SeBA could arise from this quarter.

4.3 Enterprise Spirit

While technology, process, and infrastructure are necessary for SBA / SeBA practice, the critical attribute of such practice is its enterprise-wide collaborative operational approach. Establishing enterprise teams attuned to this cultural requisite, and able to provide effective guidance on its application, is a real challenge we have to face today. Even here, however, recent efforts are auspicious.

In one case, a small business was able to establish, within weeks, a Team committed to SBA / SeBA practices in response to a formal government procurement solicitation. Composed of industrial leaders in software development and data management, academic institutions, and government laboratories, this Team crafted a solicitation response which manifest conspicuous assets, related logically to the objective system need, and combined conceptually by the precepts of SBA / SeBA practice. While somewhat unusual, this Team was realized largely upon the strength of the appreciation of its members of the opportunity which lay within SBA / SeBA practice, and the unwavering intention to 'make it work'.

5 Conclusion

Simulation is one of the few available degrees-of-freedom whereby the systems development manager and procurement executive can hope to face the escalating challenger of systems acquisition and life cycle management. Simulation will serve to support the acquisition of systems that are economical, effective, and available…if and only if we commit to actively manage the use of M&S in the procurement business practices of the future.

In this paper, we have taken pains to illustrate the degree to which simulation technologies, economics, and business practices are fundamentally 'ready' to support SBA / SeBA strategies. Certainly, we have deferentially acknowledged many of the considerations which stakeholders must address in adopting SBA / SeBA practices. And, we have indicated how the business case stands as a necessary for m of rationalization for SBA / SeBA execution. Nevertheless, we hold to our thesis, that there is nothing to do now but to proceed to elect one or another of a set of candidate systems development programs and to implement SBA / SeBA with the intention of succeeding. In effect – *just do it!*

Consequent to these initial implementations and associated honing of the SBA / SeBA practices, we will be positioned to accept SBA / SeBA as a necessary element of 'corporate' strategic policy for defense acquisition.

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[13] c.f. the 'Technology Adoption Life Cycle', a model which grew out of social research in the 1950's about how communities respond to discontinuous innovations and popularized recently in Crossing the Chasm, by Geoffrey A. Moore.

[14] **technology** – *n.* **1.** The practical application of *knowledge* especially in a particular area. **2.** A manner of accomplishing a task especially using technical processes, methods, or *knowledge*. **3.** The branch of knowledge that deals with the creation and use of technical means and their interrelation with life, society, and the environment, drawing upon such subjects as industrial arts, engineering, applied science, and pure science.

[15] **standard** – *n.* … **2. a** an acknowledged measure of comparison for quantitative or qualitative value; criterion; norm. *adj*. **1. a** serving as a standard of measurement or value.

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[28] **process** – *n.* **1.** a. progress, advance <in the ~ of time> b. something going on. **2**. a natural continuing activity or function b. a series of actions or operations conducting to an end.

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[32] **technique** – *n.* The systematic procedure by which a complex or scientific task is completed.

[33] **abstraction** – *vt.* The activity wherein the fundamental character, qualities or attributes of a real or potential system are derived – through a mixture of discovery and invention – and documented in terms of some neutral, intermediate notation. Abstraction entails inferring the articulate identification of the parts of a system, the functions performed by those parts and the relationships among those parts.

[34] **conceptual modeling –** *vt.* The activity wherein one or another coherent and useful representation of the subject system is established in terms of its abstracted qualities.

[35] **architecture** - *n.* The entities which comprise the whole, the relationships among those entities, and the behaviors of those entities and of the whole.

[36] DRAFT V1.0 IEEE 1471 - "There has not yet emerged any reliable consensus on what 'architecture' is, what purpose descriptions of it serve, in what forms, for what users, and in what situations."
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