General Interoperability Concepts

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INTRODUCTION

Ongoing military operations throughout the world have demonstrated an increased reliance on the cooperation and collaboration of many nations and multiple services that employ disparate systems and varying procedures. Although combined operations of the past seem similar on the surface, the coalition operations of today typically involve a greater number of nations with more complex systems. These complex systems, and their associated training systems, were typically acquired in isolation with little to no consideration given to interoperability. Only recently have some nations begun to expend resources on addressing the grander issue of incompatibility within the battlespace.

Consider the following anecdote as a means of portraying this situation. Within a larger, long term campaign, a two-ship close air support (CAS) package form Nation A has been assigned a short notice high priority target to assist friendly ground forces in securing a strategic objective. The target area is likely well protected, but it is in rugged terrain and the level of integrated air defence is currently unknown. Nevertheless, the CAS package is launched. Target ingress is successful and weapons are launched as planned; however, upon initial egress, enemy air defences engage the CAS package, and the situation is compounded by local area unfamiliarity. Ultimately, one of the CAS aircraft is downed leaving the pilot behind enemy lines. Airborne early warning and command and control assets from Nation B are notified, and a combat search and rescue (CSAR) effort from Nation C, in concert with already embedded Special Forces from Nation D, is initiated immediately. As with the CAS package, the CSAR effort is unfamiliar with the target area and must rely on quick planning using traditional paper products (i.e. maps). Although the rescue effort eventually succeeds (12 hours later), the component forces encounter difficulties exchanging data and procedural information, which nearly compromises the Special Forces element, and the entire mission.

Had the various elements of this operation been able to train and mission rehearse in a networked and distributed synthetic environment (SE), participating nations may have been able to identify and correct some of the technical and non-technical issues, resulting in a more effective and efficient outcome. Such an effort is by no means trivial – the wide range in roles and systems necessitate an equally wide range in simulation systems (virtual simulators, visualisation and analysis software, environmental data, networking elements); however, the task is not insurmountable, and the technology exists today to make networked, SE-based training and mission rehearsal a reality for coalition forces. Concerned nations and agencies must first articulate the need in the form of characteristic solutions, and recognise the long-term benefits that initial investments in SE technology and processes have to offer. Of course, technology does not hold all of the answers; technical solutions must be complemented by efforts in the organisational and military cultural domains as well.

The aim of this paper is to examine some of the fundamental concepts and issues surrounding interoperability within the modelling and simulation (M&S) and SE realm. By taking a look at

Searle, J.; Brennan, J. (2006) General Interoperability Concepts. In *Integration of Modelling and Simulation* (pp. 3-1 – 3-8). Educational Notes RTO-EN-MSG-043, Paper 3. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

interoperability basics, the concept of reuse and some of the associated challenges, we hope to shed some light on the feasibility and issues concerning the collective use of M&S / SE tools to enhance defence processes.

INTEROPERABILITY BASICS

The idea of networking systems together, whether generically or for use specifically in simulation is not new. Networking information systems, particularly via the Internet, has lead to a vast increase in the availability of information. Given proper oversight, this high degree of information sharing has the potential to increase the effectiveness and efficiency of virtually any domain[1]. The M&S realm recognised the benefits of networking, and the current day practice of connecting military simulations over a wide area network (WAN) began with the SimNet project under DARPA in the early 1980s[i]. Over the past two decades, the supporting technology and processes have taken networked distributed simulation to a new level wherein complex models and simulations federate together to address a wide variety of issues within the defence arena.

Notwithstanding the significant advances in technology, the creation of a distributed network of disparate simulations is certainly not a trivial task; the wide variety of simulations and their associated applications have lead to different architectures and methods of interoperating. Figure 1 identifies some of the various classes of simulations, as well as some of the systems common to the United Kingdom (UK) Ministry of Defence (MoD). All of the simulations in Figure 1 can be networked but not necessarily to each other. The reason for this limitation is that each of the simulation examples shown uses a different architecture for networking among multiple instantiations of themselves. On a larger scale, in order to even begin thinking about achieving interoperability among multiple, disparate systems, one must explore some of the fundamental differences in networking architectures.

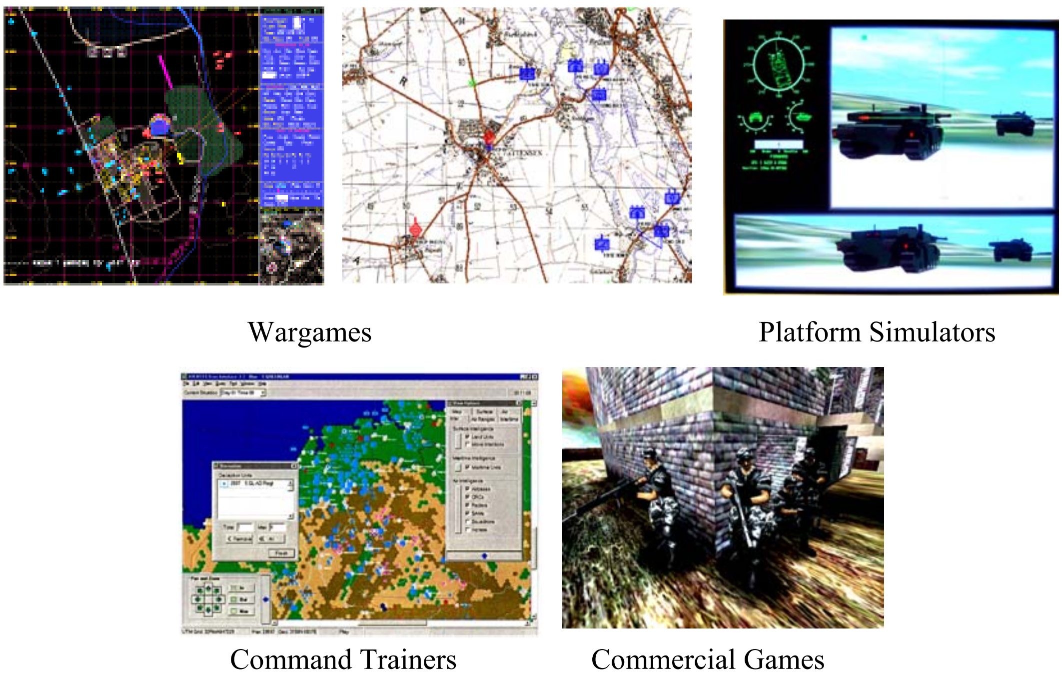

Figure 1: Various Networkable Simulations.

[1] Robert Metcalf's Law states that the value or power of a network increases as the square of the number of its nodes.

The early days of networked simulations employed what we will call the classical simulation architectures – architectures that provided limited networking functionality. Figure 2 portrays a schematic of the classic *Terminal Server* architecture, wherein all of the data resided and all of the battle processing occurred on a central server. The individual player terminals were simply graphical interfaces through which the users would respond to only graphics commands that were literally sent from the central server to the individual player stations. The Janus wargame, still in use by the British and Canadian armies, functions according to this architecture.

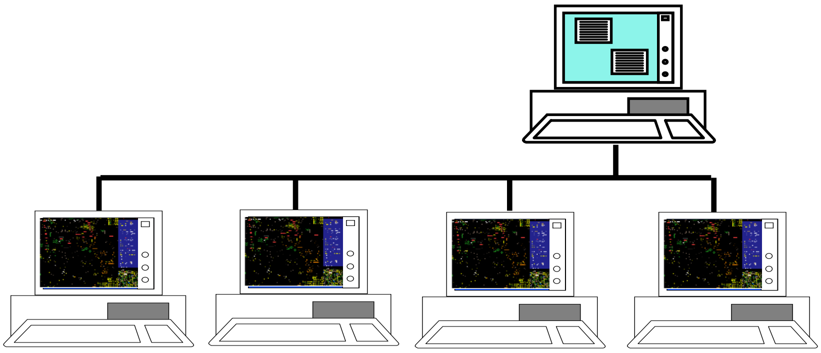

Figure 2: Terminal Server Architecture.

A comparable architecture from the perspective of the user is shown in Figure 3. Despite the apparent similarity, the *Client Server* architecture is sufficiently different once one begins to look a little deeper. In this architecture, all battle assessments are still executed on the central server. The difference is that the server then sends battle update information (vice simple graphics commands) over the network and the individual client stations run some form of local intelligent processes. Some data is retained at the client station, which is displayed on a locally stored map. The extent of local processing may vary among different client server systems, giving rise to the terms *Fat* and *Thin* clients. The ABACUS command and staff training (CAST) wargame functions according to this architecture. Although these two classical architectures facilitated networking, it was done within a single, closed system using proprietary constructs and protocols. As such, an attempt to interoperate two systems such as Janus and ABACUS would be non-trivial in the least, and may not even make sense from a conceptual and functional perspective.

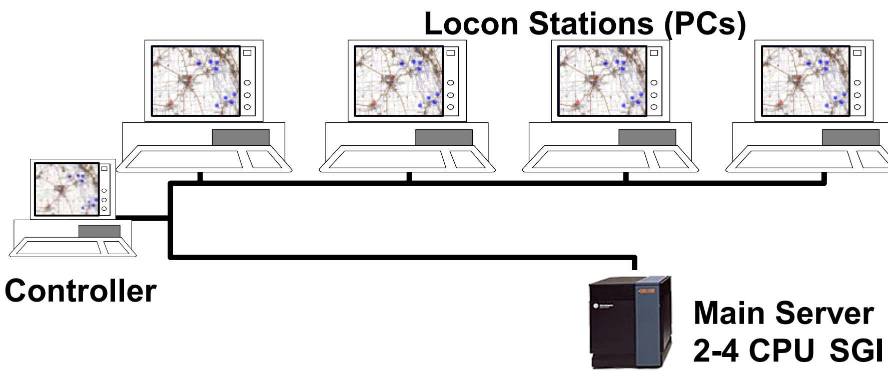

Figure 3: Client Server Architecture.

Interoperability can carry different meanings within different domains. The North Atlantic Treaty organisation (NATO) defines interoperability as:

"The ability of Alliance forces and, when appropriate, forces of Partner and other nations to train, exercise and operate effectively together in the execution of assigned missions and tasks".[ii]

More simply, the Longman Dictionary of the English Language (1984) defines *inter* as "among … carried on between" and *operate* as "to carry on military … action or mission". Essentially interoperability within a military context means for all participating elements to have the ability to function in a combined and consistent manner to achieve a common objective. Aside from any textbook or academic definition of interoperability, the fundamental concept of enabling many agencies and organisations to cooperate for increased effectiveness and efficiency should be somewhat intuitive. Indeed, the desire and ability to pool resources is certainly not just an M&S community issue; Figure 4 identifies the Levels of Information Systems Interoperability (LISI)[iii] and the NATO C3 Technical Architecture Reference Model for Interoperability, both of which categorise generic information sharing and data exchange in a progressive and hierarchical fashion. Even though the general concept of interoperability may have global commonality, the precise understanding and associated benefits within specific domains will vary.

LISI – Levels of Information System Interoperability	NMI – NC3TA (NATO C3 Technical Architecture) Reference Model for Interoperability
Isolated Systems	No Data Exchange
No physical connections	No physical connection
Connected Systems	Unstructured Data Exchange
Homogeneous product exchange	Human readable free text
Distributed Systems	Structured Data Exchange
Heterogeneous product exchange	Human interpretable,
Integrated Systems	Manual action required
Shared apps & shared data	Seamless Data Sharing
Universal Systems	Common data model
Enterprise-wide shared systems	Automated data sharing
	Seamless Information Sharing
	Universal interpretation
	Cooperative data processing

Figure 4: Levels of Interoperability.

Within the defence M&S realm, interoperability has specific benefits and challenges from technical and non-technical perspectives. First and foremost, the ability to interoperate disparate simulation systems promotes the *train as you fight* philosophy and enables the expansion of individual activities to team activities. The networking of live, virtual and constructive simulation systems amongst themselves and to real world systems has facilitated both the move away from training, analysis and experimentation in isolation, and the creation of collaborative working environments. It is within these synthetic environments[2] that defence organisations have found some relief from the fiscal constraints imposed over the past 15 to 20 years. New and innovative methods, enabled by advances in technology, are beginning to create alternative means to carry out defence activities where the lack of resources simply will not allow one to employ the live systems as in the past. Despite the bright future that M&S seems to promise, these potential benefits do not come without their issues and challenges. Some of these challenges will be highlighted later in the paper. Finally, a topic that will be examined in more detail in the next section,

[2] The UK MoD defines a synthetic environment as "A computer-based representation of the real world, usually a current or future battle space, within which any combination of 'players' may interact. The 'players' may be computer models, simulations, people or instrumented real equipments." www.mod.uk/issues/simulation/policy.htm

simulation interoperability has lead to the concept of reusing any existing M&S investment in new or different ways.

INTEROPERABILITY AND REUSE

Reuse (the concept of taking something that has already been designed and developed for one purpose and using it for a similar or another purpose) is a topic that is not new to the science and engineering realms[3]. Indeed the automotive industry has leveraged this concept for many decades. In the software realm, designers, developers and coders have been striving to produce modular systems with the intent of being able to reuse component elements (such as functions) from one application to the next. In fact, “code reuse is increasing with the advent of standards such as COM and JavaBeans.”[iv] Thus, it is not surprising that reuse has become a prominent theme in M&S.

A key issue when considering reuse is what exactly a simulation practitioner should aim to reuse. Many defence M&S agencies have established structured and managed collections of models and simulations, known, in most instances, as modelling and simulation resource repositories (MSRR)[4]. Typically, these repositories list simulation applications representing completed executable systems as opposed to reusable component models. This level of reuse may or may not be appropriate; what should M&S practitioners aim to reuse: whole models; sub-models; components; data; databases? Figure 5 uses a conceptual model of an aircraft in an attempt to depict the various levels at which model reuse might be appropriate. In fact, not all communities agree that reuse is always appropriate. Take for instance the operations research (OR) community, which has been developing and employing models for many decades. This community tends to abide by the fundamental definition of a model – a representation of an element of the real world *for a specific purpose*. As such, the OR view is that any useful model will be fit for purpose and should not be used for applications other than that for which it was designed. Another perspective is that one cannot simply keep complex components on the shelf waiting to be reused; this would likely result in a deterioration of the knowledge and skill associated with models. Whether or not there is a conclusive answer to this question is a debatable issue.

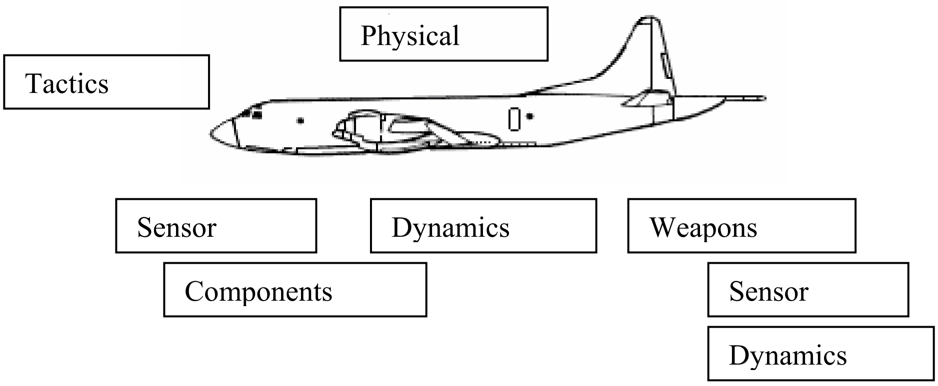

Figure 5: Conceptual Model Example.

[3] An example that makes significant use of this concept is the recent upgrade to the US Marine Corps AH-1 and UH-1 helicopter fleets wherein an 84% commonality of components (drive train, cockpit, software) between the two platforms will ensure a reduction in logistic support and strategic lift requirements. (USMC Concepts + Programs, Aviation Combat Element legacy Platform Modernization, March 2005)

[4] Examples include: the USAF – afmsrr.afams.af.mil; the US Army – www.msrr.army.mil; the Canadian Forces - www.drdc-rddc.gc.ca/seco/msrr_e.htm.

Assuming that reuse is appropriate and viable in the M&S community, one can begin to see that interoperability and reuse are closely related. In order to reuse a given component within a larger system, one must ensure that it can interoperate with the other elements of the systems (at least those with which data/information must be exchanged). This issue is one of the many at the forefront of research efforts in the M&S realm. Over the past two decades networked and distributed simulation activities have expended significant effort on achieving interoperability amongst disparate systems. Figure 6 portrays a ladder of interoperability and reuse signifying progress as networked and distributed simulation technologies and methodologies have matured[v]. This push up the ladder of interoperability has been facilitated by an increase in reuse through a broadening in technical concepts and standards.

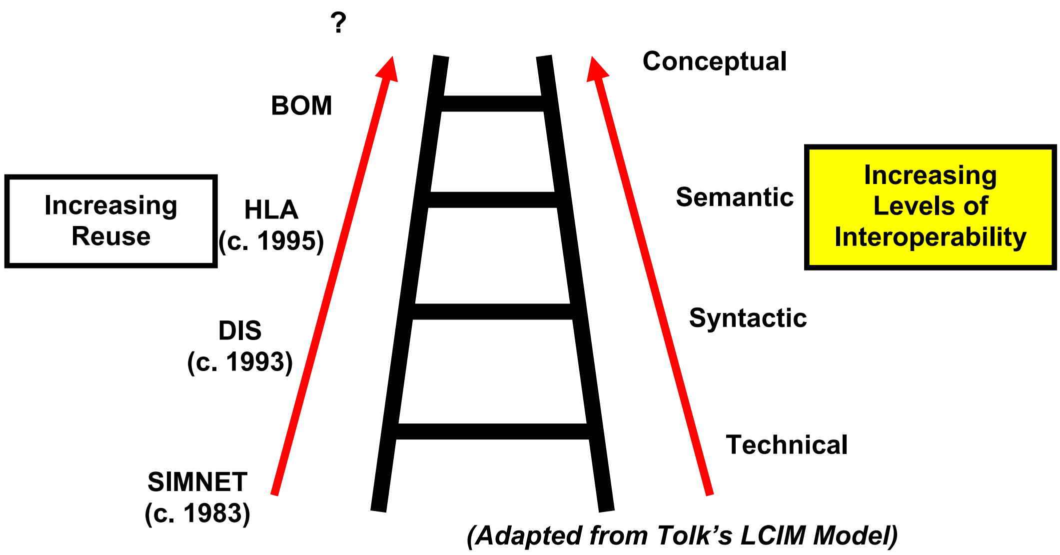

Figure 6: Ladder of Interoperability.

The increase in reuse and the broadening in interoperability have impacted defence processes, technology, operations and culture. Considering M&S as a tool that has potential to be applied across the entire spectrum of defence activity, increased interoperability and reuse facilitate the dissolution of stove-piped capability generation. One current example of pan-defence application of M&S is found in the Joint Strike Fighter (JSF) Distributed Product Description (DPD)[5] that operates in two collaborative environments: one managed by the government (focused on strike warfare) and another managed by the contractor (focused on engineering and manufacturing)[vi]. Figure 7, from the JSF DPD Project Coordinator, provides an overview of how M&S serves as a facilitation layer between the JSF DPD and the various functional elements in the life cycle. The push towards distributed and federated systems, and the rapid advances in information technology, has prompted defence organisations to support, adopt and leverage commercial standards. Distributed Interactive Simulation (DIS) and the High Level Architecture (HLA) began as US DoD efforts and then transitioned to IEEE standards (IEEE 1278 and IEEE 1516 respectively).

[5] A DPD is a web-based, distributed collection of authoritative information provided to users in such a manner as to appear as a single product representation.

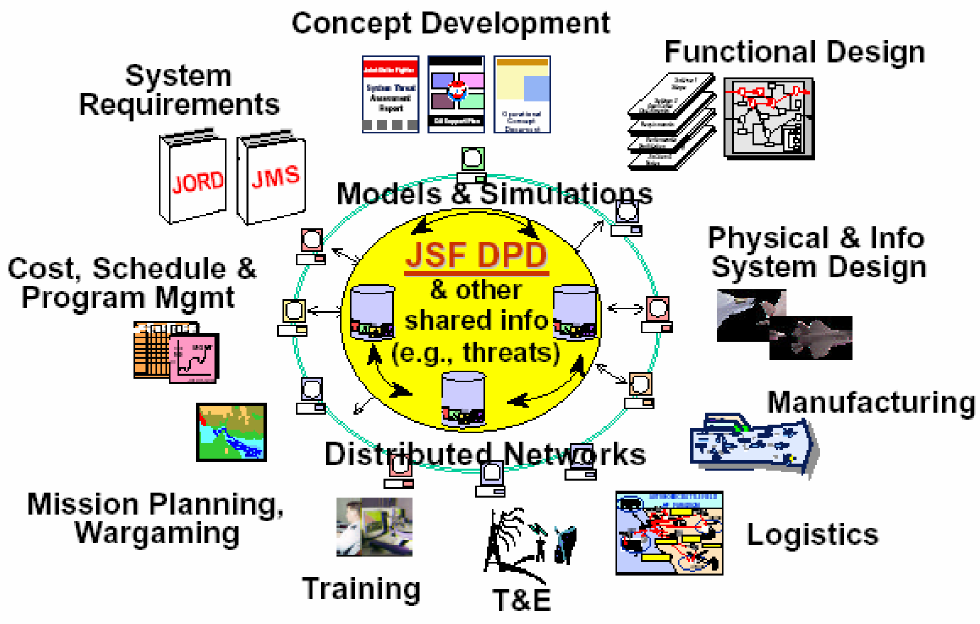

Figure 7 : JSF DPD (www.dtic.mil/ndia).

One final example demonstrates the impact on operations and culture – the push towards implementing the concept of network enabled capability (NEC).[6] In simple terms, NEC aims to leverage technical interoperability to eventually achieve conceptual interoperability amongst distributed, disparate forces to generate common, more thorough situational awareness. Herein lies the parallel: networked simulations aim to achieve a similar goal by bringing together distributed resources for a whole that is greater than the sum of its parts.

CHALLENGES

It should be evident by this point that interoperability and integration as related to M&S is a non-trivial task. There are challenges both within the realm of M&S itself and between the M&S realm and the real world.

Technology has made significant advances, to the point where technical and syntactic interoperability have been made easier (but certainly not trivial). Greater challenges reside in higher levels of interoperability (i.e. the appropriate alignment of purposes between distributed simulation participants); this becomes more important and challenging when one looks to span M&S across the entire life cycle of a capability. Other challenges include:

- Matching capability amongst participating simulations;
- Matching fidelity amongst participating systems;
- Sharing information between services and across borders (functional, domain and political); and
- Integrating legacy systems that still have a purpose.

When examining challenges that exist between the M&S realm and real world one must first recall the fundamental definition of a model: *a representation of an element of the real world for a purpose.* As such, models, by nature, will have *gaps* when compared to the real world. As one attempts to

[6] For a more detailed look at NEC from a UK MoD perspective see www.mod.uk/issues/nec/ .

interoperate M&S systems with real world systems, these gaps could prove to be problematic; the real world system might attempt to exchange, or might be expecting data/information for which the simulation was not designed to handle. As an extension to this concept, in specifying new simulation systems, designers might encounter a desire to incorporate too much complexity (in an effort to allow a more seamless interface with the real world); consequently, a challenge to abstract appropriately arises. Fundamentally, one must ensure that the necessary data can be exchanged between the two realms and that any exceptions are handled gracefully.

SUMMARY

Interoperability has long been the *Holy Grail* within defence communities world wide – particularly of late with the increase in joint and coalition operations. The shift to an increased use of M&S for training and mission rehearsal has seen a transfer of similar issues across to the M&S realm. Interoperability of distributed simulation systems began wider use in the early 1980's and has seen steady increase ever since. The concept of reuse has also become more prominent as it is closely related to, and can facilitate, interoperability – the primary question here is at what level does one focus reuse efforts.

Benefits do not come without their challenges. Many technological issues have been addressed over the past two decades with a certain degree of success. One must also address non-technical challenges – those challenges that have their roots in practical and conceptual level views of the problem domain. Finally, as the overlap between the M&S realm and the real world grows, more challenges will surface.

REFERENCES

[i] See http://www.peostri.army.mil/PRODUCTS/PC_BASED_TECH/.

[ii] APP-6 (V) NATO Glossary of Terms and Definitions, August 2000.

[iii] *The Levels of Conceptual Interoperability Model*, Dr Andreas Tolk et al, September 2003.

[iv] *Software Engineering – An Object-Oriented Perspective*, Eric J. Braude, 2001, John Wiley & Sons.

[v] The underlying concept for this ladder is an adaptation of Tolk's LCIM Model: *The Levels of Conceptual Interoperability Model*, Dr Andreas Tolk et al, September 2003.

[vi] *Building a Distributed Product Description for the Joint Strike Fighter*, Jim Hollenbach, www.dtic.mil/ndia/2001sbac/hollenbach.pdf.