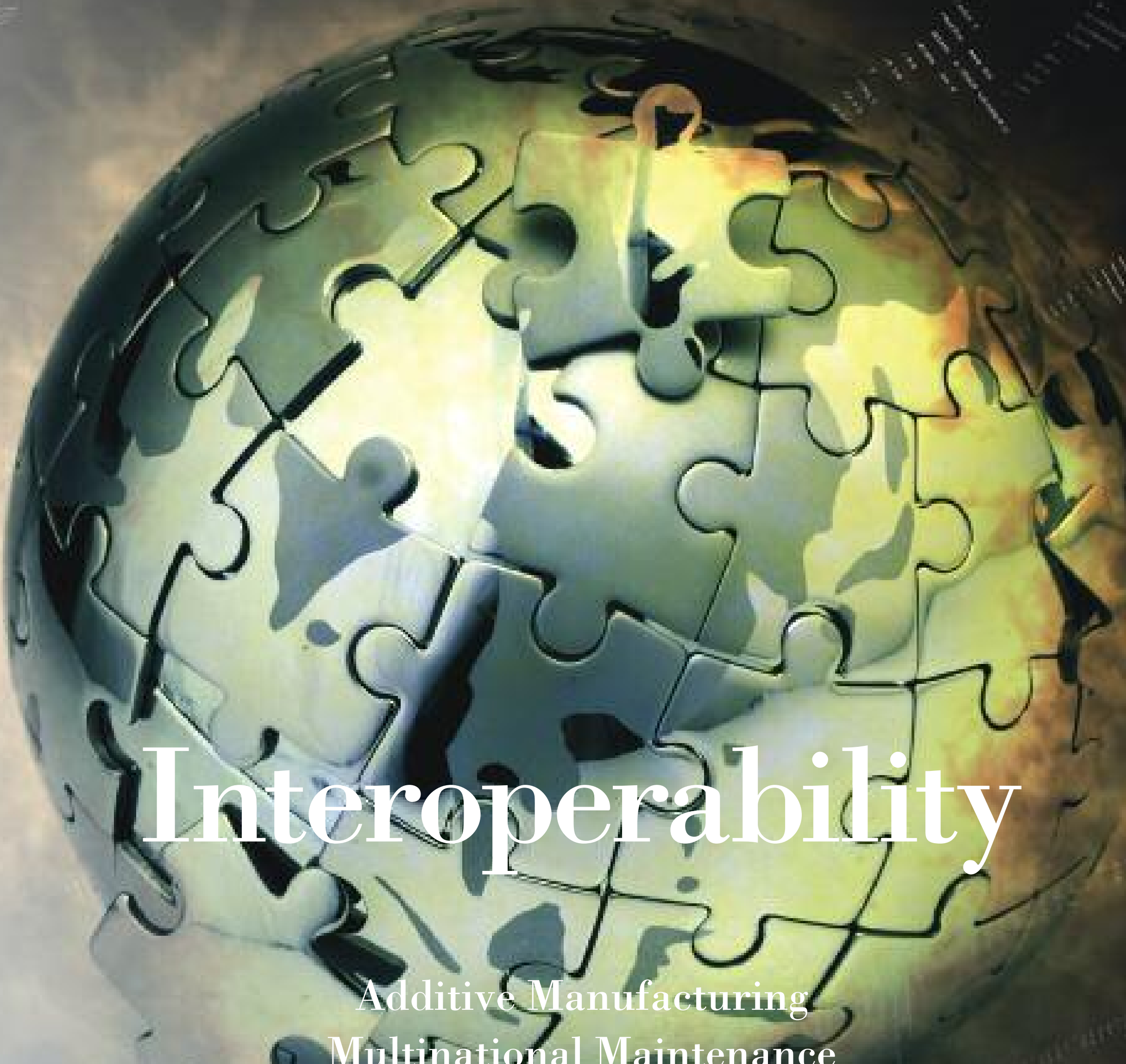
Defense Standardization Program

Journal

July/September 2013



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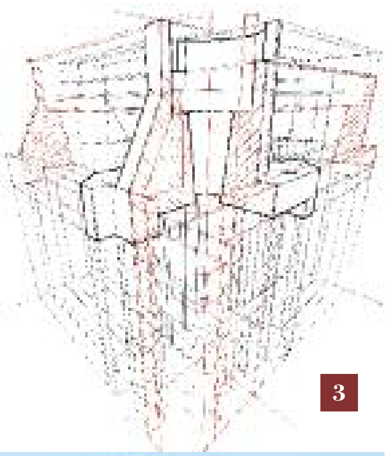

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Director's Forum

"Interoperability is the ability of making systems and organizations to work together (inter-operate)." Source: Wikipedia.

Defense Standardization Program Office – Making Systems Work Together. Source: DSPO Logo.

The Defense Standardization Program has always been about "Making Systems Work Together."

Though often talked about purely in terms of information technology, interoperability is crucial at many different levels: signal, data format, communication protocols, and languages, to name a few examples from the IT world. But thread size, voltage requirements, connector configuration, and material compatibility are equally important in determining physical interoperability. One of the old stories about standardization comes from the Great Baltimore fire of 1904 when it was discovered that fire hoses from the surrounding jurisdictions—Altoona, Annapolis, Chester, Harrisburg, New York, Philadelphia, Wilmington, and York—could not be used at the hydrants in Baltimore. Some of the hoses fit Baltimore hydrants; others did not.

Though better today, there is still a lack of standardization among fire hydrants. According to a 2004 National Institute of Standards and Technology report, *Major U.S. Cities Using National Standard Fire Hydrants, One Century After the Great Baltimore Fire*, "fire districts next to areas with different hydrant specifications carry adaptors to their equipment to connect to a variety of hydrants. For example, the fire districts near the Maryland/District of Columbia line carry adaptors because DC hydrants have 4 inch-pumper connections while the surrounding Maryland counties have national standard (4 ½ inch) hydrants." In other words, though not standard, the hoses are interoperable through the use of special adapters.

Gregory E. Saunders
Director
Defense Standardization Program Office

Borrowing a little from a NATO discussion on standardization, there are levels of standardization or interoperability. Commonality is the highest level of standardization, but it imposes the greatest restriction on innovation. The next level—interchangeability—allows for much greater innovation as long as interfaces and function remain unchanged. The least "interoperable" of the levels is compatibility, which means systems can work in the same environment without sabotaging each other, but they don't actually "work together."

Interoperability is a force and capability multiplier. Each individual unit can deploy with a smaller footprint knowing that other, interoperable forces are deploying with them. Interoperability means that a maintenance crew can draw its spares from multiple sources, often in multiple geographic locations. My radio can talk to your radio, your ammo fits my gun, my IFF recognizes your transponder, my computer understands your computer, your fuel nozzle fits in my filler tube, and on and on.

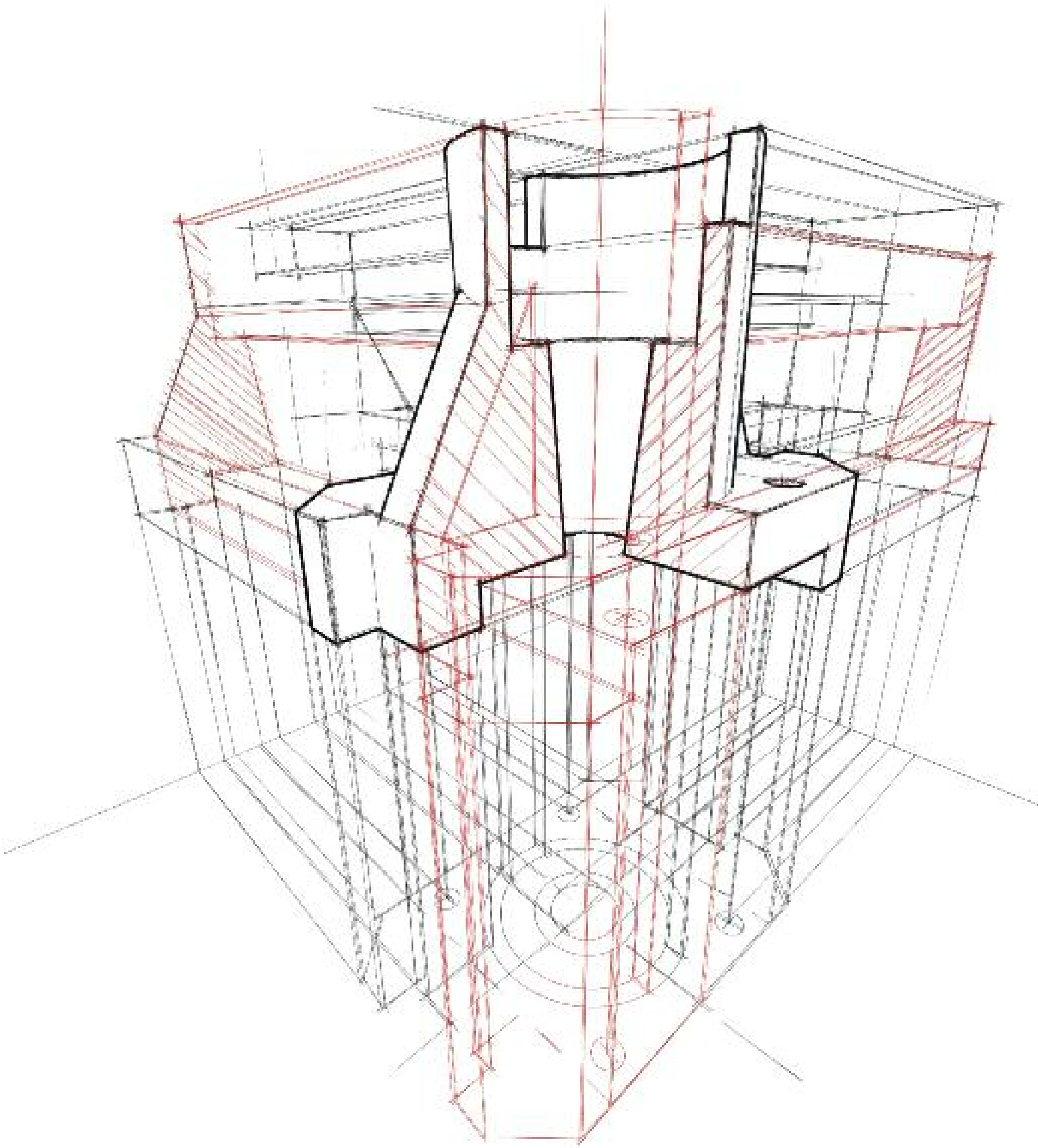
It is cliché to talk about the uncertainty of future budgets, but it is nearly certain that we will need to find ways to better our return on investment both quantitatively and qualitatively. New thinking is required, but so is renewed and innovative application of tried and true approaches. Standardization and interoperability are proven to deliver increased capability and lower costs. Mr. Frank Kendall, Under Secretary of Defense for Acquisition, Technology, and Logistics, recently said that we can't sustain current spending and at some point will have to "limit our reach to stay within our grasp."[1] Standardization leading to interoperability is one of many tools that can help us to extend our reach.

This issue of the *DSP Journal* focuses on some of the ways that interoperability can be a force and capability multiplier. Interoperable and standardized processes, materials, software, and terminology enable the kinds of additive manufacturing that produces capability for rapid prototyping, enhanced flexibility, and labor and cost savings. Interoperability also has made possible a new approach to shared, multinational maintenance in Afghanistan. Using open systems architecture is another approach that helps ensure that our systems will be interoperable and that future changes to these systems can be integrated in a cost-effective manner. By taking an open-systems approach, we are better able to handle the budgetary ramifications of our wants, while, at the same time, ensuring that our needs from a capability standpoint are met. Finally, a model-based enterprise approach—the use of 3D models throughout the product life cycle—enables collaboration on preliminary design, virtual prototyping, manufacturing, and maintenance and reduces cycle times, errors, and costs.

[1]See http://www.defensenews.com/apps/pbcs.dll/article?AID=2014301080018.

Additive Manufacturing

By Denise Duncan



It takes more than a billion parts per year to keep DoD's weapons and other systems running and, thus, to keep soldiers, sailors, and airmen safe and effective in the field. When a new technology or process is developed that has the potential to improve the logistics of providing those parts where and when needed, DoD pays attention. So it is with a new manufacturing process called additive manufacturing (AM), sometimes referred to as "3D printing."

Though additive manufacturing has existed since the 1990s, only in the last few years has it achieved a foothold in the manufacturing marketplace and matured to a point at which it is catching the attention of the defense community at large. AM has the potential to be a transformative technology, completely changing the way we think about designing, manufacturing, and delivering parts and goods. A special report by *The Economist* on manufacturing and innovation called additive manufacturing "a third industrial revolution."[1]

AM is the process of building an object by depositing layers of material, one layer at a time. Contrast that approach with our current "subtractive" processes in which we cut away, or subtract (by milling, grinding, drilling, or some other method), material from a block of metal or other material.

To imagine one AM approach, picture a laser printer that, instead of ink cartridges, has cartridges filled with very fine powdered metal or plastic. A 0.1 millimeter-thick layer of powder is laid down, and a laser sinters the powder only in those places where a cross-section of the final object will be solid. The "build platform" then drops 0.1 millimeter, and the process is repeated. Videos of AM abound on the Internet and are useful for gaining some understanding of the process.[2]

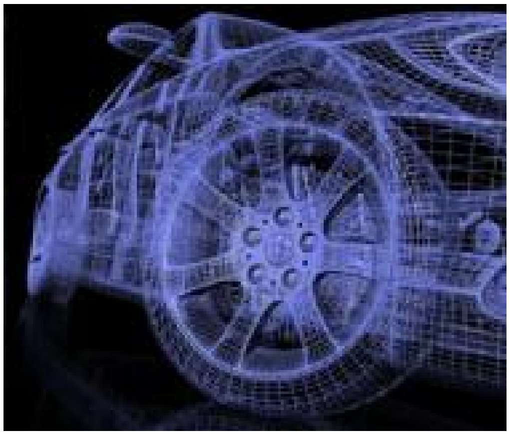
Characterizing AM by Processes Used

In general, the AM process starts with creating a three-dimensional (3D) model—for example, a wireframe model or a solid model—of the object to be built. (Figure 1 contains examples of both model types.) The model is usually created by computer-aided design software or from a 3D scan of an existing object. A 3D scan can be especially useful for repair or rebuild tasks, because the scan will capture changes to the object due to use, which is useful feedback for designers.

The next step, in almost all cases, is converting the file containing the 3D model into a file in the .STL format.[3] The .STL file is then sent to "slicing" software, which creates the layers for the AM process. After these three steps, the actual AM process takes place.

Many different AM processes exist. ASTM International has released ASTM F2792-12a, "Standard Terminology for Additive Manufacturing Technologies," which defines the

Figure 1. Example of a Wireframe Model (on the left) and a Solid Model (on the right)



following terms for AM processes:

- Material extrusion, in which material is deposited selectively using a nozzle.
- Binding of granular materials, in which powdered material (usually metal or plastic) is spread in a thin layer on the build platform and then fused. The material is fused by laser to melt it or, for some plastics, with a binder sprayed through jets. The build platform is lowered by the thickness of a single layer, and the process is repeated. At some point, the excess powder is removed and may be recycled, depending on the material and whether a binder is used.
- Photopolymerization, in which various types of polymers are solidified by exposure to various kinds of light. In vat photopolymerization, a vat of polymer in liquid form is the build platform. Starting at the bottom of the vat, a laser beam is focused in the area where a solid piece of the object is desired. The laser is then focused on higher "layers" to additively build the object. Stereolithography, one of the older forms of AM and often abbreviated SLA, is a form of vat photopolymerization.
- Material jetting, which is similar to material extrusion, except that droplets of the material are sprayed where needed.
- Binder jetting, in which a binding material in liquid form is sprayed onto powder materials to cause powder materials to join.
- Sheet lamination, in which thin sheets of materials are bonded to create a product.
- Powder bed fusion, in which electron beams and laser beams create products or parts from polymer and metal powders in a powder bed.
- Directed energy deposition, in which material is melted by a laser or other energy source as material is being deposited. This is similar to material extrusion, except that, instead of feeding melted material through a nozzle, the wire or powder feed material is melted as it is being deposited. The nozzle can be moved horizontally and vertically to deposit the material where solid parts of the desired object are to be built.

Table 1 summarizes the key characteristics of these processes grouped into three categories, or types, of AM.

Table 1. Characteristics of AM Types

Type of AM	Process name	Materials	Process
Material extrusion, or deposition of molten material	Fused deposition modeling	Plastic or metal wire	Material is melted and extruded in layers to build up the object.
Binding of granular materials	Electron beam melting	Titanium alloys, including gamma titanium aluminide	The electron beam melts metal powder in thin layers in a vacuum.
	Selective laser sintering (SLS) and direct metal laser sintering (DMLS)	For SLS, metal or polymer powder For DMLS, powdered stainless steels, maraging steels, cobalt chromium, inconel, and titanium Ti6Alv4	Lasers are used to sinter metal or plastic powders. Sintering is the process of heating material (below its melting point), causing atomic diffusion of the particles in the powder.
	Inkjet printer	Plaster or resin	Thin layers of material powder are spread across the build platform, and a binder is sprayed through the inkjets to set the powder for the solid area on each layer.
Photopolymerization	Stereolithography	Polymers	Lasers are directed into a vat of polymer.
	Digital light processing	Polymers	Safelight is used with masks to expose a vat of polymer to digital light.
	Inkjet printer	Polymers	Each layer is cured by ultraviolet light upon deposition.
	Photolithography	Synthetic resin	Light emitting diodes are focused on a block or vat of resin.

Advantages of AM

One of the early uses of AM was for rapid prototyping. Studies have shown that the use of 3D modeling software, combined with rapid prototyping, results in significant savings of both time and money.[4] Businesses that used the combined approach typically got products to market earlier and saved significantly on product development costs. For example, when businesses send an article out for fabrication, it typically takes 2 to 3 weeks until they have the prototype in hand. In contrast, when businesses use in-house AM, the time can be cut to 2 to 3 days.

Another advantage of AM is its flexibility, which gives businesses the ability to quickly modify prototypes or customize products for different customers. Finally, the processes employed in AM allow freedom of geometry, and that changes the rules of design. The "design for manufacturability" step can be greatly simplified, and items can be produced with significantly fewer process steps. That, in turn, makes it possible to produce highly complex geometries economically.

Labor savings also are significant, because once the design files are loaded to the AM process, little labor is involved, except for a finishing process for some products. As an example of the potential labor savings, Graco Children's Products, Inc., which makes strollers and other items for children, produces 6,000 to 8,000 parts per year with four AM systems and one operator. Another example is a large toy manufacturer that makes 12,000 models and prototypes per year with only two operators.

Finally, AM has positive logistical impacts. By building items close to where they will be used, much of the transportation of the finished object can be eliminated. For example, the National Aeronautics and Space Administration has tested 3D printing in zero-gravity flight; its aim is to develop AM for the International Space Station to reduce the number of spare parts required to be transported to, and stored on, the station.

Disadvantages of AM

AM has a few limitations. In particular, the size of the build platform is limited. Typically, objects are smaller than a cubic yard, although with electronic beam melting, the build platform can be up to about 5 feet long, 3 feet wide, and 5 feet high. Further, some larger build platforms—several meters in all three dimensions—are used for "printing" buildings in sandstone or concrete. The availability of materials in the proper form for AM is another limitation. Table 2 shows some of the materials available now, and new materials are being added continually.

Finally, AM is not the optimal process for high-volume manufacturing unless some customization is required. For example, AM is used to mass produce the clear plastic "aligners" used to straighten teeth. These are built from a model of a client's teeth, and then the model is changed very slightly over many iterations, to gradually align the teeth to the desired "bite." But typical assembly-line methods are more suited for mass producing products that are identical for every customer.

Current Applications of AM

Rapid prototyping is an example of AM integrated with traditional manufacturing processes. Even when mass production is needed, AM can shorten cycle times for engi-

Table 2. Types of Materials Used in Additive Manufacturing Processes

Process	Materials used
Material extrusion	Thermoplastic; may require support structures.
Material jetting	Photopolymers/thermoset plastic or wax-like materials for investment casting patterns.
Binder jetting	Plaster powder with water as binding agent. Metal powder or sand, with glue-like binding agents; finished by sintering in a furnace. Acrylic polymer, with a monomeric liquid binder.
Sheet lamination	Paper, with adhesives. Metal tapes and foils, with ultrasonic welding.
Vat photopolymerization (also known as stereolithography)	Liquid photopolymer, including ceramic-filled photopolymer. Cured with light (usually lasers). Digital light processing uses micromirrors to project an image of the layer onto the vat, curing an entire layer at once.
Powder bed fusion (also known as laser sintering, selective laser melting, direct metal laser sintering, and electron beam melting)	Polymer and metal powders; sometimes, sand. Uses thermal fusion, usually from a laser or an electron beam.
Directed energy deposition	Metal powders and focused thermal energy.

neering reviews by providing a physical prototype in much less time than getting prototypes developed by an outside firm. Reverse engineering is used to (for example) reproduce items if the design documentation has been lost. When technology is used to create a 3D model of the item (whether by laser scanning, x-ray, or magnetic resonance imaging), the 3D model can be used as input to the AM process.

Medical and dental device applications are plentiful, due to AM's customization capabilities. For example, AM is used to develop surgical guides, customized prostheses, and engineered tissue scaffolds. In addition, AM is used in some applications to create geometries not possible with traditional manufacturing techniques, resulting in new designs with higher strength and lower weight. AM also supports manufacturing of electronic items, by printing the electronics embedded into the final product.

DoD Applications of AM

Additive manufacturing is already in use by DoD and its supply chain. Original equipment manufacturers routinely use AM for rapid prototyping of new products, for molds and casting patterns, and for direct part production. The Joint Strike Fighter contains many parts manufactured using laser sintering and other AM techniques. DoD is using AM in medical applications as well, for example, to plan surgeries and to visualize reconstructive surgery, surgical implants, and prosthetics.

The Army's Rapid Equipping Force has deployed two mobile laboratories to the war zone in Afghanistan. Each mobile lab—a roughly $2.5 million investment—is a 20-foot container and can be transported by truck or helicopter to any location. The first lab, deployed in 2012, contains 3D printers, computer numerical control mills, laser cutters, and water cutters for fabricating parts on the spot. The second lab, similar to the first lab, was deployed in late 2012. A third mobile lab has been built, but not yet deployed.

Engineers can work with the warfighter inside the mobile lab to create needed items or repair parts made of plastic, steel, and aluminum. The labs speed up the design and production processes, and the warfighter can provide feedback to the designer. Rapid iterations enable the labs to quickly proceed to a design for a complete solution. If the end item is going to be mass produced, the design can be transmitted back to the United States for procurement and production.

[1]*The Economist*, April 21, 2012, http://www.economist.com/node/21553017.

[2]See http://www.ted.com/talks/lang/en/lisa_harouni_a_primer_on_3d_printing.html.

[3]STL can stand for Standard Tesselation Language (file format) or STereoLithograpy (an additive manufacturing process).

[4]Aberdeen Group, *The Transition from 2D Drafting to 3D Modeling Benchmark Report*, September 2006.

About the Author

Denise Duncan is a senior fellow at LMI with 30 years of information systems management experience. She has managed a wide variety of projects, from assisting senior leaders with portfolio management to strategic planning for chief information officers. For the last 10 years, Ms. Duncan has worked extensively on the application of data management principles to engineering and scientific data. She has authored standards, handbooks, and training materials in enterprise-level data management and information management. Ms. Duncan has been honored as a technical fellow of TechAmerica and is the vice president for programs in the local chapter of Data Management Association–International.

Multinational Maintenance

A New Approach to Logistics Interoperability

By George Sinks

Throughout and after the end of the Cold War, U.S. and Allied efforts to improve interoperability in logistics focused largely on the development of standards for fuel and ammunition. These efforts yielded some significant achievements, which included the ability of Allies to share 7.62 mm small arms ammunition and 125 mm artillery shells, as well as jet fuel. The U.S. and Allies' ability (and willingness) to share or exchange logistics maintenance services, though, remained limited, primarily due to the number of different major system platforms and associated maintenance requirements. However, recent NATO operations in Afghanistan have witnessed the emergence of new and creative approaches to multinational maintenance services for helicopters and certain types of wheeled vehicles; those approaches have produced tangible political, financial, and operational benefits. Though the development of these approaches was anything but easy, the extent of their benefits was such that it is worthwhile to discuss how they evolved and consider the lessons learned for similar arrangements in the future.

Strategic and Operational Context

The evolution of multinational maintenance arrangements in Afghanistan was directly shaped by the challenging physical and operational circumstances in that country. Since July 2010, the NATO-led International Security Assistance Force (ISAF) has comprised six regional commands (RCs), three of which (RC East, RC South, and RC Southwest) have been led by the United States. The others—RC West, RC North, and RC Capital—have been headed up by Italy, Germany, and Turkey, respectively. Other NATO and 19 non-NATO nations have deployed personnel to one or more of the six RCs.

The nature of the terrain and the security conditions on the Afghan road network make helicopters, both attack and transport variants, essential to the conduct of operations and the resupply of the numerous and widely dispersed bases from which ISAF troops routinely operated. Notwithstanding their operational importance, NATO nations, with the exception of the United States, struggled to field sufficient numbers of helicopters in Afghanistan.[1] Although Allies deployed a wide range of helicopter types in ISAF, many of the Allies operating with or near U.S. forces—principally, the United Kingdom, Netherlands (NL), Canada, and Australia—operated U.S-origin helicopters like the AH-64 Apache and CH-47 Chinook.

In addition, the increased frequency and sophistication of enemy improvised explosive device (IED) attacks on ISAF troop and supply convoys forced the Allies, led by the United States, to field large numbers of a new type of wheeled vehicle, the Mine Resistant Ambush Protected (MRAP) vehicle, for use in Afghanistan. By the end of 2011, the United States had deployed more than 10,000 MRAPs of various types to Afghanistan, and other Allies had deployed approximately 1,500 of their own. However, the cost and logistical complexity of the MRAP system meant that many smaller ISAF nations could not afford to purchase or operate such vehicles, which, in turn, made their deployed troops more vulnerable to IED attacks than the United States or other larger NATO Allies. To address this politically awkward imbalance, the United States began providing MRAPs to smaller NATO and non-NATO ISAF nations as cost-free loans. By the end of 2011, the U.S. had loaned well over 500 MRAPs to other ISAF nations, principally in the three RCs headed by the United States.

It would be oversimplification to argue that the ISAF operations in Afghanistan depended on the availability of just two types of equipment—helicopters and MRAPs—but their importance to the effectiveness of those operations and safety of ISAF personnel cannot be underestimated.

Shared Maintenance Arrangements 1.0: Helicopters

Not surprisingly, helicopters emerged as the initial object of Allied logisticians seeking more efficient ways of supporting operations in Afghanistan. In 2009, the NATO Logistics Committee,[2] perhaps motivated by the difficulty in getting Allies to deploy sufficient numbers of helicopters in RC South the previous year, launched the ISAF helicopter initiative. Its purpose was to increase the number of flight hours available from ISAF helicopters by improving the collective logistics and maintenance available in theater. To carry this initiative forward, Allies formed three platform-centric groups to coordinate in-country support: North American, led by the United States; Western European, led by France; and "Mi" (Russian), led by the Czech Republic. The North American group focused on collaborative logistics arrangements for U.S.–designed helicopters (CH-47s, CH-53s, UH-60s, and AH-64s) flown by coalition partners. The intent was to leverage the in-theater U.S. support capability to provide phase maintenance, spare parts, and ground support for these aircraft.

The ISAF helicopter support initiative achieved its most concrete results through the North American subgroup. Using a combination of Foreign Military Sales (FMS) and Acquisition and Cross-Servicing Agreements (ACSAs), the United States provided phase maintenance support to NL AH-64s deployed to Afghanistan. Prior to the initiative, the Netherlands had brought these helicopters back to Europe for this service via contracted strategic airlift. Under the new arrangement, Dutch logisticians were able to access U.S. in-country facilities and supplies to complete phase maintenance for their AH-64s in Afghanistan. As a result, maintenance time for these aircraft was reduced from 120 days to 10 days, resulting in increased availability of airframes and a substantial cost savings due to elimination of the requirement to transport AH-64s back to the Netherlands. A key feature of this arrangement was that the support was provided in a blended fashion in which time-sensitive services, such as three phase inspections, were authorized under FMS (which provides a guarantee of service) and the associated back-shop time and miscellaneous supplies were provided under the more flexible ACSA authority. Also, notwithstanding the fact that the United States provided the core maintenance support for NL helicopters, the Netherlands remained responsible for providing personnel and signature authority for test flights and post-support acceptance of the helicopters. This ensured that NL maintenance standards for AH-64 support were met. Other activities under the first phase of this initiative included U.S.-furnished maintenance and spare parts for Australian and Canadian CH-47s and German CH-53s. Although initially limited to one nation due to a shortage of U.S. ramp and hanger space in Afghanistan, the shared U.S.–NL arrangement for AH-64 phase maintenance support served as a model for a subsequent 2012 agreement involving the United States and Spain under which the latter used in-country U.S. facilities to conduct phase maintenance for its CH-47 transport helicopters.

Shared Maintenance Arrangements 2.0: MRAPs

The success of the ISAF helicopter initiative encouraged NATO logisticians to look for other systems that could benefit from shared support arrangements in Afghanistan. NATO discussions quickly focused on MRAPs. As important as the U.S.-initiated loans of MRAPs were, the long-term utility of this program depended on the ability of the recipient nations to keep these complex vehicles operating. In spring 2010, the NATO Logistics Committee agreed that the nations and NATO should investigate opportunities for multinational logistics support arrangements for MRAPs in Afghanistan. Later that year, the nations agreed to establish separate users groups for U.S. and Italian vehicles in addition to the existing German users group to develop or refine multinational support arrangements to improve the operational availability of MRAPs in Afghanistan.

Most of the effort under this initiative focused on loaned U.S.-origin MRAPs. To support the increasing number of these vehicles deployed to Afghanistan, the U.S. Central Command, in coordination with the U.S. MRAP program office, established a series of Regional Support Activities (RSAs) located in various sectors in Afghanistan.[3] Supplementing the RSAs, which provided depot-level maintenance and battle damage repair, was a network of contractor field service representatives who provide maintenance support advice at the operating unit level. Under the current support concept for loaned MRAPs, a coalition partner operating MRAPs contacts its sponsor U.S. unit, which coordinates required support or battle damage repair (including vehicle recovery) at the unit or RSA level. From the RSA perspective, maintenance or repairs for loaned coalition MRAPs are managed in the same way as for U.S. vehicles. Under this system, nations had flexibility as to how to use the capability of the U.S. RSAs. Most conducted routine MRAP support through their organic logistics assets and relied on the RSAs only for major maintenance or battle damage repair work.[4] By contrast, nations operating MRAPs purchased from the United States generally received support on a reimbursable basis through an FMS support case or ACSA.

The shared maintenance structure established for loaned MRAPs in Afghanistan was the first of its kind, and it was not without problems. Several nations reported difficulty in obtaining timely information on the maintenance status of loaned MRAPs under repair in RSAs, as well as long delays in replacing vehicles destroyed as a result of enemy action. Some nations who had purchased U.S. MRAPs complained about delays in obtaining spare parts ordered through the FMS system and the lack of training, procedures, facilities, and equipment to repair battle-damaged MRAPs. Notwithstanding these issues, the shared MRAP maintenance arrangements established in theater contributed significantly to the central objective of the NATO initiative: increase the operational availability of MRAPs in Afghanistan. In September 2011, operational availability of coalition MRAPs was 94 percent, compared to 91 percent for the Army and 93 percent for the U.S. Marine Corps.

The establishment of successful shared maintenance arrangements was not confined to U.S.-origin MRAPs alone. In late 2012, Italy and Spain concluded an agreement under which Italy provided Spain access to the contractor-managed supply system for the Italian LINCE MRAP, which was also operated by Spain. Under this system, LINCE spare parts are owned by the manufacturer, IVECO, and stored in containers near the main Italian workshop in Herat. As a result of the 2012 agreement, Spain can order spare parts on the same terms as an Italian customer; specifically, it pays only for the spare parts it actually orders. The initial success of this agreement in reducing the time and cost of maintaining Spanish LINCE vehicles in Afghanistan has led the two countries to consider extending the shared warehousing concept to other operations.

Lessons Learned

The rationale, scope, and structure of the multinational maintenance arrangements in Afghanistan were driven by the unique physical and operational circumstance of the NATO operation in that nation. Having said that, NATO's experience with these arrangements may yield useful lessons learned for both operators and logisticians in future Alliance operations. These are summarized as follows:

- *Multinational maintenance arrangements work.* The helicopter and MRAP support established in Afghanistan in the 2009–12 time period achieved the principal objectives established by NATO. They saved participating nations both money and time in providing required maintenance and repairs and, thus, increased the operational availability of the systems affected.

- *Established legal and procedural enablers are vital.* Multinational system maintenance involves the sharing of extensive logistical facilities and/or the transfer of expensive or specialized parts and services. Nations owning the facilities or spare parts will generally expect reimbursement for material or services provided, which, in turn, requires established legal authorities and execution processes. In the case of the United States, the implementation of both helicopter and MRAP support arrangements in Afghanistan depended on the existence of the FMS and ACSA authorities, which minimized (though it did not eliminate) the need for new authority or procedures to make these arrangements work. The Italian–Spanish shared warehouse agreement, which also relied on existing contract-provider support processes, is another example of this lesson learned.
- *Mission organization and national equipment inventories will shape multinational maintenance arrangements.* Unlike other logistics commodities and services (such as fuel and transportation) that have been traditionally provided through multinational means, maintenance support is not always fungible. Equipment commonality is a prerequisite for a viable multinational support arrangement among two or more nations, with or without a third-party "broker" for such arrangements. Physical proximity of nations operating the same system is useful, but not essential, to an effective shared maintenance arrangement.
- *The scope for nationally supported multinational maintenance support may be limited.* The initial success of the AH-64 multinational support arrangement in Afghanistan led several other Allies operating U.S.-origin helicopters to ask about similar arrangements for their aircraft. The United States was unable to support these requests due to a shortage of in-country ramp and warehouse capacity. Nations rarely plan for multinational support in sizing their deployed maintenance capability, which provides an opportunity for a properly designed capability provided by a third party (NATO).
- *National standards must be maintained.* To be accepted by both operators and logisticians, a multinational support arrangement must allow for individual national maintenance standards to be met. In practice, this means structuring the arrangement to allow the recipient nation to execute and/or certify critical procedures or inspections. Any effort to build a third-party provided maintenance capability must take this requirement into account.

Conclusion

The principle of multinationality has been firmly embedded in both NATO and U.S. logistics policy and doctrine since the mid-1990s, but maintenance has remained one area of logistics that nations have historically preferred to obtain via national means alone. NATO's experience in Afghanistan, however, demonstrates that multinational maintenance arrangements yield real benefits for a modest investment of time and resources. They saved money, reduced system downtime, and increased the operational availability of mission-essential weapons systems. Afghanistan also underscores the importance of context—in the form of equipment commonality; preparation, in the form of tested implementing procedures; and patience, in the form of political will—in ensuring the success of these arrangements. Multinational maintenance support may not be possible or necessary in every Allied or coalition operation, but its success in Afghanistan, however limited, has established it as part of a proven suite of approaches to logistics interoperability in future operations.

[1]The extent of this challenge was illustrated by NATO's inability to find non-U.S. sources for helicopters to meet its requirements in RC South late in 2008. Absent national contributions, NATO was forced to contract out and common fund its helicopter needs in that region.

[2]At the time, the Logistics Committee was known as the Senior NATO Logisticians Conference.

[3]Initially, six RSAs were established in Afghanistan; this number grew to nine by 2011.

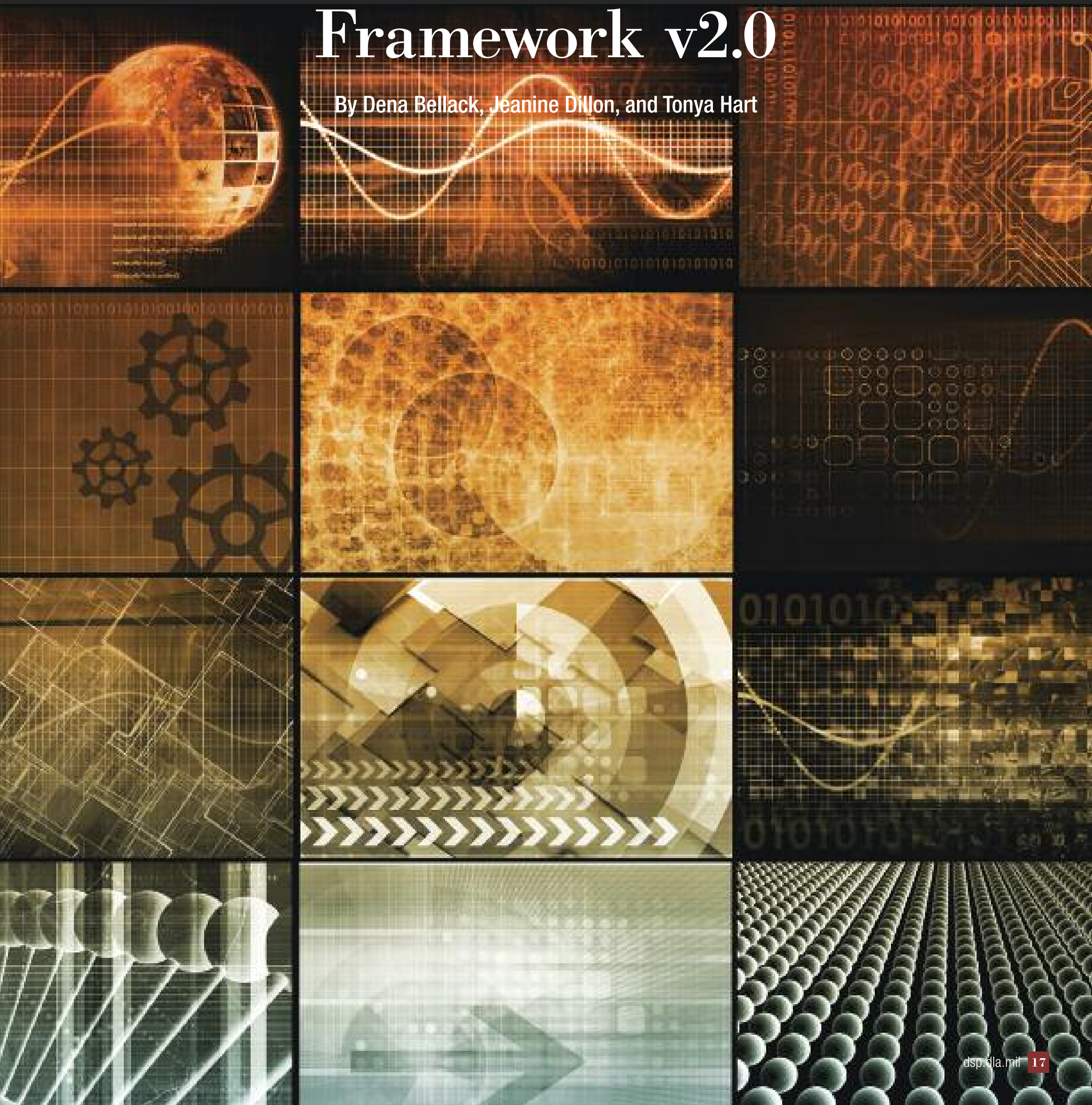
[4]The experience of the Danish ISAF contingent, which operated 40 loaned MRAPs, was typical in this regard. Under its revised MRAP support plan, Danish maintenance personnel worked directly with a collocated U.S. field service representative (FSR), rather than an FSR at the U.S. sponsor unit, to complete required maintenance and access any needed U.S. spare parts. The FSR also arranged for moving loaned Danish vehicles to U.S. maintenance facilities for any work that Denmark itself could not complete.

About the Author

George Sinks is an LMI research fellow with extensive experience at many levels of DoD in strategic planning, training development, organizational and process improvement, policy analysis, and procedures development for international defense programs and activities. From 2006 to 2009, he served on an Intergovernmental Personnel Act assignment in the Office of the Deputy Assistant Secretary of Defense for Europe/NATO Policy, with responsibility for NATO budgets, acquisition, and logistics. Since then, he has supported DoD participation in the NATO Logistics Committee and other multinational logistics programs and activities.

Enabling System Interoperability through Data Standardization Using the DoD Architecture Framework v2.0

By Dena Bellack, Jeanine Dillon, and Tonya Hart



System interoperability within DoD is crucial. In fact, DoD Directive 4630.5, "Interoperability and Supportability of Information Technology (IT) and National Security Systems (NSS)," mandates that existing and planned IT systems employed by U.S. forces be interoperable. System interoperability requires an integrated enterprise architecture, that is, an architecture—consisting of multiple views or viewpoints (operational, systems, and standards, for example)—that facilitates integration and, thus, promotes interoperability across capabilities and among related integrated architectures.

The DoD Architecture Framework (DoDAF) Version 2.0 (v2.0) is DoD's principal guide for developing integrated architectures. DoDAF v2.0 has data throughout the architecture. To facilitate understanding of the data's integration points, DoDAF v2.0 organizes the data into eight viewpoints:

- All Viewpoint, which describes the overarching aspects of architecture context that relate to all viewpoints.
- Capability Viewpoint, which articulates the capability requirements, the delivery timing, and the deployed capability.
- Data and Information Viewpoint (DIV), which articulates the data relationships and alignment structures in the architecture content for the capability and operational requirements, system engineering processes, and systems and services.
- Operational Viewpoint (OV), which includes the operational scenarios, activities, and requirements that support capabilities.
- Project Viewpoint, which describes the relationships between operational and capability requirements and the various projects being implemented. The Project Viewpoint also details dependencies among capability and operational requirements, system engineering processes, systems design, and services design within the Defense Acquisition System process.
- Services Viewpoint, which presents the design for solutions providing for or supporting operational and capability functions.
- Standards Viewpoint (StdV), which articulates the applicable operational, business, technical, and industry policies, standards, guidance, constraints, and forecasts that apply to capability and operational requirements, system engineering processes, and systems and services.
- Systems Viewpoint (SV), which articulates the design for solutions articulating the systems and their composition, interconnectivity, and context providing for or supporting operational and capability functions.

The data in each viewpoint are documented in a variety of ways, such as models, mappings, descriptions, event traces or process flows, hierarchical structures, and so on. DoDAF refers to these items collectively as architectural models. To develop a truly integrated architecture, data required in multiple architectural models must be standardized, which means they must be defined and commonly understood. A best practice for data standardization is to follow the ISO 15000-5 Core Component Technical Specification (CCTS).[1]

Of the eight viewpoints, the DIV is the most important for enabling system interoperability, because it documents the most granular level of data—specifically, data entities and elements—in three data models. The DIV models allow for traceability of data or pieces of information throughout the architecture. Unfortunately, in DoD enterprise architectures, the DIV is often overlooked due to lack of understanding of why it is important within the architecture, how to develop the DIV data models and integrate them with the rest of the architecture, and how the DIV data models can enable system interoperability.

This article describes how to build the DIV data models while integrating data at key points in the architecture. We begin with a discussion of the CCTS, because it is the foundation on which data entities and elements are created.

Data Standardization and Core Components

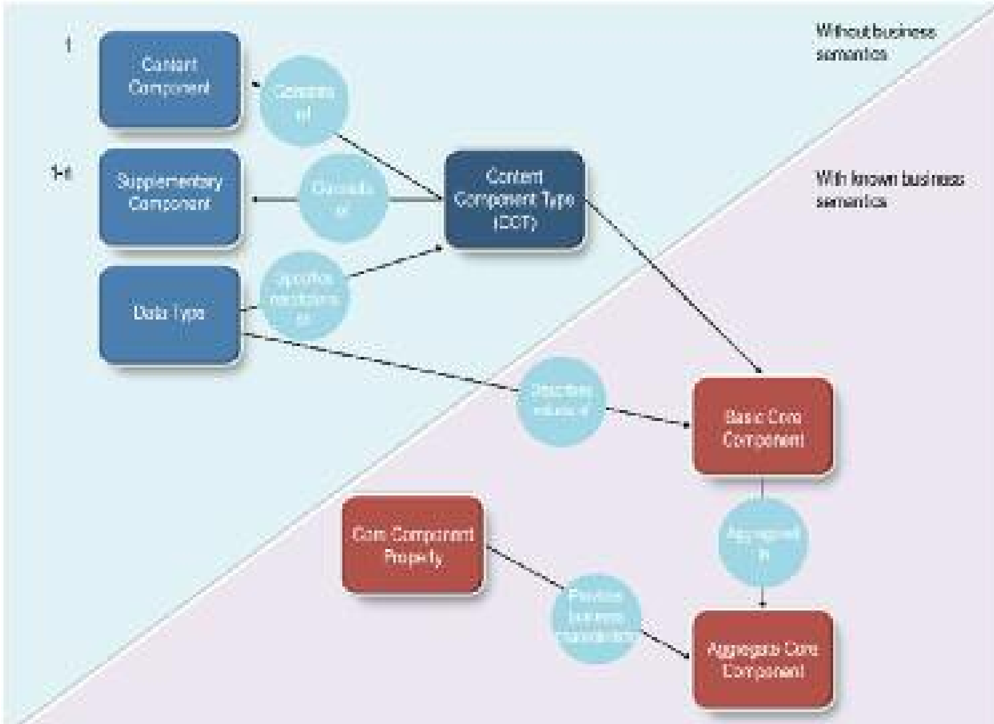
Data standardization promotes more agile analysis of enterprise data and facilitates system integration and interoperability. Data architectures based on the CCTS promote a canonical structure for data models, therefore simplifying system integration and interoperability. A canonical data model is any model in its simplest form based on a common view within a given context. The intent of a canonical model is to provide a data dictionary: a set of reusable common terms and definitions that are agreed upon by the enterprise or a group of systems to be integrated. This dictionary, in turn, enables systems to share data and, therefore, to integrate more easily.

The CCTS provides a method for developing a common set of semantic building blocks that represent the general types of business data in use today. It also provides for the creation of new business vocabularies in the future.

The CCTS is built on a fundamental concept known as a "core component" (CC). Defined as the lowest common denominator of an information element, a CC functions as a reusable, syntax-neutral building block. For effective modeling of real business problems, CCs may have extensions, context, or both, and they can be aggregated into other CCs. Figure 1 illustrates the hierarchy of the CC construct as outlined by the CCTS.

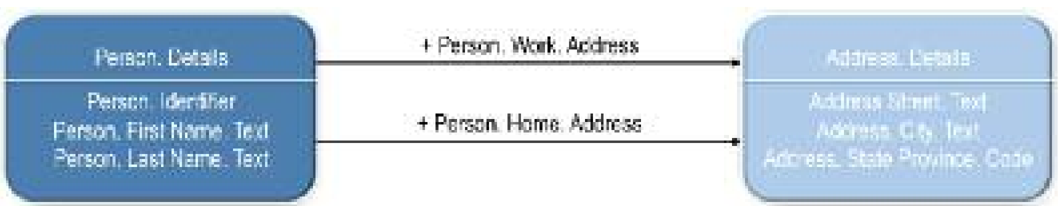
CCs are neutral in the notation for every kind of industry and, in the system, for every kind of business, document, standard, or implementation. They are given a business context through the addition of business context descriptions, thus creating a separate mod-

Figure 1. Hierarchy of the Core Component Construct



eling construct known as a business information entity (BIE). At each level of the CC modeling process, the analyst typically registers the names and meanings of each unique CC and BIE. The registration process allows for interoperability among different industry domains and areas. It also creates a namespace that enables the pieces to be reused at any level and by numerous industries. Figure 2 illustrates a CC model for "person, address." Each of the information items in this model corresponds to the different CCTS modeling constructs in Figure 1.

Figure 2. Example of a Core Component Model



CCs provide a basis for standardization but not for syntax-specific expressions. They are technology neutral, which means that the development work done within the CCTS method can be translated to other technologies, thus protecting an enterprise's e-business information assets.

Currently, numerous federal agencies are embracing the CCTS. Similarly, industry and associations—for example, the Petroleum Industry Data Exchange, Chemical Industry Data Exchange, and OpenTravel Alliance—are actively engaged with projects related to CCs.

Overview of Key DoDAF v2.0 Data Integration Points

The DIV, OV, and SV are the most important DoDAF viewpoints for achieving system interoperability. Table 1 identifies the specific models within the DIV, OV, and SV that must be integrated, and Figure 3 depicts their data integration points.

The DIV models contain the most granular level of data and information:

- DIV-1 contains the high-level data concepts—entities—and their relationships.
- DIV-2 contains the entities and their attributes (data elements), along with their associations, commonly documented in an entity relationship diagram.
- DIV-3 contains the physical implementation of the DIV-2. Examples are physical schemas, represented by tables and columns, and message formats.

The OV models with key integration points to the data components are the OV-2, OV-3, OV-5b, and OV-6c. The SV models with key integration points to the data components are the SV-1, SV-4, SV-6, and SV-10c.

The following sections provide detail on the key DIV, OV, and SV integration points needed to achieve system interoperability.

DIV Integration Points for System Interoperability

The DIV provides a framework to articulate the operational and business information requirements and constraints (business rules) of the architecture. The detailed information captured in the data models represents the information inputs and outputs of the operational activities in the OV-5b and OV-6c models. The activity resource overlaps (AROs) identified in Figure 3 are the inputs and outputs of the activities. Developing the data models on the basis of activities and business rules allows for traceability of the information pieces throughout the architecture.

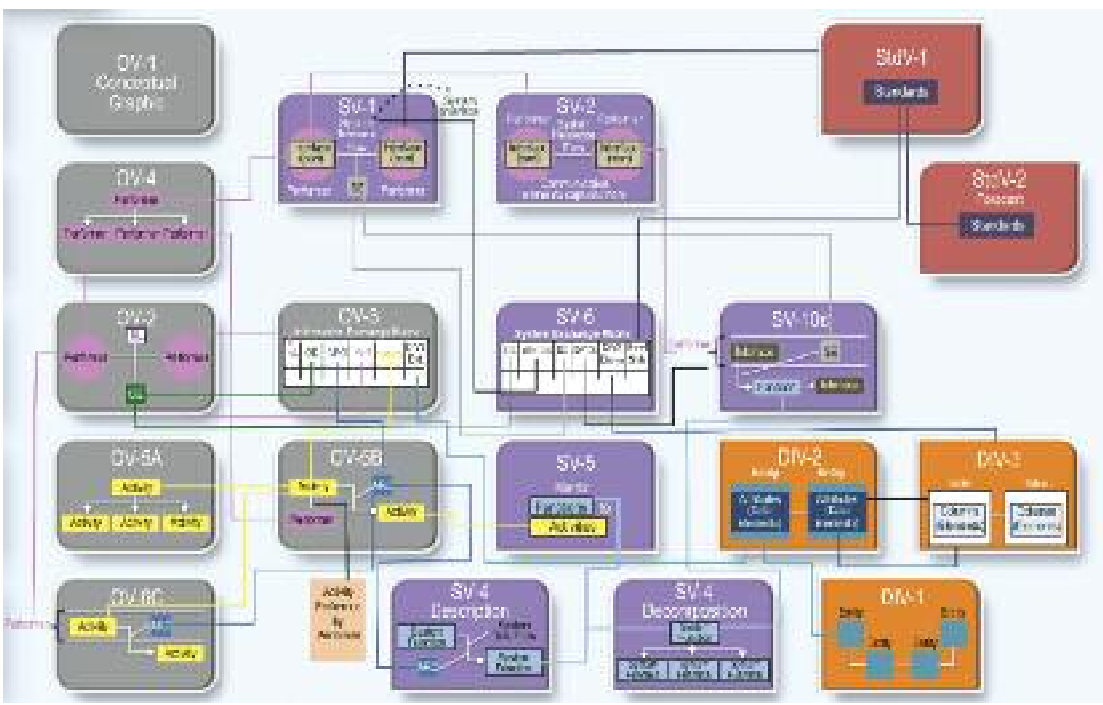
The DIV's three models associate the information exchanges—called operational exchanges (OEs)—to information entities, attributes, tables, and columns and define their interrelationships. From a systems integration perspective, it is critical to develop all three models.

The DIV-1, Conceptual Data Model, documents the business information requirements and constraints (business rules) of the architecture. The conceptual data model contains the high-level information entities and relationships of the information based on the business requirements and constraints. The high-level data entities are beneficial

Table 1. Key DoDAF Models for System Interoperability

Model	Name
DIV-1	Conceptual Data Model
DIV-2	Logical Data Model
DIV-3	Physical Data Model
OV-2	Operational Resource Flow Description
OV-3	Operational Resource Flow Matrix
OV-5b	Operational Activity Model
OV-6c	Business Process Flow
SV-1	Systems Interface Description
SV-4	Systems Functionality Description
SV-6	Systems Resource Flow Matrix
SV-10c	Systems Event-Trace Description

Figure 3. Key Data Integration Points



Notes: ARO = activity resource overlap, NL = needline, OE = operational exchange, and SE = system exchange.

for system interoperability, because they clearly identify what types of information the systems do and do not share. The DIV-1 entities are based on the ISO 15000-5 CCTS and are associated to the entities in the DIV-2.

The DIV-2, Logical Data Model, is the representation of the architecture data, organized in terms of entities and relationships. The logical model is based on the entities identified in the DIV-1 and documents the business requirements and constraints that are captured in the OV-6c. The entities tie to the inputs and outputs of the activities in the OV-5b, represented as AROs. The AROs are information exchanges—such as purchase orders, maintenance requests, or invoices—that systems use to exchange information. The CCTS is the foundation on which the entities and data elements are created. The DIV-2 is referred to as the canonical model for the architecture, meaning it provides a common naming convention, definitions, and values. The canonical structure is key in reducing costs and enabling standardization of data across systems. The OV-3 captures the information relationships from the operational perspective. The DIV-2 provides the entities that are associated with each OE and ARO.

The DIV-3, Physical Data Model, is the physical instantiation of the DIV-2, showing how the DIV-3 is actually implemented to form an operational system. It defines the structure of the data from the system perspective. Architectures commonly use the physical database schema of a specified system or systems as the physical data model. The DIV-3 is composed of tables and columns (commonly referred to as elements) and the associations between them. The DIV-3 tables are associated to the DIV-2 entities, and the DIV-3 columns (elements) are associated to the DIV-2 attributes. The SV-6, system information exchange matrix captures the information relationships from the system perspective.

OV Integration Points for System Interoperability

The OV describes the tasks and activities, operational elements, and resource flow exchanges required to conduct operations. The OV models support interoperability in a number of ways. For example, they can be used to help answer questions such as "What activities are being supported or automated by a capability or capabilities?" or "What information must be passed between capabilities?" However, four of the OV models are particularly applicable to data and information integration to enable system interoperability.

The OV-2 contains "needlines" with associated OEs. The needlines in the OV-2 represent the need to exchange information. It is the information on these high-level needlines that represents all of the information in the architecture to be exchanged between performers, which can be an organization, person/role, system, or service.

The OV-3 is one of a suite of DoDAF architectural models that address the resource content of the operational architecture; the others are the OV-2, OV-5b, and DIV-2. On its own, the OV-3 addresses operational resource flows exchanged between operational activities and performers. Resource flows provide further detail about the interoperability requirements associated with the operational capability of interest. The focus is on resource flows that cross the capability boundary. The intended usage of the OV-3 is to define interoperability requirements.

The OV-5b shows activities connected by resource flows, and it supports development of the OV-3. The OV-5b describes the operational activities (or tasks) that are normally carried out to achieve a mission or a business goal. The OV-5b also describes input and output flows between activities and to/from activities that are outside the scope of the architecture.

The OV-6c provides a time-ordered examination of the resource flows as a result of a particular scenario. The OV-6c is valuable for moving to the next level of detail from the initial operational concepts. An OV-6c helps define interactions and operational threads. It can also help ensure that each participating operational activity and location has needed information at the right time to perform its assigned operational activity. Key to integration and interoperability, the information content of messages in an OV-6c may be related with the resource flows in the OV-3 and OV-5b and with information entities in the DIV-2.

Operational information is integrated among the OV-2, OV-3, OV-5b, and OV-6c, as well as with the data and information resident in the DIV models. For example, performers in an OV-2 are reused as pools or lanes in a business process diagram (OV-6c). An OV-5b's AROs relating the exchange of resources between activities are contextualized as message flows between tasks in the OV-6c business process diagram. Defined needlines, OEs, and AROs in these other OV models culminate in the OV-3, a data-rich matrix describing operational information exchange needs for solutions, materiel, and so on. The hook to the DIV models is achieved by identifying (1) the data entity from the DIV-2 that needs to be carried on the needlines by the OE in the OV-2 and exchanged by activities in the OV-5b and (2) the AROs that connect activities on the OV-6c.

SV Integration Points for System Interoperability

The SV describes systems and interconnections providing for, or supporting, DoD functions. The SV models associate system resources to the operational and capability requirements. These system resources support the operational activities and facilitate the exchange of information. Four SV models are particularly important for system interoperability.

The SV-1 documents and defines system names and their interconnections. The SV-1 links the operational and systems architecture models by depicting how information interacts to realize the logical architecture specified in an OV-2. The SV-1 depicts all system resource flows between systems that are of interest. Resource flows between systems may be further detailed in an SV-6.

The SV-4 describes the functionality of a system (system activities) and the data that flow among system functions. In other words, this SV model is used to specify the functionality of resources in the architecture (functional, systems, performers, and capabilities). The SV-4 is the behavioral counterpart to the SV-1 in the same way that the OV-5b is the behavioral counterpart to the OV-2.

The SV-6 details the resources flowing between and among systems and defines the attributes of those exchanges. Like its counterpart in the OV-3, the SV-6 culminates in a data-rich matrix describing system exchange needs and the attributes of those exchanges.

The SV-10c is one of three models used to describe system functionality. It is the systems equivalent of the OV-6c, but it depicts system-specific sequences or events that are described operationally in the OV-6c. The SV-10c is valuable for moving from the initial solution design to the next level of detail. The SV-10c helps define a sequence of functions and system data interfaces, and it ensures that each participating resource or role has the information it needs, at the right time, to perform its assigned functionality.

Systems information is integrated among the SV-1, SV-4, SV-6, and SV-10c, as well as with the data and information resident in the DIV models. For example, the system interfaces defined in the SV-1 and SV-2 and implemented as system exchanges are the same system exchanges that appear on the system message flows between system functions on the SV-10c. These elements of the SV are directly related to the data entities on the DIV-2 as attributes and on the DIV-3 as elements of the column tables in the physical systems data model.

Putting It All Together

What does this all mean for enabling the interoperability of IT systems employed by U.S. forces?

- Standardized data—allows for improved information exchange and the potential to standardize data across systems
- Understanding of where the data are used in a business process—allows for the integration of business processes across supporting systems

- Discovery of redundancy in data being exchanged—allows for the proper integration of those exchanges.

By following DoDAF guidance and best practices for planning, building, and documenting IT systems, DoD will have a truly interoperable systems environment in which operational capabilities are supported by the same data that are documented and implemented in data and systems models.

[1]ISO/TS 15000-5:2005, "Electronic Business Extensible Markup Language (ebXML)—Part 5: ebXML Core Components Technical Specification, Version 2.01(ebCCTS)."

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Ms. Bellack, who has 10 years of enterprise architecture experience, has provided her data and information expertise to a variety of LMI clients, such as the General Services Administration, Department of Homeland Security, Transportation Security Administration, and several intelligence community agencies. Most recently, she has been working with the Army on programs such as the Army Integrated Logistics Architecture (AILA), the Army Materiel Command (AMC) CBM+ Common Architecture, and the Logistics Modernization Program (LMP).

Ms. Dillon, a DoDAF CEA, has 14 years of enterprise architecture experience. She has been providing her architecture expertise to Army programs such as AILA, AMC CBM+ Common Architecture, LMP, and Global Combat Support System–Army (GCSS-Army). She also has helped the Product Manager Joint–Automatic Identification Technology with its Radio Frequency In-Transit Visibility (RF-ITV) architecture.

Ms. Hart is a DoDAF CEA with 12 years of enterprise architecture experience. She has been providing architecture expertise primarily to the Army, supporting AILA, CBM+ Common Architecture, LMP, GCSS-Army, and the RF-ITV architecture. She also has provided her expertise to the U.S. Army Program Executive Office Enterprise Information Systems.

Enhancing Interoperability through Open Systems Architecture

By Joseph Norton

A constantly changing technology landscape and expectations to adapt and innovate quickly make it challenging to acquire, integrate, and upgrade fielded systems, especially in the current economic environment. Highly integrated systems are often proprietary and vendor locked, expensive, and difficult to upgrade with emerging technology. A strategy for overcoming these challenges is to design highly interoperable systems. This means enabling systems or components to exchange services and information through seamless, end-to-end connectivity. This article describes how open systems architecture (OSA) leverages reusable components, well-defined interfaces, and standard interface specifications to enhance system interoperability. This article also discusses design principles for implementing OSA to enhance interoperability.

Open Systems Architecture—An Overview

OSA is an integrated business and technical approach to acquire and assemble interoperable components using modular systems design. The business strategy is to drive down costs, enable systems to easily adapt to changing business needs, and increase the number of available vendors to create competition-driven product lines. The technical approach decomposes systems into components that interact through key interfaces according to formal specifications.

OSA aims to enhance interoperability by realizing the following benefits:

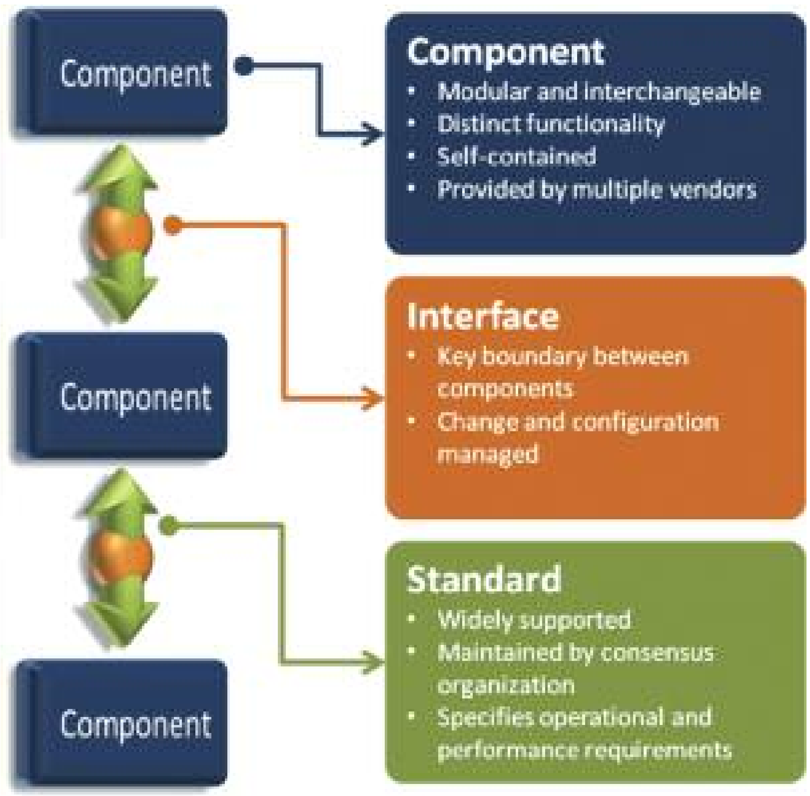
- Increased flexibility in vendor selection fostered by competitive marketplaces
- Interchangeable components to simplify maintenance, upgrades, and technology insertion
- Greater accessibility to innovative technology
- Shortened design times and streamlined development processes
- Improved information sharing and data quality
- Reduced total cost of ownership.

OSA applies to all types of systems. Although some of its most familiar uses are in computers, software, and electronics, this approach applies to other areas, such as communications, electricity production and use, and the design of weapons, vehicles, and artillery for armed forces. Computer networks are tightly integrated systems that employ standard hardware, such as cables, routers, and servers. This hardware uses standard protocol to enable devices and machines to communicate and exchange information. With constantly changing operational needs for new weapons and armor, the armed forces use a similar approach to enhance interoperability in military vehicles. By developing standard electronic platforms and mounting systems, military vehicles can quickly access electronic and information assets and introduce new weapon and sensor capabilities.

Components, Interfaces, and Standards

OSA abstracts systems into three key elements: components, interfaces, and standards. Figure 1 describes these elements and their characteristics. These are generic to any system and span several dimensions of interoperability, including technical, informational, and organizational. This involves the physical connections and communications between components, their information flows, and relationships between people and organizations.

Figure 1. Elements of Open Systems Architecture



Components are the physical modules of a system. Each component has distinct functionality and operates independently and with limited impact on the rest of the system. This decouples the components from each other and makes it possible to interchange units provided by alternate vendors. The desired functionality and inner workings of components may also vary across vendors.

Interfaces define the key boundaries between components and how they interact. The types of interfaces depend on the physical connections, information, or services the components need to exchange. Interfaces should be standardized, change and configuration managed, and publicly available.

Standards define the specifications for how components interact through defined interfaces. These include operational and performance requirements, such as security, reliability, and maintainability, that describe how an interface should perform. Standards should be managed by consensus groups and widely accepted to ensure they meet the requirements across all systems.

Design Principles to Ensure Interoperability

OSA considers interoperability through the entire life cycle of a system. A program must design its systems to be interoperable from the time it acquires and defines its components, interfaces, and standards through the time when those systems become operational and eventually are decommissioned. Several critical success factors contribute to successfully implementing OSA principles:

- Firm commitments and well-defined governance
- Available, reliable, and economical components
- Controlled interfaces
- Mature standards.

Firm Commitments and Well-Defined Governance

Interoperability requires cooperation. The programs and involved systems should be dedicated to an enterprise-wide strategy to implement and realize the benefits of OSA. This includes developing a strategic sourcing approach for acquiring system components, contributing to the ongoing development of open standards to meet business and system requirements, and providing guidance and oversight to align systems to OSA principles. Political and financial support from program offices, project managers, and senior managers who understand the long-term benefits of OSA are crucial to its successful implementation.

A program implementing an OSA system should establish enterprise governance through policy, guidance, and enterprise planning to develop and maintain its systems. Interdisciplinary practices, such as systems engineering and enterprise architecture, enable organizations to manage system complexity and align resources with an OSA strategy.

Organizations should establish governing bodies supported by communities of interest and working groups or committees to oversee design and implementation, champion enterprise-wide adoption, and assess benefits realization. Governing bodies should make funding and approval decisions for systems to proceed through key life-cycle milestones.

Available, Reliable, and Economical Components

OSA focuses on decomposing systems into modular components. In order for these components to be interoperable, easily upgraded, and maintained, there must be a broad range of components that meet the functional and performance requirements of a system. The specifications for components must be formal and publicly available to encourage broad commercial support. This will allow a number of vendors to produce the same or similar components with standardized functionality. This will also promote competition between vendors to produce usable, reliable, and economical components and to incentivize productivity and innovation.

Controlled Interfaces

Controlled and consistent interfaces enhance the interoperability of components. Interfaces should be controlled, monitored, and published to clearly and fully define all inputs and outputs of a component. Interfaces separate the functionality of each component and define the requirements that interface standards need to support. By monitoring the number of interfaces within a system, their rate of change, and their conformance with standards, a program will be able to assess the openness, interoperability, and affordability of a system over time.

Mature Standards

To mitigate the risks associated with enhancing interoperability, systems should use standards that are well-developed and stable and that have achieved widespread adoption by industry. This will ensure interfaces meet current industry-wide operational and performance requirements, adapt to changes due to emerging technology or innovation, and are published. Programs should participate in standards development to ensure their adopted standards continue to meet their business and technical requirements.

Standards organizations often manage the overall production and evolution of mature standards among a wide base of adopters. These organizations benefit from collaborative participation from industry, universities, and government to develop robust and comprehensive interface specifications. Well-known standards organizations such as the ISO, International Electrotechnical Commission, and International Telecommunication Union have developed standards for all types of interfaces, including physical, data, network, and applications. These standards support various OSA-based approaches, such as the Open Systems Interconnection (OSI) model and service-oriented architectures. Consistent with an OSA approach, OSI decomposes communications systems into functional layers where components within each layer interact through well-defined protocols. Similarly, service-oriented architectures separate software systems into loosely coupled pieces of software that communicate using standard web-based services and that can be published and discovered. In both cases, mature standards enable interoperable machine-to-machine interaction over a network.

Summary

OSA decomposes systems into components, interfaces, and standards to enhance interoperability. As long as the interfaces are fully defined and there are mature standards to govern them, system owners can interchange components with the same or similar ones. OSA overcomes the challenges of highly integrated, proprietary systems by using a modular architecture that allows commercial companies to build systems or subsystems to common industry specifications. This enables organizations to directly impact the interoperability, supportability, and affordability of their systems.

About the Author

Joseph Norton is an enterprise architect with LMI. He manages systems engineering and information technology projects, with a focus on facilitating enterprise architecture development and adoption within the federal government.

DoD as a Model-Based Enterprise

By Denise Duncan and Paul Huang

DoD is one of the largest buyers of complex systems and the parts to maintain them; it spends billions annually on weapons systems, spares, parts, and related supplies. These systems are in active use for decades and must be ready for use at any time. Over the entire life cycle of a given system, sustainment is the largest cost, surpassing even the original purchase price. Sustainment costs can be as much as 60 to 80 percent of the total life-cycle costs of a weapons system.

Costs during the sustainment phase can be driven by a number of factors, but technical data—for example, design and engineering models, manufacturing processes, and maintenance instructions—are key. DoD has traditionally used two-dimensional (2D) technical data, such as engineering drawings. Two-dimensional technical data were the state of the art when many of the legacy systems were designed, and DoD's policies, infrastructure, and staffing for technical data still reflect that 2D environment. For example, many DoD programs require technical data to be delivered in 2D drawings, even though contractors typically use three-dimensional (3D) models. To satisfy DoD's deliverable requirement, contractors must convert their 3D models to 2D drawings.

Cycle times, errors, and costs can be reduced by the use of 3D models throughout the product life cycle—from the start of system design through the disposal of the system. The use of 3D models throughout the product life cycle is often identified as a model-based enterprise (MBE) approach.

What Is MBE?

MBE uses the 3D models initially created in the conceptual design phase and evolves the models throughout the rest of the product life cycle (see Figure 1). The MBE concept evolved because, over the last few decades, major manufacturers have adopted 3D models in computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing, and numerically controlled machines. Those who have implemented MBE and some Lean manufacturing techniques have seen a significant return on that investment.

Fully implementing MBE means creating electronic models of early designs (in the conceptual design phase) and using those models to facilitate collaboration on those designs. Electronically shared 3D models enable collaboration on preliminary design, detailed/engineering design, virtual prototyping, manufacturing process design, and maintenance process design and documentation. During the sustainment phase, 3D models provide a consistent representation of the product line for various operations and sustainment processes. The models contain all of the information needed to define the

Figure 1. 3D Models at Different Stages of the Product Life Cycle

product in a form that allows the data to be automatically extracted for other uses, from virtual prototyping to Interactive Electronic Technical Manuals. This is how MBE shortens schedules, reduces errors and miscommunication, and saves money.

Why MBE in DoD?

The production of DoD weapons systems has been plagued by schedule and cost overruns for decades. A 2009 Government Accountability Office study of selected weapons programs found that cumulative cost overruns are almost $296 billion in 2009 dollars and that 64 of 96 defense programs active in 2009 reported increases in their projected cost since their initial cost estimate.[1] Studies of manufacturing organizations have shown that using an MBE approach can significantly reduce both nonrecurring costs and time-to-market.

One study on the transition from 2D drawings to 3D modeling classified companies as "best in class," "average," or "laggards," according to five parameters:

- Product revenue targets
- Product cost targets
- Development cost targets
- Launch dates
- Quality expectations.[2]

When assessed against each of the parameters, companies in the top 20 percent were classified as best in class, those in the middle 50 percent were classified as average, and those in the bottom 30 percent were classified as laggards.

A subsequent study showed that best-in-class performers adopted 3D modeling early and integrated it with all parts of the manufacturing process.[3] Compared with other organizations, best-in-class organizations are

- 40 percent more likely to have engineers use CAD directly—concept design begins in a model;
- half as likely to document any design deliverables on paper and 12 percent more likely to develop them completely electronically;
- 24 percent more likely to use the extended design capabilities of 3D modeling and 55 percent more likely to use its downstream capabilities;
- 1.6 times more likely to use digital methods in the testing process to provide guidance on the instrumentation of tests;
- 2.7 times more likely to augment surface modeling with realistic rendering and 3D scanned data for use in virtual fit-up, to develop a clearer picture of the design;
- 2.0 times more likely to use additive manufacturing (often referred to as 3D printing) and rapid prototyping to create quickly representative parts and products, as well as to use CAD and CAE tools for assessing a product virtually;[4] and
- 1.3 times more likely to digitally review test results to collaboratively find the root cause of product failures.

These characteristics match many of the MBE characteristics in terms of use of 3D models early in the life cycle, from conceptual design through sustainment. The gains they realize are substantial. Best-in-class organizations

- hit revenue, cost, launch date, and quality targets for 84 percent or more of their products;
- typically produce 1.4 fewer prototypes than average performers; and
- average 6.1 fewer change orders than laggards.

Best-in-class manufacturers that make the most complex products get to market an average of 99 days earlier than other organizations, and their product development costs are about $50,600 lower.

Considering the size of DoD acquisition programs (billions of dollars) and the very long life cycle of DoD systems (some systems operate for 50 years or more), the benefits of MBE in DoD would be substantial in terms of dollars. Further, because of the changing threats DoD faces, and the need for agility in responding to those threats, the shorter cycle times can translate to lives saved through faster fielding of new or modified systems.

The impact of MBE across the acquisition life cycle is significant. In the early phases of the life cycle, MBE can enable the following:

- More complete evaluation of the trade space

- Improved communications among stakeholders—by distributed, collaborative concept development
- Improved requirements
- Improved cost modeling of design alternatives, integrated with 3D CAD
- Earlier evaluation of manufacturing feasibility—producibility scoring during analyses of alternatives
- Distributed, collaborative design for virtual prototyping
- Producibility tool integration
- Verified product models
- Earlier risk identification and mitigation
- Early evaluation of manufacturing processes.

During detailed design and manufacturing process design, MBE supports the following:

- Earlier risk identification and mitigation
- Concurrent and collaborative engineering
- Verified producible design
- Distributed manufacturing process simulation
- Verified component and process cost models
- Visualization of end-to-end production and test processes
- Reduced defects and rework costs
- Accelerated development schedule
- Improved system and software reliability and quality
- Design reuse.

MBE can provide the following during production and deployment:

- Distributed manufacturing using a single digital master file
- Flexibility in location of manufacture
- Use of models for production line layout and work instructions
- Networked supply chains that permit greater visibility into parts, availability, and so on
- Time savings in both the manufacturing and fielding of systems
- Reduced manufacturing risk through simulation and virtual prototypes
- Reduced manufacturing-related costs and schedule.

During operations and sustainment, MBE provides advantages such as these:

- Earlier development of technical manuals—operator manuals and Level 1 maintenance manuals—driven by the authoritative model

- Higher quality instruction due to reuse of MBE data for audiovisual instructions in technical publications and manuals
- Accelerated parts procurement due to the use of 3D models, which expedites bidding and may decrease lead-times.

At the end of the product life cycle, 3D models support disposition decisions, whether for the Foreign Military Sales program; environment, safety, and health assessments; or destruction. Models can provide a complete picture of the system or subsystems, including locations of parts that require specific disposal processes.

In summary, MBE is an approach that has been used in the DoD industrial base for more than a decade. It can be implemented utilizing existing, commercially available tools. MBE can potentially generate large returns on investment, and it can help meet aggressive schedules for both initial production and sustainment. Various DoD organizations have been using 3D models on select acquisitions, and some have documented the benefits. The time is right for programs to consider the use of MBE for the full life cycle and for DoD to investigate the most efficient and effective ways to implement MBE.

[1]Government Accountability Office, *Defense Acquisitions: Assessments of Selected Weapon Programs*, GAO-09-326SP, March 2009.

[2]Aberdeen Group, *The Transition from 2D Drafting to 3D Modeling Benchmark Report*, September 2006.

[3]Aberdeen Group, *Complementary Digital and Physical Prototyping Strategies: Avoiding the Product Development Crunch*, February 2008.

[4]For more information, see "Additive Manufacturing" in this issue of the *DSP Journal*.

About the Authors

Denise Duncan is a senior fellow at LMI with 30 years of information systems management experience. She has managed a wide variety of projects, from assisting senior leaders with portfolio management to strategic planning for chief information officers. For the last 10 years, Ms. Duncan has worked extensively on the application of data management principles to engineering and scientific data. She has authored standards, handbooks, and training materials in enterprise-level data management and information management. Ms. Duncan has been honored as a technical fellow of TechAmerica and is the vice president for programs in the local chapter of Data Management Association–International.

Paul Huang leads the Army Research Laboratory's MBE program, which includes ManTech programs funded by the Army and the Office of the Secretary of Defense. In addition, he was the co-chair of the DoD Engineering Drawing and Modeling Working Group, leading the revision of MIL-STD-31000, "Technical Data Packages"; the group is reviewing standards documents for their relevance to MBE. Mr. Huang currently is on detail to the Office of Naval Research and serves as the Navy's primary panel member to the Advanced Manufacturing Enterprise Subpanel of the Joint Defense Manufacturing Technology Panel.

Program News

Topical Information on Standardization Programs

ANSI Launches Online Portal for Standards Incorporated by Reference

Originally published in ANSI News and Publications, October 28, 2013 (http://www.ansi.org/news_publications/news_story.aspx?menuid=7&articleid=3771).

The American National Standards Institute (ANSI) is proud to announce the official launch of the ANSI IBR Portal, an online tool for free, read-only access to voluntary consensus standards that have been incorporated by reference (IBR) into federal laws and regulations.

In recent years, issues related to IBR have commanded increased attention, particularly in connection to requirements that standards that have been incorporated into federal laws and regulations be "reasonably available" to the U.S. citizens and residents affected by these rules. This requirement had led some to call for the invalidation of copyrights for IBR standards. Others have posted copyrighted standards online without the permission of the organizations that developed them, triggering legal action from standards developing organizations (SDOs).

"In all of our discussions about the IBR issue, the question we are trying to answer is simple. Why aren't standards free? In the context of IBR, it's a valid point to raise," said S. Joe Bhatia, ANSI president and CEO. "A standard that has been incorporated by reference does have the force of law, and it should be available. But the blanket statement that all IBR standards should be free misses a few important considerations."

As coordinator of the U.S. standardization system, ANSI has taken a lead role in informing the public about the reality of free standards, the economics of standards setting, and how altering this infrastructure will undermine U.S. competitiveness. Specifically, the loss of revenue from the sale of standards could negatively impact the business model supporting many SDOs—potentially disrupting the larger U.S. and international standardization system, a major driver of innovation and economic growth worldwide. In response to concerns raised by ANSI members and partner organizations, government officials, and other stakeholders, ANSI began to develop its IBR Portal, with the goal of providing a single solution to this significant issue that also provides SDOs with the flexibility they require to safeguard their ability to develop standards.

IBR standards hosted on the portal are available exclusively as read-only files. In order to protect the intellectual property rights of the groups holding these standards' copyrights, the portal has built in security features that prevent users from printing, downloading, or transferring any of the posted standards; in addition, screenshots will be disabled and the standards will contain an identifying watermark.

For this first phase of the portal, ANSI has secured the participation of thirteen major domestic and international standards developers. Those that have agreed to have their IBR standards directly available on the ANSI IBR Portal include

- the International Organization for Standardization (ISO);
- the International Electrotechnical Commission (IEC);
- the Association of Home Appliance Manufacturers (AHAM);
- the American Welding Society (AWS);
- the International Association of Plumbing and Mechanical Officials (IAPMO); and
- the Illuminating Engineering Society (IES).

In addition, seven SDOs have agreed to allow the portal to provide direct links to read-only versions of IBR standards hosted on their own websites. Those organizations are

- the American Petroleum Institute (API);
- the American Plywood Association (APA);
- ASHRAE;
- MSS—the Manufacturers Standardization Society;
- NACE International—the Corrosion Society;
- the National Fire Protection Association (NFPA); and
- UL (Underwriters Laboratories).

With the launch of Phase I of the portal, ANSI expects that many more SDOs—both in and outside the community of ANSI-accredited standards developers—will sign on to participate.

"Time and again, we heard that there is demand for a single solution, to make it easy for those affected by any piece of legislation to view the related IBR standards. But at the same time, there is also a strong need to allow for flexibility, so that each SDO can provide reasonable access in the way that makes sense for their business model and doesn't undermine their ability to function," said Mr. Bhatia. "We believe that the ANSI IBR Portal does all that. And as coordinator of the U.S. standardization system, we are very proud to present this solution."

To view the ANSI IBR Portal, visit ibr.ansi.org.

Events

Upcoming Events and Information

April 1–3, 2014, Kettering, OH

SYS 120 Defense Standardization Workshop

The Defense Acquisition University will be offering "SYS 120 Defense Standardization Workshop," which covers DoD policies and procedures for the development, management, and use of non-government standards, commercial item descriptions, and specifications and standards. Individual and group practical exercises emphasize the application of standardization tools, policies, and procedures. This course is designed for professionals actively involved in the development or management of specifications and standards, handbooks, commercial item descriptions, or non-government standards. For more information or to register, please go to www.dau.mil and click "Apply for a Course." Please note that this course has prerequisite requirements that must be fulfilled prior to registration.

April 29–May 1, 2014, McLean, VA

PSMC Spring 2013 Meeting

The Parts Standardization and Management Committee (PSMC), chartered by DSPO, will hold its spring meeting at LMI in McLean, VA. The agenda will include presentations on current parts management topics and breakout sessions for subcommittees to work specific tasks. If you are involved in parts management and are interested in participating, please e-mail Donna.McMurry@dla.mil or call her at 703-767-6874. Additional information will be posted on the PSMC website: http://www.dscc.dla.mil/programs/psmc/events.asp.

August 11–14, 2014, Ottawa, ON, Canada

63rd Annual SES Conference

The Standards Engineering Society (SES) will host its 63rd Annual Conference at the Chateau Laurier, in Ottawa, Ontario. The theme of this conference is "Standardization and Conformity Assessment across Borders." For more information on this event, please go to http://www.ses-standards.org/displayconvention.cfm.

People

People in the Standardization Community

Welcome

Julie Redfern from Marine Corps Systems Command has been named as the Marine Corps Standardization Officer. In this capacity, she is responsible for establishing standardization policies and processes for Marine Corps ground systems, as well as for supporting overall Department of the Navy DSP-related matters. Ms. Redfern also oversees the Marine Corps technical drawings/models efforts and in-service engineering initiative.

Kimberly Watkins was recently named the Defense Information Systems Agency (DISA) Standardization Executive. She replaces Michael O'Connor, who recently accepted a position at NATO. Ms. Watkins also serves as the technical director for enterprise engineering at DISA.

Farewell

Michael O'Connor recently accepted a new position with the U.S. National Technical Experts Office at NATO. Prior to this position, Mr. O'Connor served as the Standardization Executive for DISA, as well as the chief for interface standards within DISA's Enterprise Engineering Directorate.

Joseph Delorie retired from the federal government on January 2, 2014, with 41 years of service to the Department of Defense. For more than 20 of those years, he served as a senior analyst at DSPO. Mr. Delorie developed DSP policy and procedures in a number of areas; however, his particular focus has been on developing and maintaining automated tools that support the mission of the DSP. He presided over the ASSIST database for almost 20 years, guiding it from a character-based, client-server system to the World

People

People in the Standardization Community

Wide Web. Under his leadership, ASSIST has developed into a suite of integrated applications and systems with websites on public, public-restricted, and private networks.

Due to Mr. Delorie's extensive knowledge and background in the DSP, he has been brought back to DSPO as a part-time rehired annuitant to mentor less-experienced employees. We wish him well in his retirement, but we are glad to have him back on a part-time basis to provide continuity as critical tasks and responsibilities are transitioned to others.

Samuel Merritt retired on January 10, 2014, after more than 43 years of commendable service to the nation as both a Vietnam veteran and a member of the federal service. As the director of the Engineering and Technical Support Directorate at the DLA Land and Maritime, Columbus, OH, Mr. Merritt had management responsibility for ensuring the proper implementation of the defense standardization programs (product qualification, specification preparing activity, parts management, etc.), along with other technical and engineering programs. He shaped the organization through numerous initiatives to focus on the always-changing technical needs of the DLA Land and Maritime supply chains. He was also the driving force within DLA to develop and implement methods to mitigate and detect counterfeit microcircuits. These strategies included the establishment of the Qualified Suppliers List of Distributors Program, the Qualified Testing Suppliers List Program, and the Deoxyribonucleic acid (DNA) marking requirement for microcircuits. We wish him well in his retirement.

Defense Parts Management Portal–DPMP

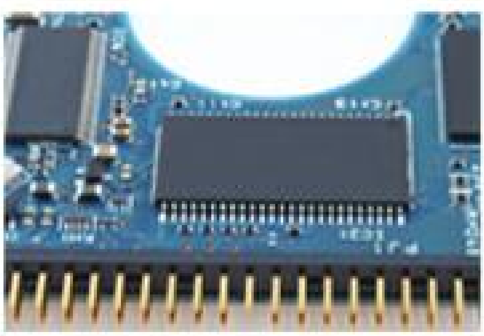
The DPMP is a new public website brought to you by the Parts Standardization and Management Committee (PSMC) to serve the defense parts management community.

The DPMP is a new resource, a new marketplace, and a "one-stop shop" for parts management resources. It is a navigation tool, a communication and collaboration resource, and an information exchange. It gives you quick and easy access to the resources you need, saves you time and money, connects you to new customers or suppliers, and assists you with finding the answers you need.

This dynamic website will grow and be shaped by its member organizations. A new and innovative feature of the DPMP is its use of "bridge pages." Organizations with interests in parts and components are invited to become DPMP members by taking control of a bridge page. Chances are good that your organization is already listed in the DPMP.

There is no cost.

Explore the DPMP at https://dpmp.lmi.org. For more information, look at the documents under "Learn more about the DPMP." Click "Contact Us" to send us your questions or comments.



Upcoming Issues
Call for Contributors

We are always seeking articles that relate to our themes or other standardization topics. We invite anyone involved in standardization—government employees, military personnel, industry leaders, members of academia, and others—to submit proposed articles for use in the *DSP Journal*. Please let us know if you would like to contribute.

Following are our themes for upcoming issues:

Issue	Theme
October/December 2013	Counterfeits
January/March 2014	Qualification/Conformity Assessment
April/June 2014	Standardization Stars

If you have ideas for articles or want more information, contact Tim Koczanski, Editor, *DSP Journal*, Defense Standardization Program Office, 8725 John J. Kingman Road, STOP 5100, Fort Belvoir, VA 22060-6220 or e-mail DSP-Editor@dla.mil.

Our office reserves the right to modify or reject any submission as deemed appropriate. We will be glad to send out our editorial guidelines and work with any author to get his or her material shaped into an article.