

How to Implement National Information Sharing Strategy: Detailed Elements of the Evolutionary Management Approach Required

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Abstract

Data sharing is today's principal Information Technology challenge. All sectors—commercial, government, academic, and military—seek improved information exchange to achieve operational benefits, whether in the form of greater profits, improved situational awareness, intellectual advancement, or ability to respond to threats endangering respective interests. Nations and organizations within and across nations have set forth policies to promote greater data sharing, but often without empowering or enabling change agents to introduce measurably better capabilities. While progress is being made in some quarters, in others there is almost a counter-reaction where organizations are closing in on themselves, perpetuating traditional closed pockets of valuable information, even if sometimes having the appearance of adhering to the new policies. The advances are coming in fits and starts, resembling chaotic self-organizing systems, but with no overriding pressure to bring about incremental adaptive improvements. This paper describes an evolutionary management approach that addresses this fundamental failure in many current programs to achieve greater efficiency in data sharing. We advocate adoption of corresponding policy guidelines by the DoD.

1. Introduction

Data sharing (or, more broadly, information sharing) is the information technology watchword of our time. Revolutions in information exchange and interoperability are underway among organizations in all sectors—commercial, academic, government, and military—throughout the world. The change is

manifested across the IT spectrum, from policies on the strategic end to data standards and applications on the implementation end. Goals include mobilizing data, facilitating process integration, and reducing friction and costs when accomplishing transactions across enterprises and borders. For example, the US Federal Government has committed to information sharing across numerous fronts:

- The Federal Enterprise Architecture [1] includes the Data Reference Model [2] for business-focused data standardization and cross-agency information exchanges.
- The 9/11 Commission [3] highlighted the need for information sharing and a change in posture from “need to know” to “need to share” resulting in a major Department of Homeland Security (DHS) focus on interagency and local-state-federal information sharing.
- The Department of Defense (DoD) is creating the Global Information Grid (GIG) to enable information sharing across joint services and echelons to achieve goals of the Net-Centric Data Sharing Strategy [4]:
“...Net-Centric Data Strategy defines a modified paradigm for data management within the Department. This Strategy expands the focus to visibility and accessibility of data rather than just standardization. It also recognizes the need for data to be usable for unanticipated users and applications, as well as for those that have been predefined. This Strategy identifies approaches that will improve flexibility in data exchange, supporting interoperability between systems without requiring predefined, pair-wise interfaces between them. This flexibility will be essential in the “many-to-many” exchanges of a net-centric environment.”

- The Intelligence community has a major focus on information sharing; together with the DHS, it is heavily committed to the National Information Exchange Model (NIEM) [5] as a way to accomplish this.
- The Department of Defense participates in the Multilateral Interoperability Programme (MIP) [6] to promote interoperability of command and control information across coalition partners, with the need to extend capabilities to various agencies and Non-Governmental Organizations (NGOs). Several DoD services and programs are committed to adopting the MIP-managed Joint Command, Control, and Consultation Information Exchange Data Model (JC3IEDM) as a common interchange structure and protocol.

Similar initiatives are underway world-wide. In February 2004, the MIP (introduced above) and the North Atlantic Treaty Organization (NATO) Data Administration Group signed a memorandum of agreement stating intent to collaborate in data modeling efforts to produce the JC3IEDM [7]. To address threats of terrorism, numerous nations are working together to achieve greater ability to share information of critical importance rapidly in finding and defeating terrorist organizations [8].

While these initiatives are important to achieving more efficient and cost-effective data sharing capabilities, many systems already existing around the world embed legacy information models. For the most part, these systems do not interoperate. What data exchange exists often is implemented through highly specialized point-to-point interactions between the systems. Such systems cannot be replaced quickly or affordably. Despite the desire to share information effectively, there is significant inertia perpetuating low levels of interoperability and information sharing.

In the commercial sector, businesses have been working on collaborative enterprise methods for more than 20 years. Lately, significant advances have developed around a few related ideas:

- Transaction-centered process reengineering, where business processes are redesigned and re-implemented to optimize efficiency in discrete units of value [9]
- Service-oriented architecture (SOA), where software services can be shared over a widely interconnected network [10]
- Information models using the World-Wide Web Consortium (W3C) Extensible Markup Language (XML) and other open web-based standards and methods to define the payloads these services operate upon [11]

These new methods can gain leverage from existing systems and infrastructure, but they attempt to

introduce incremental changes rather than wholesale replacements. Under best practices, the incremental changes instantly provide value along a dimension of interest, whether quality, timeliness, cost, or other measure. Given the urgency and perceived high value, executives want to move quickly to implement information sharing. They tend not to understand the alternative methods available or their relative costs and benefits. They are prone to making simplistic and bad decisions. However, making wise decisions in this arena is vital. Because we have limited resources even in the DoD, the external environment is continually and rapidly changing and we can at most achieve a small fraction of all possible information sharing objectives in the near term.

We need a smart implementation strategy to ensure that we get significant bang-for-the-buck as early as possible. Real problems demand real solutions through representing meaning that matters; that is, by providing solutions that directly meet an operational requirement to provide a measurable benefit. Different concerns and problems require different semantics. As nations and organizations address the information sharing challenge, multiple problems are being addressed through co-evolving semantic bodies. Given the extremely large differences in the problem contexts involved, there is a need to describe how to manage the numerous semantic portfolios effectively and efficiently. To do so in a deliberate and coordinated fashion across the broad national and international arena, policies and process guidance is needed. We will show that current approaches (such as communities of interest, federated registries, and other techniques in vogue today) need such support to be effective. First, though, we describe the vision for bringing direction to the chaos.

2. Desired outcomes and qualities

The information sharing problem we have described manifests several principal challenges, including broad scope, urgency, intellectual complexity, and a variety of interested parties and their associated concerns. We must adopt engineering and investment approaches that can meet these challenges and deliver substantial positive returns for our efforts. The specific challenges define a broad space of potential engineering efforts, which implies that we consciously need to adopt a portfolio management approach. Specifically, we should assess potential information sharing efforts from a benefit, cost, and risk viewpoint, aiming to spend precious money wisely. In short, we want an approach that ensures we attain the best “bang for the buck” we can. In the case of information sharing, that means we want to implement

the most valued information exchanges we can, incrementally, with minimum delay, cost and risk of failure.

Our national imperative to foster a culture of information sharing results from an obvious inability to accomplish important interagency processes quickly and effectively. In the Defense Department, moreover, we want to integrate capabilities into effective joint and coalition forces. This requires systems from different services to participate in cooperative business and command-control processes. In short, we need to put together “value delivery chains” that move information across organizational boundaries to deliver benefits to users who don’t really care about the internal details of those processes.

From this standpoint, we need information sharing to increase productivity in the domain of interest. Productivity measures benefit delivered per unit cost. Productivity increases by delivering results that users value more and by reducing costs and other factors that delay or degrade the value of deliveries. Thus, value derives from users and what they need information for. Succinctly, if certain information can improve user decisions and the outcomes of user missions, users will value that information. The more value delivered, the better. At the same time, we’d like to minimize the cost of delivering the valued information. In the case of information delivery chains, costs generally correlate with the number of people and processing steps required to move the information from its source to its ultimate recipient. Such costs accrue in the form of poor data timeliness, reduced quality, inaccuracy, and human/machine processing and communications bandwidth expended. The fewer hands and steps involved, the lower the cost. Information value suffers when any of the 5C+S qualities (concurrency, completeness, conciseness, consistency, correctness, and significance [12]) degrade as typically results from increases in latency, ambiguity, redundancy and noise.

Efforts to implement information sharing, therefore, should focus on increasing the productivity of transactions that deliver valued information. We seek implementations that can be deployed quickly to deliver high value at low cost. In moving from a world of Service-specific (speaking here of military Services such as the Army, Navy, and Air Force) and agency-specific “stove-piped systems,” we should expect that some collaborative systems that cross traditional boundaries will deliver unprecedented value. Examples of such high-value systems would include those that track dangerous people, conveyances and cargo. We want our engineering practices to generate high-value transactions as soon as possible, wherever they can be implemented affordably.

When we try to implement such transactional systems, we necessarily engage in some experimentation. We don’t always know all factors involved in integrating processes across multiple systems. Some ambiguity will exist about the precise meanings and significance of terms. Any type of value-delivery chain can improve based on empirical results and process improvement practices. When we implement information sharing value-delivery chains, we will discover how well they work and where they need improvement. In short, once we implement information sharing based on value, we will become engaged in an eternal process of continuous improvement.

The need to implement information sharing with partial, initial, high-value transactions and to engage in continuous improvement shows clearly that we are embarking on an adaptive evolutionary process. We want to bring new capabilities “to market” quickly, so we can capitalize on high-value opportunities. If we choose low-value opportunities, our returns will disappoint us and not sustain additional investments. If we dally or delay, our returns will come late or may actually evaporate as when problem characteristics change or foci shift. As in evolutionary processes, our best strategy will emphasize reuse and continuous improvement of components. In an information sharing context, such components will consist chiefly of base ontologies, domain models, and meta-models that have proved useful in earlier transactions and that can be leveraged and enhanced for additional purposes. Engineering efforts that produce low value, either because the components proved poor or the users didn’t perceive value in the deliveries, earn reduced investment going forward. Our portfolio approach, emulating natural selection, reinforces components that produce high value while we continue to add value-delivery transactions that occupy favorable (high-value) niches.

We need users and operators to be involved directly in creating the information models that support their collaboration and transactions. This assures that the transactions actually deliver what the principal users judge valuable. Involving the users also accelerates continuous improvement, because they quickly detect problems and missed opportunities. Leaving users and operators out of the process would significantly reduce the value of the portfolio we create and employ.

3. The implementation management approach: adaptive evolutionary portfolio strategy

Our goal, then, is to specify the basis for a national strategy for information sharing grounded in the pragmatics of measurable value delivered. In this section, we address the key assumptions underlying the approach and then describe the proposed management approach to begin the evolutionary transformation of our information sharing practices.

3.1. Key assumptions

As a basis for the proposed approach, we make a number of assumptions about the current state of practice and policy. Although the information sharing challenge is faced at national and international scales, we focus on the Department of Defense (DoD) as being representative of the larger scale issues and needs while also being the principal research and development focus of the authors of this paper.

First, we assume at least one identifiable approach exists which can bring the DoD to a significantly higher state of information sharing. This assumption is validated readily by observing the benefits achieved in the private sector from the approach we advocate.

Second, we assume the management culture in DoD will allow the proposed approach to be adopted. To be candid, this is the largest potential pitfall for any effort that tries to make a major change in DoD procedures, and is likely to be an even greater challenge for information sharing. The history of information innovations in DoD is littered with programs that failed because of the well known (if poorly understood) distractions in the environment:

- *Too many problems and opportunities:* There are innumerable challenges in DoD. An extremely high level of discipline is needed to focus on a few of the most important.
- *Too little time and money:* There is never enough of either, so top leaders must cut budgets ruthlessly among that large fraction of programs that are not producing high gain, in order to devote funds to information sharing that will make a difference.
- *A total solution is impossible, too costly, and/or too late:* This is unfortunately a basic truism but, rather than being a cause for despair and paralysis (“best is the enemy of better”), it should motivate us to realize that workable partial solutions exist and can make a significant difference in the capability to share information across major parts of DoD.

- *Program timelines are not synchronized:* Different lifecycles cannot be rigidly aligned. Best practices must be adapted incrementally if possible.
- *Sharing of information can be damaging to program funding or reputation:* There has long been a culture of information hiding to protect programmatic interests, even when more open exchange may have resulted in earlier cost-savings through changes to the program. The difficulty in obtaining program verification, validation and accreditation (VV&A) information is a key example. There is hope that future program managers and project leaders from today’s FaceBook and MySpace generation will bring with them a new culture of openness that will further stimulate the proposed approach. This is a realistic assumption since open-source collaborative programs already show the best rates of progress, overall quality and affordability.

It is frightening to realize that logical evolution of current directions in DoD is highly likely to run into barriers due to at least one of these pitfalls, and more likely to all four. This does not mean that information sharing is doomed to failure in DoD, but rather that leadership needs to adhere ruthlessly to best practices of commercial success stories that combine principles of natural selection, intelligent software architecture, and smart portfolio management. This will require that:

- Multiple paths are pursued simultaneously across the enterprise.
- Modular, interoperating namespaces are developed by empowering users with simple rules that emphasize value chains.
- Resources are directed to opportunities where the benefits are greatest, following the epidemiological approach, which recognizes that, while complete success is impossible, intelligent management can yield significant breakthrough results.
- Successes are leveraged through reuse of best capabilities and resource allocation, to feed a spiral of growing success.
- Correspondingly, failures and competitive losers are pruned to free resources for the successes.

3.2. Specific proposed management approach

To succeed in information sharing at the national or international level, we certainly need to emulate the best practices established in industry. Here we summarize the main lessons learned from those successes.

First, information sharing should focus on high-value transactions that require effective collaborations between partnering agencies or enterprises. To do this, we must identify the critical elements of information

within the problem domain, determine how to define and model these, and make explicit how value-delivering transactions share that information between their process steps. We must maintain focus on our goal, namely to deliver high value quickly at affordable cost. We should assess and prioritize alternative development efforts in terms of return on investment (ROI) or return on assets employed (ROAE). Advanced and proven tools and techniques for information modeling should be leveraged where possible.

Because we are maintaining an evolutionary portfolio of information model components and enabled value-delivering transactions, we want to adopt architectural processes that improve our implementation capability over time. Specifically, we want to capture, generalize and reuse proven information models as components as well as patterns of sharing that improve the quality of transactions. While this kind of learning and product line architecture increases short-term costs, returns on these investments should pay back handsomely as we find ourselves implementing additional valued transactions faster, better and cheaper.

Thus, information sharing depends on a deliberate plan to develop a portfolio incrementally, study results obtained, harvest and manage components that prove useful, and consciously exploit those architectural patterns to increase engineering efficiency over additional applications. This type of software product line, architectural approach depends on continuous support by architecture teams responsible for implementing multiple transactions across multiple components. In particular, this result does not occur in the absence of a responsible and qualified organization charged with that mission.

Application of this proposed adaptive evolutionary portfolio approach over time will bring about a steady state characterized by hundreds of thousands of high-value transactions occurring across multiple systems and domains, with hundreds to thousands more identified and prioritized for implementation based on experimentally and/or analytically measured value to be gained. Hundreds to thousands of highest-value information engineering efforts will be underway at any point in time, namely those that implement the highest bang-for-the buck transactions or high bang-for-the-buck architectural components.

Associated architecture will consist of reference use cases, reusable vocabularies, conceptual models and grammars, relevant standards, and supporting tools (or other elements of the artifacts that are applicable), including simulations for measuring value delivered from architectural, procedural, or transactional changes. All of this will transpire in an environment of open information sharing at the programmatic level as well,

where knowledge of implemented and in-process information sharing transactions and applications will reduce duplication of efforts.

4. Best practices

As indicated above, we model our proposed strategy on proven best practices. Both the business and government arenas have yielded successes worth emulating. The need is to ensure such successes are attained systematically and consistently. We consider the best practices of business first and then consider some observed best practices in government.

4.1. Business best practices

Information sharing in business focuses on enabling collaborative commerce, i.e., value-delivery chains assembled from multiple partner companies. Most products and services reach the end customer through such delivery chains today. Globalization emphasizes the ability to transmit information among these partners across the entire world. Principles of just-in-time, lean and agile manufacturing emphasize reducing costs and capital by synchronizing flows to minimize inventories, idle resources, and latency. In a nutshell, best business practices seek to increase the value produced in proportion to the assets employed.

When applied to information processes that deliver valued information, the same concerns apply: maximize value delivered in proportion to assets employed. When we look at implementing information value-delivery chains then, we see two ways that must consume assets. Any product, new or old, incurs two kinds of engineering costs, those non-recurrent engineering (NRE) costs involved in designing and producing the first product and the recurrent engineering (RE) marginal costs required to improve product and production processes. Both costs contribute to the denominator of a return on investment (ROI) or return on assets employed (ROAE) measure. Typical information systems departments rank opportunities for new projects using these ratios, determining which new or improved systems will yield the greatest benefit for dollar consumed. Thus, Information Systems departments regularly manage their systems as *portfolios of capabilities delivering valued transactions* against an associated investment base. When choosing between two alternative investments, the prudent business prefers investing where it can deliver the greatest improvement in value to its customers per dollar spent.

Many efforts have focused on how collaborative enterprises can implement high-value transactions, where eventually an obvious answer emerged.

Companies that want to implement collaborative commerce need to identify, focus on, and explicitly implement such high-value transactions. The industry refers to such transactions as “straight-through processing.” When collaborating companies create information models for sharing in such arenas, they seek to find or build a portfolio of components that enable the companies to assemble high-value transactions. Each transaction comprises multiple process steps performed by partner companies and data connecting the steps employ the portfolio of agreed information models as a basis for representation and meaning.

Service-oriented architecture (SOA) borrows this high-value portfolio approach and abstracts it further. In SOA, business processes consist of choreographed services mediated by information exchanges. The business partners offer various services. The information exchanges adopt agreed information models as their standard semantic foundation.

To date, two organizations have led the way in developing collaborative business processes following this approach. RosettaNet, the first, focuses on transactions for purchasing electronic components. The Mortgage Industry Standards Maintenance Organization (MISMO), a more recent effort, focuses on transactions for obtaining real estate mortgages. The straight-through-processing in both areas aims at helping buyers complete acquisition of a valued good with 5C+S qualities. In addition, the groups both emphasize agile commerce objectives whereby new service suppliers can join the marketplace simply by understanding and supporting the agreed information models. The entire marketplace increases productivity through a shared commitment to collaborative processes that define what information means and how the partners will use it to add value.

When we consider such successful collaborative enterprises, several important characteristics stand out. First, they are driven by ROI, which means they want to deliver significant new value to the users, soon, while achieving maximum bang-for-the-buck. Second, all of the transactions require business-to-business information exchanges, so the partners must agree on meaning and representation of information. Because everything has associated costs, they look for ways to achieve high return soon, while deferring less attractive efforts till later. Because they expect to engage in long-term development and expansion of their collaborative activities, they seek architectural approaches that can reduce their NRE costs and also improve their ability to reuse components for new purposes. In this regard, they view information sharing for collaboration as a broad area of product opportunity, and see the benefits of

software product lines [13] and product line architectures [14] to reduce their costs.

Architectural approaches to software, such as information models for collaborative enterprises, can produce orders of magnitude improvement in productivity because they reliably improve product quality while reducing cost and time to market. Boiling down the lessons learned from numerous studies, the best software architectures incorporate experience from practical applications and generalize these into reusable patterns and components. In the information sharing arena, this means that successful engineering efforts will exploit architectures that have learned good answers to these questions:

- What information to model
- How to model it
- What services have greatest value
- How to implement and access services

Architectures have great value for entire marketplaces. The best architectures reduce the cost of entry to new partners, so the community of contributors to valued processes increases rapidly. The larger the number of players who participate in the architecture, the greater the benefits for collaborative enterprise and the less the cost for all participants.

In sum, the best commercial practices for creating information models to support collaborative enterprise involve: (1) a collection of collaborative partners who have a business stake in delivering new and improved value to customers through straight-through-transactions; (2) development of reusable information components that can link services provided by any partner in overall transactions that deliver high value at low cost; (3) a portfolio approach that focuses first on high bang-for-the-buck transactions; and (4) an empirically-driven architectural approach that identifies effective components and patterns from early wins and incorporates these into reusable elements that guide and improve subsequent developments.

4.2. Government and military best practices

The US Government and Department of Defense have been particularly careful observers of commercial practices over the past decade. The current era of declining Research and Development budgets in the DoD has stimulated the initiation of several transformations to information management and processing practices. The most extensive of these is the Global Information Grid (GIG). Here we take a brief look at this initiative and some of its implications in light of the proposed adaptive evolutionary management approach to information sharing. We follow with brief discussion of some other military and government initiatives relevant to the proposed

approach, in order to further motivate the concepts and principles.

4.2.1. Global Information Grid and Net-Centric Data Sharing Strategy. In the US Department of Defense, including DoD intelligence agencies and functions, the guiding document for information sharing is the Net-Centric Data Sharing Strategy [4]. The document defines net-centricity as “the realization of a networked environment, including infrastructure, systems, processes, and people that enables a completely different approach to warfighting and business operations.” The network foundation is the Global Information Grid, “the globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating, and managing information on demand to warfighters, defense policymakers, and support personnel.” Data assets addressed by the strategy include system files, databases, documents, official electronic records, images, audio files, websites, and data access services. Users and applications can search for and “pull” data as needed, or they can receive alerts when their subscribed data is updated or changed. The goals of the strategy are to make data:

- *visible* - users and applications can discover the data assets
- *accessible* - users and applications can obtain the data assets
- *institutionalized* - data approaches are incorporated into DoD processes and practices
- *understandable* - users and applications can comprehend the data, both structurally and semantically to address specific needs
- *trusted* - users and applications can determine the authority of the source of the data assets
- *interoperable* - metadata is available to allow mediation or translation of data to support many-to-many exchanges of data
- *responsive to user needs* - mechanisms for improvement through continual feedback are supported to address particular perspectives of data users.

The data sharing strategy is being addressed through (1) self-organized Communities of Interest (COIs) for identification and maintenance of data; (2) metadata describing the data assets; and (3) GIG Enterprise Services supporting data tagging, sharing, searching, and retrieval. Numerous COIs have formed in recent years to define information sharing requirements within their respective domains and across domains. The Net-Centric Data Sharing Strategy directs COIs to take the lead in establishing COI-specific metadata structures, defining community

ontologies, cataloging data and metadata, and having members post data. A *community ontology* “provides the data categorization, thesaurus, key words, and/or taxonomy” that can be used to “increase semantic understanding and interoperability of the community data” [4, pp. 5-6]. Taxonomies “enhance discovery by providing a hierarchical means of searching for data while providing users and applications with additional insights about data assets by indicating their placement among other data assets” [4, p. 15]. Furthermore, COI-developed vocabularies will define terms used in describing data assets, and the thesauruses will identify related terms to assist translation services. Many COIs are posting schemas, taxonomies, and ontologies actively to the DoD Metadata Registry in order to inform the community of important data structures, to stimulate re-use of common information elements, and to support data mediation.

Through the establishment of policies and overall service-oriented framework, the GIG and Net-Centric Data Sharing Strategy provide the vision for evolution of information sharing practices. The top-level vision and policies have not been faulty; but the lower-level practices toward achieving the high-level information sharing goals have been hit-or-miss, lacking direct guidance. Progress toward the grand goals has been sporadic, without a clearly defined management approach for adaptive evolutionary implementation guided by best value as described in this paper.

4.2.2. National Information Exchange Model (NIEM). The NIEM “is designed to develop, disseminate, and support enterprise-wide information sharing standards and processes across the whole of the justice, public safety, emergency and disaster management, intelligence, and homeland security enterprise at all levels and across all branches of government” [5, p. 1]. The NIEM seeks to enhance governmental decision-making through accurate, timely, complete, and relevant information and to achieve greater efficiency, effectiveness, and ROI in operations by accelerating information exchange design and development. A major goal is to break down the stovepipes that have previously prevented real-time, secure, enterprise-wide information sharing.

The NIEM is not a nationwide integration of local, state, tribal, and federal databases, but instead focuses on cross-domain information exchanges through defined information exchange package documents (IEPDs) available through an online repository. The NIEM provides consistent structure and semantics for common interpretation of data across systems. The NIEM “Core” consists of data components that have agreed-upon semantics and structure by all domains. The Core data components can be extended for

domain-specific purposes by each domain, while retaining commonality of the agreed-upon elements for information interchange. The NIEM employs standard engineering practices for software management and has established processes for explicit governance of the model.

The concept of domains in the NIEM extends and broadens the COI concept described above for the GIG. Domains are expected to provide content to NIEM, provide domain subject-matter expertise to support content development, have existing COIs or the ability to enroll or formulate COIs, possess the ability to perform outreach to relevant COIs, support their own governance, participate in NIEM governance as appropriate, maintain strategic alignment within the scope of NIEM, agree to the principles and practices of NIEM including conformance to NIEM Naming and Design Rules (NDR), maintain alignment with the NIEM taxonomy, and authoritatively support internal and external harmonization [5, p. 8].

It is striking that these major information sharing efforts embodied in the GIG and the NIEM have similar approaches: top-level information sharing vision and policies enabling self-organizing communities of interest to form, driven by information needs identified within the COIs and the directives for information sharing across COIs (and domains, in the NIEM terminology). The policies of both provide a certain degree of evolutionary pressure on the system, but lack the precision needed as we've discussed previously. Such pressure must surely come from the need to meet operational needs. This is slowly moving the enterprise toward more effective information sharing but it is inadequate to achieve the needed value before the effort is overtaken by the well-known pitfalls described above. Articulation and establishment of the focused evolutionary management approach advocated here can accelerate these advancements sufficiently to make the effort successful. The following example illustrates this point, showing how emphasis on operational pragmatics undergirds development of information solutions.

4.2.3. Maritime Information Exchange Model (MIEM). DoD often has used Joint Capabilities Technology Demonstrations (JCTDs) to accelerate introduction of new capabilities into the armed forces. Since 2006, the Comprehensive Maritime Awareness (CMA) JCTD has been developing improved fusion techniques for tracking vessels, people and cargo of interest and a maritime information exchange model (MIEM) to support collaborative tracking with other agencies and allies. The MIEM has just entered Beta test [15] after an earlier period in 2007 of Alpha testing. To create the MIEM, an architecture team

gathered stakeholders from across various government agencies who were concerned with improving the creation and sharing of actionable intelligence. The architecture team and stakeholders developed more than 100 scenarios of high-value transactions that they wished the MIEM to enable. Scenarios were prioritized in terms of expected value and development cost and risk. Stakeholders rated all scenarios in terms of “bang for the buck.” The architects selected the top one-third of these for initial development focus.

From these scenarios, about 100 vignettes were created illustrating in concrete ways specific information sharing cases. These vignettes would be used to motivate and validate the information model ultimately created.

The MIEM team adopted several best practices from industry including a focus on straight-through-processing, XML schemas for documents that would be shared, and service-oriented architecture for collaborative processing. In addition, the MIEM models looked at current documents and reports that exist throughout the concerned agencies and worked directly with end users including US Coast Guard personnel who are responsible for boarding and inspection operations.

The MIEM modelers identified nine levels of increasing semantic richness that would support increasing levels of information sharing. At the lowest level, the MIEM model provides ways to express simple sensor reports and observations. At the highest level, entire case file histories of vessels or people of interest are modeled in XML schemas corresponding to potentially multi-year histories. In addition, because all intelligence is based on evidence, assumptions, analysis and interpretations, the MIEM makes it possible to associate rich metadata with all assertions, so that every belief can be traced to its origins and intervening inferences.

The Maritime Domain Awareness (MDA) COI was established contemporaneously with the CMA JCTD. Their data sharing working group began independently to define simple XML schemas suitable for sharing sensor data such as Automatic Identification System (AIS) vessel transponder reports. In 2008, the working group is participating as a Beta tester of the MIEM. A preliminary assessment of the MIEM for modeling and sharing Advanced Notice of Arrival data has proved successful.

In formulating the MIEM, the team used best practices from industry. They occasionally encountered other players in the broad maritime community who had concerns different from the actionable intelligence for threat interdiction that primarily motivates the MIEM. Such differences are natural and can't be avoided. The MIEM team maintains a backlog of

possible extensions in both semantic content and pragmatic purpose, but these are unlikely to warrant near-term engineering efforts. Making the first high-value transactions effective is the principal focus.

The MIEM developers emphasized discovering semantic requirements from value-delivery use cases. This gives the MIEM a strong flavor of “actionable intelligence,” because valued information transactions end in detecting, interdicting, and investigating threats. To perform those functions effectively and in a timely manner requires that end users receive clear, detailed, and substantiated assertions about mobile threats in their area of responsibility. The end users’ requirements directly determine what semantics the information model must address. Steps in these transactions, which may include judicial review for probable cause, also strengthen requirements for explicit and sound treatment of evidence within explicit inference chains.

4.2.4. Multilateral Interoperability Programme (MIP). The MIP is a multi-national organization for defining and maintaining a joint command and control information exchange data model (JC3IEDM). Nations participate in the program to work toward more effective means of sharing information in coalition operations. Several nations have adopted the data model for use in their own internal C2 systems and modeling and simulation (M&S) systems to facilitate data interchange and interoperability. In the US, JC3IEDM-based initiatives are in progress in all military services and within the Joint Forces Command. As with the NIEM, the focus of JC3IEDM is on data interchange, not the data models employed by the individual systems. The JC3IEDM defines a core model (earlier called the *generic hub*) to which users can apply extensions. The MIP has established governance processes to manage the definition and content of the data model. The community provides multiple representations (XML schemas for logical, physical, and object-oriented representations) and standard implementations for broad adoption of the model across nations and organizations.

The open availability of the JC3IEDM has stimulated commercial development of tools, C2 systems, and simulations. By employing the established data model and by adhering to rules for model extension, these products are assured of the ability to exchange information with numerous other systems. New classes of solutions to operational needs are being fielded rapidly, in contrast to the long and expensive development lifecycles of earlier C2 and M&S systems. Establishment of common structures and semantics, grounded by established practices for model evolution, is meeting broad information exchange requirements in the C2 and M&S communities.

4.2.5. Aligning data models: lessons learned. Under the auspices of the Anti-Submarine Warfare (ASW) COI Data Management Working Group and the Department of Navy (DON) Chief Information Officer (CIO), the Undersea Warfare XML (usw-xml) Working Group is aligning data models to support the common transactions needed between tactical systems, simulation models, and robotics systems. The group is contributing software and XML conversion capabilities to the upcoming Autonomous Underwater Vehicle Festival (AUVfest) in Narragansett Bay 12-23 May 2008 [16] for planning AUV missions, tracking AUV mission execution, and recording AUV telemetry. Focusing on dual objectives of mine countermeasure operations and marine archaeological explorations, AUVfest 2008 provides a case study for exploring and evaluating actual results from mapping C4I vocabularies together in this domain. The work integrates several components:

- ASW Tactical Assessment System (A-TAS), a system for bringing together surface, air, submarine, integrated underwater sonar system arrays, and other asset information into a common undersea picture for analysis. A-TAS uses the Tactical Assessment Markup Language (TAML) to describe platform, contact, and sensor information. TAML is an approved submission in the DoD Metadata Registry.
- JC3IEDM-enhanced Tactical Collaboration (JTC), a prototype Navy C2 system developed by the Naval Undersea Warfare Center (NUWC) to enable entry of Operational Tasks (OpTasks) and observation of activities in the area of operations. JTC employs JC3IEDM as its internal data model as well as for content and structure of tactical messages (using the JC3IEDM Object-Oriented XML schema).
- Autonomous Unmanned Vehicle Workbench (AUV Workbench) [17], a simulation system enabling planning of AUV missions, simulated execution of the missions, and playback of recorded vehicle telemetry, whether generated by the simulation or from actual vehicles. The AUV Workbench employs the Autonomous Vehicle Command Language (AVCL) [18], to represent goal-oriented mission requirements (e.g., patrol an area of interest), detailed mission scripts (e.g., specific rudder and motor control commands), and recorded telemetry data.
- Distributed Interactive Simulation - XML (DIS-XML), an XML representation of DIS packets [19] used to broadcast vehicle information for use by visualization tools and other simulations.

Data transport occurs over standard DoD-approved XML-based chat channels using the Extensible Messaging and Presence Protocol (XMPP) [20]. 3D situational-awareness visualizations are produced in a data-driven fashion using Extensible 3D (X3D)

Graphics, the open International Standards Organization (ISO) approved royalty-free modeling standard for Web-based simulation [21].

Current transaction processing includes: (1) mappings from JTC-generated OpTasks (JC3IEDM XML) to AVCL agenda missions; (2) mappings from AUV Workbench-generated mission waypoints in AVCL to Route structures in the OpTask for viewing in JTC; (3) mappings from AUV Workbench-generated position reports in DIS-XML to JC3IEDM position reports for viewing in JTC; and (4) mappings from AVCL telemetry files to TAML track data for viewing in A-TAS. Such broad interoperability is only possible through the simplicity of XML-to-XML translation, strictly guided by carefully constructed logical mappings between vocabularies to ensure semantic correctness. Future work will include integration with the Undersea Warfare Decision Support System (USW-DSS) for more extensive operational experimentation.

The goal of these efforts is to achieve coherent data interoperability among multiple ASW systems using open standards. As advocated in this paper, the technical approach allows graceful, deliberate evolution of existing systems via incremental development and integration of capability. The work is compatible with evolving GIG, DON CIO, and DoD requirements for XML data interchange and is extendable to other C4I systems via a common abstract data model and repeatable methodology. Interaction through JC3IEDM also enables the long-term goal of C4I compatibility with coalition partners.

A common pattern is emerging from these efforts. Dozens of various representations of track data and operating area information share similar semantics. It is interesting to note that some of the languages involved (JC3IEDM, DIS, AVCL) are themselves correlations of other interoperable languages serving a variety of systems. Interchange is obtained through pair-wise semantic correspondences between the XML representations. Web Services and Service-Oriented Architecture (SOA) are the obvious and most common transport mechanism; live streaming using XMPP chat channels also is proving to be a viable alternative means for distribution of XML data. Approval to use well-known ports through institutional firewalls is another key benefit of this standards-based strategy.

While there is general concern about the size and speed of XML data over limited bandwidth tactical networks, binary compression efforts in W3C's Efficient XML Interchange (EXI) show that effective compression is feasible and even superior to tuned, handcrafted binary protocols. In the grand scheme, working with XML across a range of C4I transport mechanisms enables a coherent network architecture

rather than a collection of semantically disconnected stovepipes.

Looking ahead, establishment of XML interchange capabilities will further allow creation of generic semantic relations and rules using Semantic Web constructs. Implementation of principles enabling receipt of valued information at the right time (VIRT) appears to be practical and even more effective than the corresponding set of stove-piped semantic rules which each C4I island has maintained over time. The more systems are able to talk together, the more they will become able to reason together. Demonstrating such semantic convergence, riding atop harmonized tactical languages, is the next great challenge.

5. Tarpits: practices to avoid

In contrast to the proposed evolutionary management approach to information sharing, common pitfalls are worth mentioning so that they can be deliberately avoided. To wit:

- Various renditions of “boil the ocean” where there is an attempt to model too much before implementing value-delivering capabilities.
- “Theoretical” mandated solutions lacking evolutionary pressure for fit-for-function, often manifested in PowerPoint or “paper” models that are not backed up by implementations showing measured, demonstrated benefit in uses between agencies.
- One size fits all, a danger that can occur from naïve adoption of substantial models such as JC3IEDM. The value of information sharing cannot be assumed for all users of the model, but must be evaluated against the operational problem being addressed.
- Simple answers to hard problems often don't exist. Some seek a universal common solution to information sharing that is neither universal nor common. This can also be manifested in application of emerging semantic approaches that are misapplied, such as attempting to use descriptive logics for problems dealing with spatiotemporal or behavioral information. Solutions emerge directly from a cogent focus on pragmatic requirements, but technological novelties or faddish approaches are often promoted without clear understanding of the problem to be solved.
- Unconstrained “donations” of non-valuable XML to schema banks, such as the DoD Metadata Registry and Clearinghouse, with independent development of numerous namespaces and coerced adoption of inappropriate models to reduce diversity.
- Paving cow paths evinced by rising costs associated with sustaining legacy systems and approaches that

should be abandoned as well as expensive efforts to model “as-is” that delay or prevent actually needed “to-be” developments.

- Isolating engineering development from operations, thus raising hot-house flowers for jungle environments as evidenced by laboratory demonstrations that don’t address issues of collaborating enterprises through insufficient scale and scope. Collaborating enterprises need to define what will improve their performance and then cooperatively implement realistic and robust solutions. R&D engineers often don’t know what the end users’ operational issues really are.
- The “big bang” approach to replace the entire current suite of methods and processes with a new system that purportedly does everything required. This approach almost never works because the new systems don’t spring forth complete and correct leaving the organization without anything viable in the interim thereby creating friction, distrust, risk and opposition.
- Not executing a rapid implement-test-improve-repeat cycle for development and evaluation. Version control, unit testing, bug tracking and automated update deployment are necessary support mechanisms.

7. Conclusions and recommendations

An evolutionary management approach can address the fundamental failure in many programs to achieve greater efficiency in data sharing. Our recommended approach focuses on processes that provide incremental, evolutionary delivery of value addressing specific targeted problems of interest. These principles have been tested in multiple XML-based systems. A common theme is identifying and exploiting value chains for early success, followed by a process of continual improvement.

Critical next steps involve identifying which policies need to be changed and how, formulating new policies that may need to be written, sustaining key pilot projects and initiating additional pilot projects that adhere to and demonstrate the proposed approach. We believe the DoD and NIEM strategies for information sharing need to adopt this approach in order to succeed.

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Acknowledgements

The opinions expressed in this paper are those of the authors and do not necessarily represent the positions of their respective organizations.

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