CONCEPT OF OPERATIONS FOR DLA PROCUREMENT OF WEAPON SYSTEM PARTS USING 3D TECHNICAL DATA

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Executive Summary

This concept of operations (CONOPs) describes a proposed set of actions for enabling the Defense Logistics Agency (DLA) to use three-dimensional (3D) technical data in its daily operations, with a focus on procurement of weapon system parts.

DLA's current procurement processes are built to accommodate and use two-dimensional (2D) technical data; however, industry and the military services have transitioned to computer-aided design (CAD) and computer-aided manufacturing (CAM), both of which produce and use 3D technical data. To preclude a gap in its ability to acquire parts on behalf of the military services, DLA must ensure its process capabilities fully enable the use of 3D technical data during regular procurement actions.

DLA's current procurement process and the basic process steps for building and distributing a technical data package (TDP) do not need to change to use 3D technical data to procure parts.[1] However, there is a gap in DLA's current capability to use 3D technical data, as shown in Table ES–1.

DLA does not have suitable software or the associated training to use it to access and display the full product definition contained in 3D files stored in different CAD software formats. This precludes DLA from conducting the required checks for completeness and consistency in technical data before they are released as part of a solicitation.

[1] Minor changes to execution procedures and development of new solicitation and contract clauses will be required.

Table ES–1. DLA Process Capabilities for 2D and 3D Technical Data

TDP Build-Distribute Process Steps	**DLA Capability to Process Technical Data**	
	2D Data	3D Data
Receive/retrieve	Full capability	Full capability
View	Full capability	Limited capability
Store	Full capability	Full capability
Review	Full capability	Limited capability
Distribute	Full capability	Full capability

Green: Full capability · Yellow: Limited capability · Red: No capability

DLA has various options for mitigating or eliminating this capability gap.

- *Option 1* is to purchase software packages and associated training for each of the proprietary CAD software platforms.
- *Option 2* is to require technical data be recorded in a single proprietary CAD format for which DLA has copies of the software and has acquired requisite training for its work force to use it.
- *Option 3* is to require technical data to be recorded in a file format that can be read using vendor-neutral software for which DLA has acquired copies of the software and requisite training for its work force.

To successfully fill the existing capability gap, the chosen option needs to solve, at a reasonable cost, three major challenges related to using 3D technical data in procurement:

- Provide DLA personnel the ability to fully access and view data originally recorded in proprietary CAD software format.
- Ensure DLA personnel can easily locate and confirm the inclusion of all information necessary for procurement and manufacturing (i.e., personnel have requisite training and skill to use appropriate software tools).
- Ensure technical data in solicitation packages is accessible and useable by a majority of potential suppliers without the need for procuring expensive software and training.

Table ES–2 summarizes the viability of the three proposed options to resolve each challenge.

Table ES–2. Comparison of Options for Filling DLA's Capability Gap to Use 3D Technical Data

Options	**Challenges**		
	Full Data Access	Easily Locate Data	Supplier Accessibility to Data
(1) Purchase S/W for each CAD Platform	🟡	🟡	🔴
(2) Require TDPs in One CAD Format	🟡	🟡	🔴
(3) Require TDPs in Neutral Format	🟢	🟢	🟢

🟢 Low cost solution 🟡 High cost solution 🔴 Does not solve challenge

S/W = Soldier Weapon.

Only Option 3, TDPs in a neutral file format (i.e., 3D portable document format [PDF], with a Standard for the Exchange of Product [STEP][2] file), can solve all three challenges associated with using 3D technical data in a procurement action. Option 3 also provides a side benefit to DLA; it will not need to procure new software to access 3D PDF files since they are read using Abode Acrobat, which is already installed on enterprise information technology (IT) systems.

Option 3 should become the desired end-state for DoD. DoD programs are increasingly adopting 3D PDF as their preferred format for sharing technical data internally and externally. Accordingly, the military services should endeavor to provide DLA with 3D technical data that is complete and validated and stored in 3D PDF product representation compact (PRC) and STEP file formats.

DLA cannot take many unilateral actions to achieve the desired end state—conducting procurements using 3D technical data in 3D PDF (PRC) and STEP file formats. Some actions require collaboration with the engineering support activities (ESAs), the military services, program managers, or Office of the Secretary of Defense (OSD) subordinate offices. Still, DLA should attempt to influence or convince these activities that it is in DoD's best interest to acquire or provide technical data in a 3D PDF (PRC) format with a corresponding STEP file to facilitate parts procurement.

To that end, we recommend DLA continue its regular engagement with DoD Model-Based Enterprise (MBE) activities and groups. We further recommend DLA to initiate the following actions in concert with the military services and ESAs:

1. Conduct a 3D PDF demonstration project to prove the concept of an end-to-end process of creating and using a 3D PDF data file to solicit and manufacture an item.

[2] STEP is the informal name for ISO 10303, Standard for the Exchange of Product Model Data.

2. Specify and codify what 3D technical data content is necessary for procurement.

3. Monitor the M2A1 program for lessons learned regarding 3D PDF TDPs.

4. Update the military services' performance-based agreements (PBAs) regarding TDPs in 3D format.

5. Accept for procurement actions, new program items described exclusively by 3D models only when the technical data is in 3D PDF (PRC) format.

Collaborative actions 1 through 3 above should be started within the next 2 months. Actions 4 and 5 should be started in the next 12–15 months.

In conjunction with the collaborative actions above, we recommend DLA take the following internal actions.

1. Revise DLA procurement policy regarding the use of 3D TDPs.

2. Develop contract language addressing use of 3D TDPs in the procurement process.

3. Continue the DLA MBE Technology Roadmap activity.

4. Update the Defense Logistics Acquisition Directive (DLAD) to reflect new policy/requirements regarding 3D TDPs.

5. Update DLA TQ Deskbook to reflect new or revised TDP requirements relative to 3D data.

6. Inform DLA supplier base of impending transition from 2D to 3D technical data.

7. Educate and train DLA personnel to read and interpret 3D PDF and STEP file formats.

Internal actions 1 through 3 should be started within the next 2 months. Action 4 should be started with the next 6–12 months. Actions 5 through 7 should be started in the next 12–15 months.

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Chapter 1
Introduction

This concept of operations (CONOPs) describes a proposed set of actions for enabling Defense Logistics Agency (DLA) to use three dimensional (3D) technical data in its daily operations with a focus on procurement of weapon systems parts.[1]

DLA's current procurement processes are built to accommodate and use two dimensional (2D) technical data supplied by the military services; however, over the last 20 years, military service acquisition programs have come to rely almost exclusively on computer-aided design (CAD) and computer aided manufacturing (CAM) to plan, model, and build new weapon systems and repair/modify/upgrade legacy weapon systems. As a result, the services are increasingly making available 3D technical data, in the form of CAD files, to DLA along with 2D technical data. Presumably, 3D technical data will be the only format available in the future.

To preclude a gap in its ability to acquire parts on behalf of the military services, DLA must enhance its capability to use 3D technical data in regular procurement operations.

This CONOPs describes the current DLA procurement process relative to technical data, identifies new requirements for using 3D technical data, presents options for meeting the new requirements, and presents our recommendations for specific options and implementing actions.

[1] For the purposes of this 3D Technical Data research and development (R&D) task, we assumed the military services provide DLA with approved model-based technical data. Our focus is on the use—not the generation, validation, or approval—of technical data from an engineering standpoint.

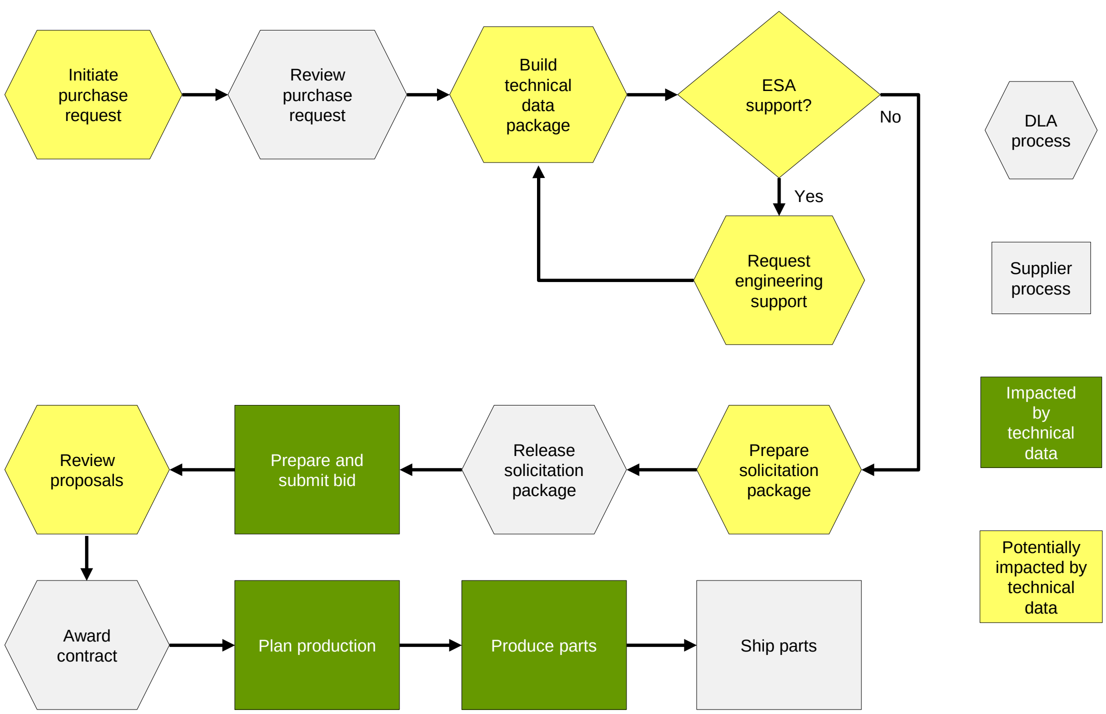
Chapter 2
Current Procurement Process

Traditionally, technical data for parts procurement has been recorded and provided to DLA in 2D format (e.g., a raster file or portable document format [PDF] file). DLA uses a standard process for obtaining, consolidating, and making the technical data available as part of its procurement process. This chapter describes that process.

DLA Procurement Process

Figure 2-1 depicts DLA's current procurement process. It delineates who (i.e., DLA or the supplier) performs each process step and whether the step is affected by the use of technical data.

Figure 2-1. DLA Procurement Process



ESA = engineering support activity.

The procurement process begins when DLA determines it needs to buy a part and initiates a purchase request (PR). DLA must then build a technical data package (TDP) that includes all relevant information about the part such that a supplier can build or source that item.

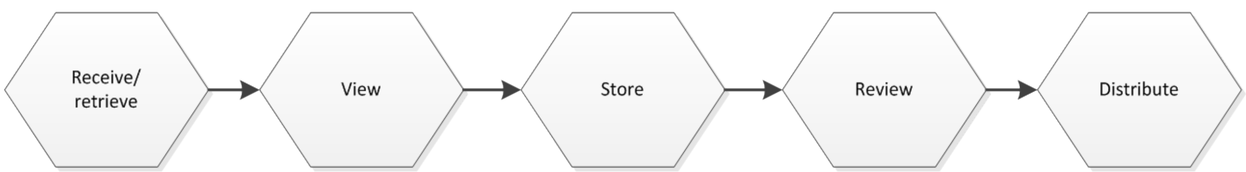
Once the TDP is constructed, a solicitation package is prepared and released to the public through the DLA Internet Bid Board System (DIBBS). Potential suppliers review the solicitation, including the TDP, and prepare a quote that they return to DLA. DLA then reviews all of the proposal submissions and selects a winning supplier to whom it awards a contract. The winning supplier uses the TDP to plan and build the item, which it subsequently ships to a designated receiving site.

Embedded in the DLA procurement process are several steps specifically related to TDPs; they are summarized in more detail in the following subsection.

BUILDING AND DISTRIBUTING A TDP

Building and distributing a TDP as part of a procurement solicitation requires a series of steps. Each step is performed by personnel with different roles, principally the product data specialist (PDS) and the product specialist (PS). Figure 2-2 summarizes the procurement steps. This process is based on the current use of 2D technical data.

Figure 2-2. Building and Distributing a TDP for Procurement—DLA Steps



Receive/retrieve. Technical data is owned and provided by the military service or the engineering support activity (ESA). If DLA has procured a part in the past, the technical data may already be stored in the DLA Document Management System (DMS). If the files are not in DMS, the PDS can search the Military Engineering Data Asset Locator System (MEDALS) or the services' repositories for the appropriate documents. The PDS uses an engineering data list (EDL) for Air Force systems or a technical data package list (TDPL) for Army systems (EDL/TDPL provided by the services) to identify and confirm the technical data files are the most current and appropriate version. The Navy only provides a top level system document to DLA, so, the PDS must do a top-down breakdown of the system by searching through Navy data repositories to identify, find, and extract the data items he/she believes describe the item to be procured. If the PDS cannot obtain the most current or appropriate version of the data, he or she will engage the ESA for assistance. Technical data provided by the ESA may be distributed to DLA by email or through regular mail.

View. The PDS opens and views the technical data to assess if it is saved in an accessible format, is legible, and is complete (i.e., contains all of the documents) per the EDL or TDPL. If there is an issue, the PDS will attempt to resolve it and may engage the ESA for help. The PDS may need to edit the technical data to make it more legible (e.g., crop images, de-speckle/de-skew images, or even change the format).

Store. The PDS uploads the technical data in the DLA DMS and links it to the appropriate material (i.e., item to be procured) in the Material Master File to build the bidset that will be used for the procurement solicitation.

Review. A PS reviews the technical data in the bidset to ensure it is legible and contains all the information required to manufacture or source the part DLA plans to procure (see Appendix A, Technical Data Checklist, for a list of data elements). The review process ensures DLA's suppliers will have the information they need to develop a bid/quote to manufacture the part. It also ensures the supplier will have the information needed to develop a process plan, manufacture the item, and perform quality assurance (QA) checks.

Distribute. When the solicitation package is approved and released for procurement, bidsets (which include the TDP) are posted automatically by the Enterprise Business System (EBS) to cFolders. Suppliers access and review the solicitations posted to DIBBS and using an embedded link, can view or download the associated TDP in the cFolders to facilitate the bid and proposal preparation as well as manufacturing (if they are awarded a contract).

The process steps described above are repeated for each procurement or acquisition. Again, these steps are based on the use of 2D technical data. Chapter 3 discusses requirements relative to 3D technical data.

Chapter 3
Current DLA Capabilities to Process 3D Data

DLA's current procurement process does not change when 3D technical data are used to acquire a part (i.e., no 2D data is included in the TDP).[1] Similarly, the basic process steps for building and distributing a TDP do not change when the technical data are in a 3D format. What changes, are the tool requirements (including user skill level) and specific procedures to accomplish the TDP build and distribution process steps.

DLA's Current 3D Data Capability

The following paragraphs describe DLA's current capability to process 3D technical data during each of the TDP build and distribute process steps.

Receive/retrieve. DLA's current software and hardware capabilities are sufficient to locate and download most 3D data files from the appropriate service repositories. There is no specific limit to the size of a file that can be downloaded to a DLA computer; however large files require more time to download. The PDS may split large files into smaller downloads to avoid restricting their computer's processing capability. For technical data that are sent by e-mail, there is a file size limit of 8–10 MB on attachments as a result of the anti-virus software package installed on the DLA computer systems. When a 3D file is too large for efficient direct download or email, the PDS can request the military service or ESA send the file on a CD-ROM through regular mail.

View. As part of its current procurement process tool kit, DLA has the Imagenation Viewer for accessing and viewing 3D technical data. Installed in the DLA DMS, the Imagenation Viewer provides a PDS the capability to import, access, and view 3D files; however, the Viewer does not provide a means to access and show all the data contained in the files. For example, some data (like drawing version, distribution statement, security, export control, revision number, and other metadata[2]) may not be accessible using the Viewer (accessibility depends on the original file type.)

Store. DLA's current software and hardware capabilities are sufficient to store 3D files in the DMS. Each file is labeled with the appropriate file extension and document identifier and indexed with associated metadata.

[1] Minor changes to execution procedures and development of new solicitation and contract clauses will be required.

[2] Metadata may include drawing number, part number, national stock number (NSN), export control, specification, notes, dimensions, tolerances, and other information.

Review. Similar to the *View* step, the Imagenation Viewer is used to access the 3D file and conduct a review of the included data. Using the Viewer, a PS can view and rotate a representation of the model (e.g., solid/wire-form geometric shape) contained in the 3D file. However, the Viewer does not provide a means to access and show all the data contained in a 3D file, which fully defines the product. For example, dimensions, notes, tolerances, material composition, bill of material, etc. generally are not accessible using the Imagenation Viewer.

Distribute. DLA's current software and hardware capabilities are sufficient to post 3D data files to the EBS cFolders, which are linked to the appropriate solicitation posted to DIBBS.

We note that DLA has only a limited capability to process 3D technical data during the View and Review steps of Figure 2-2. A summary of DLA capabilities relative to processing 2D and 3D technical data is presented in Table 3-1.

Table 3-1. DLA Process Capabilities for 2D and 3D Technical Data

TDP Build-Distribute Process Steps	**DLA Capability to Process Technical Data**	
	2D Data	3D Data
Receive/retrieve	Full capability	Full capability
View	Full capability	Limited capability
Store	Full capability	Full capability
Review	Full capability	Limited capability
Distribute	Full capability	Full capability

Full capability (green) | Limited capability (yellow) | No capability (red)

Gaps in Meeting 3D Requirements

As noted above, DLA's current capability to work with 3D technical data is limited relative to the *View* and *Review* process steps. Specifically, DLA lacks the capability to access and display the full product definition contained in 3D files. This inability precludes the PDS or PS from conducting the required completeness and consistency checks of the technical data before they are released as part of a solicitation. Accordingly, there is a significant gap in DLA's ability to routinely use 3D technical data in the procurement process. The capability gap has two parts, (1) lack of appropriate software tools, and (2) lack of necessary user skill/knowledge to operate those tools.

The gap associated with DLA's current capabilities stems from a single factor: 3D technical data are recorded in multiple proprietary CAD formats, which DLA cannot fully access because it does not have appropriate software and associated training.

Four major CAD software platforms are used for designing DoD weapon systems: SolidWorks, CREO 2 (Pro-E), NX, and CATIA. As a general rule, DLA currently does not provide to its PDSs or PSs, copies of these software programs, which are used to produce the 3D models and associated technical data for various weapon systems. To carry out its acquisition responsibilities, DLA must be able to open and view the 3D models created with these software platforms and navigate the models to confirm they are the correct version and contain the design data and metadata a supplier requires to build the parts identified in a solicitation.

In terms of tool requirements, DLA needs more capable software tools. The software tools must be fully compatible with 3D file formats to meet DLA's requirements for using 3D technical data. Full compatibility means the software can import a 3D file, then access and display all included data that describes or defines the product. Additionally, each new software tool DLA acquires to meet its procurement responsibilities will require training to ensure acquisition personnel have the required knowledge and skill to use the new software.

DLA can proceed in a number of ways to mitigate or eliminate its current capability gap and be able to fully process 3D technical data. Chapter 4 identifies various options for filling the gap and describes the pros and cons of each option.

Chapter 4
DLA's Options

DLA can overcome its current capability gap in several ways so that it can access and use 3D files throughout the procurement process.

- *Option 1* is to purchase software packages for each of the unique proprietary CAD software platforms.
- *Option 2* is to require technical data be recorded in a single proprietary CAD format, and DLA acquires copies of the software associated with that format.
- *Option 3* is to require technical data be recorded in a file format that can be read using vendor-neutral software (i.e., neutral file format[1]), and DLA acquires copies of the vendor-neutral software.

This chapter considers the details and issues associated with each option for using 3D technical data in the procurement process.

OPTION 1: PURCHASE SOFTWARE

If DLA purchases software packages for each of the four major CAD platforms, it would be able to view all data included in any 3D model produced with one of those proprietary software platforms. However, the cost of purchasing and maintaining the software would be expensive. The cost for one license of a proprietary software platform is approximately $4,000–$28,000; the cost of procuring one license for each of the four software platforms would range between $26,000–$79,000, depending on the software platforms procured (See Appendix B, CAD Platform Price Ranges). These figures do not include additional costs associated with maintenance, future versions/upgrades, or the cost to train DLA personnel to use the software.

DLA has many acquisition personnel (i.e., PDSs and PSs) who would need to use the software, so, DLA would need to procure multiple licenses for each proprietary software platform. If DLA bought one license for each platform, PDS, and each PS (approximately 850 personnel), the cost would be approximately

[1] A neutral file format is defined by international, vendor-neutral standards. As such, all relevant information, data, and intellectual property are in the hands of the marketplace, and development of the standard is driven by the community itself. International standards by their nature are stable and can be slow to evolve, but protect the investment in tools and processes of the community by ensuring the data can be used and recovered from an archive repository.

$22.1 million–$67.1 million (these figures do not consider any volume discounts that might be available).

In addition, DLA would most likely need to upgrade the hard drive, memory, and graphics card on existing desktop computers to accommodate the CAD software. The cost of these upgrades is not known; estimating that cost would require a comparison of each CAD software package's minimum requirements to the DLA desktop computers' capability, and an analysis of any additional annual maintenance costs resulting from the upgrades.

Potential Issues

In addition to the initial expense of procuring the CAD software, there are two significant issues associated with this option; software familiarity and supplier accessibility.

Software Familiarity

If DLA chooses to purchase copies of the four major CAD software programs, its acquisition personnel would, in most instances, be able to open the native CAD files.[2] However, they may not be able to locate specific technical information because they are not familiar with the native file software structure and operating rules that determine how and where data (such as dimensions, tolerances, notes, etc.) are stored. Generally speaking, DLA personnel do not have any substantial operational experience working with 3D models or native CAD files. Without formal training, DLA can expect its personnel to have difficulty using and reviewing native files because they lack a basic level of software-specific literacy (which is not easily acquired).

Gaining sufficient experience and knowledge to navigate and use a proprietary CAD software package will require significant formal training for each PDS or PS involved with the acquisition of parts using 3D TDPs. In general, DLA personnel would require at least the beginner-level of training, which equates to a 1-week course. Training costs range from $2,500 to $3,000 per student (see Appendix C, CAD Training Price Estimates) per course. This course cost does not include travel expenses. Accordingly, the cost to train one PDS or one PS on all four of the major CAD software platforms would be about $10,000–$12,000. To train all DLA PDSs and PSs (approximately 850 personnel) to use all four CAD software packages would cost roughly $8.5 million to $10.2 million.

[2] Our research indicated newer versions of a CAD software package are generally backward compatible, but older versions are generally not forward compatible. To illustrate: version 5 of a CAD software package can read files created in earlier versions of the software, but v1 cannot read subsequent versions. Current CAD software applications may not be backward compatible to every earlier software version (e.g., version 5 may only be compatible back to version 2).

Supplier Accessibility

Most original equipment manufacturers in the DoD supply chain transitioned to CAD/CAM decades ago. In 2009, a National Institute for Standards and Technology (NIST) survey of more than 400 small-scale suppliers found that fully two-thirds of those surveyed were able to receive, use, and send 3D data.[3] However, not every supplier has or uses the same CAD software.

In addition, current CAD software platforms are not fully compatible with their counterparts (see Appendix D, CAD Software Compatibility Matrix) and there is no universal CAD software nor a single viewer/reader/translator capable of showing all the details embedded in the native files for each of the major CAD platforms. So, it is virtually assured that, for any given solicitation, one or more potential suppliers will not have the requisite CAD software needed to access and use the 3D files that make up the TDP. This is a potentially significant issue for DLA.

The federal government must, by law, meet the "fairness paradigm" in its procurement process. It cannot legally mandate that suppliers make large investments in proprietary software as a prerequisite for doing business with DLA. Accordingly, TDPs included in DLA solicitations must be useable by a majority of potential suppliers without a requirement for acquiring specific proprietary CAD software platforms/applications to facilitate solicitation bidding and manufacturing of a part.

Should DLA choose to issue a solicitation that includes only a 3D model in a single proprietary software format (i.e., there are no accompanying 2D data), it can expect a protest from any potential supplier that does not own a copy of the requisite CAD software.

OPTION 2: REQUIRE TDPS BE RECORDED IN ONE CAD FORMAT

Requiring that TDPs be recorded in a single proprietary format would significantly limit the number of software programs that DLA would need to procure and train its PDS/PS personnel to use. Obviously, this option would be less expensive for DLA; however, it still would require significant expenditures.

At a minimum, DLA would need to purchase one license for the selected CAD software for each of its acquisition personnel required to view TDPs. As noted earlier, the cost would be between $4,000 and $28,000 per license (depending on the software platform), which works out to be between $3.4 million and $23.8 million if DLA equips all PDSs and PSs who would need the software. As before, these figures do not include additional costs associated with maintenance, future versions/upgrades, or the cost to train DLA personnel to use the software. Nor do they account for any volume discounts the software provider might offer.

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[3] http://model-based-enterprise.org/mbe-2009-supplier-assessment.html.

In addition, DLA would likely need to upgrade the hard drive, memory, and graphics card on its existing desktop computers to accommodate the CAD software. The cost of these upgrades is not known; estimating the cost would require a comparison of the CAD software's minimum requirements to the DLA desktop computers' capability, and an analysis of any additional annual maintenance cost resulting from the upgrades.

Potential Issues

Identical to the first option, there are the significant issues associated with software familiarity and supplier accessibility, as described previously. This option does nothing to resolve those issues.

Another major issue is associated with Option 2. It is extremely unlikely that the military services (let alone their individual program offices) would agree to this approach because implementation could require major changes to their acquisition methods or significant additional expenditures to convert any 3D models not originally produced in the selected/designated proprietary CAD format.

This option would also effectively create a monopoly for the CAD software developer whose system was chosen as the single format of record. Not only would this preclude any cost benefits that might accrue from competition, it likely violates the Federal Acquisition Regulations (FAR).

OPTION 3: REQUIRE TDPS BE RECORDED IN A NEUTRAL FILE FORMAT

Requiring TDPs to be recorded in a neutral file format will have some additional cost, but the major software cost issues, software familiarity issues, and supplier accessibility issues associated with purchasing proprietary software are eliminated or substantially mitigated.

Our research indicates there are five vendor-neutral 3D file formats currently available: JT, STEP, integrated graphics exchange specification (IGES), hypertext markup language 5 (HTML5), and 3D PDF. Using one or more of these formats eliminates the issues associated with proprietary software because the software required for viewing each comes at a low cost or no cost.

None of the vendor-neutral formats by themselves can provide the complete product definition required for manufacturing most cannot meet the publishing requirements for product definition data sets[4] (i.e., TDPs). In fact, only the HTML 5 and 3D PDF formats can provide an "approval indicator" that is required

[4] Naval Air Warfare Center Aircraft Division, Support Equipment Engineering Division, Lakehurst NJ, Design Data Report No. NAWCADLKE-DDR-486600-0008, 10 July 2013 (See *Appendix E. 3D PDF as the Solution for Model-Based Definition*).

in publishing a TDP.[5] In fact, as a result, only the HTML5 and 3D PDF formats, when combined with a Standard for the Exchange of Product Model Data (STEP) file, can provide the complete product definition and meet the requisite publishing requirements. (The STEP file provides the necessary geometry to create machine code required for manufacturing.)

HTML5 is supported by all major web browsers using the Web Graphics Library (WebGL) application programming interface (API) to enable 3D viewing. While HTML5 supports 3D viewing, it requires a connection to the source databases to extract data. Accordingly, its use in providing TDPs to suppliers as part of the procurement process is problematic because it would require suppliers be granted firewall access to .gov or .mil networks that house the source data.

The 3D PDF format has no such limitations. See Appendix E, 3D PDF as the Solution for Model-Based Definition, and Appendix F, 3D PDF Details and Supporting Information, for detailed discussions of the attributes of the 3D PDF that meet DoD/DLA needs relative to 3D technical data.

3D PDF

A 3D PDF file that uses the product representation contract (PRC) format permits the import of all major CAD applications into a universal PDF file. The PRC format supports exact geometry data and tessellated data, product structure, and product and manufacturing information (PMI). 3D PDF files are read using Adobe Acrobat or Adobe Reader. (See Appendix F, 3D PDF Details and Supporting Information, for additional detailed information regarding 3D PDF.)

Adobe Acrobat is already installed on DLA computers, so there is no additional cost to DLA for purchasing new software. Since Adobe Reader software is available via the Internet and free of charge to anyone, DLA suppliers who don't already have the software can obtain it at no extra cost.

In addition, there is little to no unique training required to open and navigate a 3D PDF because it follows the standard rules for all PDF documents. What makes the 3D PDF file different from a standard PDF file is the (intuitive) interactive 3D model embedded in the 2D page, which allows the reader to manipulate (rotate and query) the model.

[5] Per ASME Y14.41, paragraph 4.3.2 (Approval): "The data set shall be approved in accordance with ASME Y14.100." Per ASME Y14.100, an approval indicator shall be electronically affixed. An approval indicator must be unique to an individual, capable of verification, and under the individual's sole control. Publishing is an established process for all TDPs. Reference: Naval Air Warfare Center Aircraft Division, Support Equipment Engineering Division, Lakehurst NJ, Design Data Report No. NAWCADLKE-DDR-486600-0008, 10 July 2013.

Potential Issues

Despite its benefits, there are three potential issues associated with using a 3D PDF format:

1. It cannot be used as an input into CAM and QA software packages. In other words, it does not include the geometry to create machine code.

2. A specific software translator is required to obtain PMI data when converting CAD files to 3D PDF files.

3. A formatted template is required to display data in 3D PDF files in the way a user would expect to see the data.

These issues are discussed in the following paragraphs.

CAM Machine Code

A 3D PDF file does not contain the geometry required to produce machine code in a CAM software package. This issue is easily solved, however, by attaching to the 3D PDF file a validated STEP file for the appropriate item.

All of the major CAD software platforms can export their data into a STEP AP203 format, so there is no additional cost to a program for purchasing software to create a STEP file. The AP203 format provides geometric information to create a machine code for computer numerical control (CNC) manufacturing; but it does not provide the complete product definition. Specifically, the STEP AP203 file format includes only geometry, so the original CAD features, geometric dimensioning and tolerancing (GD&T) relationships, and part metadata are not included.

A 3D PDF file with a validated STEP file attached as part of a TDP can include all of the information necessary for a supplier to manufacture a part irrespective of which CAD/CAM software package they may be using.

PDF Conversion Software

Each major CAD platform comes with conversion software for translating native file data to a number of neutral file formats STEP). However, the embedded translators do not produce 3D PDF files. Additional software is required to convert native file data into3D PDF files.

A number of companies specialize in providing software for converting native CAD data into 3D PDF data (see Appendix G, Conversion and Training Providers for 3D Technical Data). Some 3D PDF conversion software also may require a translator relative to the specific CAD software package to convert the CAD file to 3D PDF. The translator allows the user to obtain PMI, GD&T, metadata and other necessary technical data for procurement and manufacturing. Selecting 3D

PDF conversion software will require attention to detail to ensure the output product will meet the requirements for procurement and manufacturing.

At least three companies (Anark, Lattice Technology, and Tetra4D) offer 3D PDF conversion software potentially capable of producing a file with the requisite technical data for procurement and manufacturing. A single copy of the conversion software costs between $500–$25,000, depending on user requirements and the software provider. Appendix H provides approximate costs for single licenses and server applications for conversion software.

To effectively implement the 3D PDF plus STEP solution, DoD/DLA will need to identify and match their specific data requirements to conversion software capabilities. Subsequently, DoD/DLA will need to decide the best approach for locating and using the software within the overall weapon system acquisition process (e.g., procure conversion software for the ESAs and assign them responsibility for producing 3D PDF data for the systems under their cognizance, or require each Program Office to acquire the conversion software and deliver 3D PDF documents to the ESAs).

PDF Template

A template is required when converting a native CAD file to 3D PDF. The template enables the display of data in locations that meet the user's needs. A standard template is typically provided as part of the 3D PDF conversion software discussed above. The standard template may not include all the data elements required by the program office or DLA for procurement. In such cases, the standard template can be customized to the specific data and format requirements of an individual program office and DLA. The standard template can be modified using Adobe Acrobat software.

If the template is modified in-house, the only cost is the developer's time. Alternatively, the companies that provide the 3D PDF conversion software and other companies that work with 3D PDF technical data can customize a standard template. The time required for customization varies based on the user's requirements, but generally, the cost ranges from $8,000–$10,000, depending on the number of data elements and the complexity of the template layout.

To effectively implement the 3D PDF plus STEP solution, DoD/DLA will need to ensure all the mandatory data elements for procurement are captured in the 3D PDF template. DLA may also need to provide its PDS/PS personnel some training on data location within the different PDF templates. (Appendix G provides a list of companies that provide 3D PDF training.) We expect that such training will be minimal because basic PDF format and operating rules are standard and intuitive making navigation and data location relatively easy.

Chapter 5
Conclusions

Although DLA's procurement processes are built to accommodate and use 2D technical data, industry and the services have transitioned to CAD and CAM, which produce and use 3D technical data. To preclude a gap in its ability to acquire parts on behalf of the Services, DLA must ensure its processes can accommodate the routine use of 3D technical data during procurement actions.

DLA's current procurement process does not need to change to accommodate 3D technical data.[1] Similarly, the basic process steps for building and distributing a TDP do not need to change. To fully carry out the steps of the procurement, DLA needs additional software tools and associated user training to access and display the full product definition contained in 3D files. DLA's current inability to access such files precludes the agency's personnel from conducting the required completeness and consistency checks of 3D technical data before TDPs are released as part of a solicitation. As a result, there is a significant gap in DLA's current ability to routinely use 3D technical data in the procurement process.

Comparison of Options

DLA has three possible options for mitigating or eliminating the gap in its current capability to use 3D technical data.

1. Purchase software packages and associated training for each of the four major CAD software platforms.

2. Require technical data to be recorded in a single CAD format and acquire copies of the software and associated training for that format.

3. Require technical data to be recorded in a file format that can be read using vendor-neutral software and acquire copies of the software associated with that format.

To fill the existing capability gap, the chosen option needs to solve, at a reasonable cost, three major challenges related to using 3D technical data in a procurement: 1) PDS/PS personnel must be able to access and view data recorded in multiple proprietary CAD software formats, 2) PDS/PS personnel must be able to locate and confirm the inclusion of all information necessary for procurement and manufacturing (i.e., personnel have requisite training and skill to use appropriate software), and 3) technical data in solicitation packages must be accessible and useable by a

[1] Minor changes to execution procedures and development of new solicitation and contract clauses will be required.

majority of potential suppliers without need for procuring expensive proprietary software. Table 5-1 summarizes the viability of the three options to resolve each challenge.

Only Option 3, TDPs in a neutral file format, can solve the three major challenges associated with using 3D technical data in procurement.

Table 5-1. Comparison of Options for Filling DLA's Capability Gap to Use 3D Technical Data

Options	**Challenges**		
	Full Data Access	Easily Locate Data	Supplier Accessibility to Data
(1) Purchase S/W for each CAD Platform	🟡	🟡	🔴
(2) Require TDPs in One CAD Format	🟡	🟡	🔴
(3) Require TDPs in Neutral Format	🟢	🟢	🟢

🟢 Low cost solution 🟡 High cost solution 🔴 Does not solve challenge

S/W = Soldier Weapons.

DESIRED END-STATE

In an ideal world, all CAD/CAM software platforms would be fully cross-compatible and convert files (both to and from each CAD/CAM software program) with perfect accuracy 100 percent of the time. In addition, companies and manufacturers would not need a full CAD capability to fully view native CAD files. Inexpensive and intuitive CAD readers/viewers/translators would be readily available for importing and using native CAD files to bid on competitive solicitations and manufacture the appropriate part(s). Maximum competition would be assured because all potential suppliers would have access (with minimal software and training investment) to the requisite technical information included in the native CAD files, regardless of their format.

The ideal world does not exist, nor will it exist at any time in the predictable future; however, a reasonable end-state is achievable. The military services can provide DLA with 3D technical data that is complete and validated, and stored in neutral file formats that can be easily accessed, read, and intuitively navigated using low-cost and widely available software.

This desired end-state provides technical data in the 3D PDF (PRC) format that is readable using current DLA computers and Adobe Acrobat or Adobe Reader software. It also eliminates the challenge of identifying and locating requisite procurement and manufacturing technical data within different software formats. As a result, DLA will be able to access, review, and forward 3D technical data in solicitations without large investments in CAD software or training programs.

Finally, the desired end-state eliminates the risk of a legal challenge to a procurement that could arise if technical data were only provided in proprietary CAD formats. Suppliers will be able to review and use the 3D PDF (PRC) file for contract bidding and the attached STEP file for parts manufacturing without substantial investments in multiple proprietary CAD software packages and associated training programs.

Chapter 6
Recommendations for Achieving the Desired End-State

A major benefit of the desired end-state is that DLA's day-to-day procurement activities will not change, nor will DLA have to make major investments in software, hardware, and training.

DLA will continue to depend on the military services for complete and validated technical data, and will continue to store technical data in the DMS. Technical data will still be reviewed to ensure the requisite procurement and manufacturing data is included, and DLA will continue to make the technical data available to suppliers as part of a solicitation package. DLA will also continue to review the supplier bids to determine the winning contractor.

What will change is that DLA and its suppliers will be able to routinely use 3D technical data directly for procurement and for manufacturing parts.

Unfortunately, DLA cannot take many unilateral actions to ensure it achieves the desired end-state. Most actions to reach that end-state require collaboration with the ESAs, the military services, program managers, or Office of the Secretary of Defense (OSD) offices. Accordingly, where DLA cannot take independent action, it should attempt to influence or convince these other stakeholders that it is in DoD's best interest to provide TDPs in a 3D PDF (PRC) format with a corresponding STEP file to facilitate parts procurement.

We believe the most effective way to exert such influence is with an R&D demonstration project. The R&D project should be conducted in conjunction with one or two ESAs and defense supply centers. The R&D project should provide a proof of concept for the end-to-end process of creating a 3D PDF TDP (including a STEP file) and using it in the DLA procurement process to solicit, manufacture, acquire, and test/validate an item. Similar projects could be implemented with other ESAs to refine or tailor the overall process and gain support from stakeholders for the desired end-state.

We recommend DLA take a series of actions to position the Enterprise to achieve the desired end-state of routinely using 3D technical data during daily procurement operations. The actions are divided into two groups; those that require collaboration with other activities and those that are internal to DLA. Within each of the groups, the actions are further divided into near-term, mid-term, and far-term categories. We provided cost estimates for each action based on contractor support needed to assist with executing the actions.

Recommended Actions Requiring Collaboration with Services/ESA

DLA must engage other activities to effectively position the enterprise to routinely use 3D technical data in procurements. We recommend DLA take the following actions in concert with the military services and ESAs.

Near-Term Actions (Next 0–2 months)

1. *Conduct a 3D PDF demonstration project*. An R&D demonstration project will show the viability of 3D PDF as the neutral file format of choice for the military services, DLA, and DLA's suppliers. We envision a project that involves at least one ESA and one or two parts under their cognizance. DLA (as part of the R&D project) would acquire appropriate 3D PDF conversion software and a 3D PDF template to meet the requirements for converting existing technical data to a 3D PDF format. DLA may require the services of a conversion provider for any parts that have 2D technical data only (the conversion provider would convert the 2D technical data to 3D native file, to facilitate conversion to 3D PDF format, and STEP file formats). Any newly created 3D native files or STEP files will be provided to the ESA for validation and approval. The conversion software and template will be provided to the ESA for converting the technical data and validating the output 3D PDF file. The ESA will supply DLA with validated and approved 3D PDF, native CAD and STEP files for each part to be procured. DLA will subject these files to its standard pre-solicitation review process and subsequently use these technical data files in procurement actions. DLA suppliers will use the files to respond to the procurement solicitation and subsequently build the part. DLA and the ESA will test and validate that the delivered part meets the TDP requirements. A project final report will document the end-to-end process steps, responsible activities for accomplishing each step, metrics, lessons learned, and recommendations for improving the process and implementing it across DoD. Additionally, the project will provide to DLA the conversion software and PDF template for subsequent use in other R&D projects and for implementing the desired end-state across the enterprise.

   - *Owners*: DLA J3, J7, and a military service ESA (to be determined [TBD])
   - *Cost*: $300,000–$600,000 depending on the number of ESAs involved, and the specific parts and software procured for the project; actual cost may deviate from this range depending on the specific parts and software procured.
   - *Risk*: Medium

2. *Monitor M2A1 Program use of 3D PDF TDPs.* We recommend DLA contact and regularly engage the Program Manager–Soldier Weapons (PM-SW) Program Office to track the current status of procuring M2A1 Quick Change Barrel parts using 3D PDF TDP and identify lessons learned for application to DLA processes. The M2A1 Program is just beginning efforts to engage suppliers for the acquisition of parts using 3D PDF TDPs.

   - *Owners*: DLA J3
   - *Cost*: $70,000
   - *Risk:* Low

3. *Continue engagement with DoD Model-Based Enterprise (MBE) activities/groups.* We recommend DLA continue to participate in the Joint Defense Manufacturing Technology Panel (JDMTP), the DoD Engineering Drawing and Modeling Working Group (DEDMWG), and other MBE efforts to remain informed regarding trends and decisions associated to 3D product data. While participating in these groups, DLA should look for opportunities to inform the community of its needs and issues regarding technical data for parts procurement. DLA should also state its position/issues and strongly encourage the military services to develop,
   acquire, and provide complete 3D technical data in the 3D PDF (PRC) neutral file format.

   - *Owners*: DLA J3, J7
   - *Cost*: $70,000
   - *Risk*: Low

Far-Term Actions (Next 12–15 Months)

4. *Update service performance-based agreement (PBAs) regarding TDPs.* Pending the results of the recommended 3D PDF R&D demonstration, DLA should, in concert with the services, modify the Engineering Support PBAs to codify new or revised requirements relative to 3D technical data.

   - *Owners*: DLA and the military services
   - *Cost*: $50,000
   - *Risk*: Medium

5. *Accept new program items only when the TDP is in 3D PDF (PRC) format.* We recommend DLA adopt a policy of accepting responsibility for supporting new program items described by 3D models only when the technical data is delivered in a 3D PDF (PRC) format with a validated STEP file. This policy should be applied anytime the available technical data is exclusively 3D. DLA

will need to coordinate closely with the services to identify a date for implementing the policy and to develop contingency actions for emergent issues.

- *Owner*: DLA
- *Cost*: $70,000
- *Risk*: High

Recommended Actions Internal to DLA

In addition to the collaborative actions above, we recommend that DLA take the following internal actions to ensure enterprise-wide capability to use 3D technical data in procurements.

Near-Term Actions (Next 0–2 Months)

6. *Specify and codify 3D technical data content necessary for procurement*. We recommend DLA identify all of the data elements that must be included in a TDP to ensure the requisite information is present to manufacture an item. Appendix A, Technical Data Checklist, provides a list of data elements compiled during our study. We recommend DLA review and update this list as necessary. We also recommend DLA check the final list against the ESA PBAs to ensure consistency and, where necessary, engage the services and ESAs to confirm and validate the requirements. Since DLA is receiving 3D technical data from the military services, it is critical for both parties to reach agreement on the specific data requirements for TDPs. Also, we recommend documenting these data elements in the technical and quality (TQ) Deskbook as a checklist for PDS and PS personnel, and subsequently documenting the list in the ESA PBAs.

    - *Owners*: DLA J3
    - *Cost*: $45,000
    - *Risk*: Low

7. *Revise DLA procurement policy in reference to 3D TDPs.* We recommend DLA revise its procurement policy to specifically address the use of 3D technical data in procurements: (1) where it is included in a solicitation TDP in addition to 2D data, and (2) where it is the only form of technical data in a solicitation TDP.

    - *Owners*: DLA J7, J3
    - *Cost*: $45,000
    - *Risk*: Low

8. *Develop contract language addressing use of 3D TDPs in the procurement process.* We recommend DLA develop specific purchase order text statements, consistent with revised procurement policy (see previous recommendation) for inclusion in solicitations to address the use of 3D technical data.

   - *Owners*: DLA J7, J3
   - *Cost*: $45,000
   - *Risk*: Low

9. *Continue the DLA MBE Technology Roadmap activity*. We recommend DLA continue its MBE Technology Roadmap activity to investigate enterprise changes required within DLA to effectively use 3D product data.

   - *Owners*: DLA J3, J6, J7
   - *Cost*: $140,000
   - *Risk*: Low

Mid-Term Actions (Next 6–12 Months)

10. *Update DLAD to reflect new policy/requirements with regards to 3D TDPs.* We recommend DLA codify its revised procurement policy (see near-term actions) for the use of 3D technical data in the Defense Logistics Acquisition Directive (DLAD).

    - *Owners*: DLA J3, J7
    - *Cost*: $45,000
    - *Risk*: Low

Far-Term Actions (Next 12–15 Months)

11. *Update DLA TQ Deskbook.* Pending an update of the Engineering Support PBAs, DLA should update the DLA TQ Deskbook to reflect new or revised TDP requirements and process steps for PDS and PS personnel.

    - *Owners*: DLA J3, J7
    - *Cost*: $45,000
    - *Risk*: Low

12. *Inform DLA supplier base of impending transition from 2D to 3D technical data*. Preparing DLA to use 3D technical data is one-half of the equation. DLA's suppliers also must be prepared for the transition to 3D technical data. We recommend an awareness campaign to inform the commercial marketplace of DLA's transition to 3D TDPs and how it will affect DLA procurement activities. The awareness campaign may consist of email communication and a number of virtual "town hall" type meetings during which suppliers can have their questions answered.

   - *Owner*: DLA J7, J3
   - *Cost*: $150,000
   - *Risk*: Low

13. *Educate DLA personnel on 3D PDF and STEP file formats*. DLA must educate its personnel on vendor-neutral 3D PDF and STEP file formats. In particular, they need training on how to access files in these formats and find data required for building bidsets. Doing so will help prepare DLA buyers, PSs, PDSs, and managers to use 3D technical data effectively during the procurement process. We recommend two actions.

   - First, DLA should hold internal information sessions/demonstrations to discuss 3D PDF and STEP file formats and walk through sample documents/files to familiarize the work force.
   - Second, DLA should consider engaging a training provider that specializes in 3D technical data to educate its workforce. Appendix G, Conversion and Training Providers for 3D Technical Data contains a list of training providers that specialize in 3D data. We recommend any out-sourced training be targeted for a few select senior PDS and PS personnel to "train the trainer." Those receiving the training can serve as 3D technical data specialists within their organizations and provide in-house training to their colleagues.

   - *Owner*: DLA J7, J3
   - *Cost*: $75,000 (if education is delivered using a 'train-the-trainer' approach) to $2,200,000 (if external training providers are used to train the full work force) exclusive of any travel.
   - *Risk*: Low

The recommended actions described above are summarized in Table 6-1. They are arranged in order of suggested start time, beginning with the near-term actions we believe should start within the next 2 months.

Table 6-1. Plan of Action and Milestones for Implementing 3D Tech Data CONOPs

Action #	Summary description	Owner(s)	Estimated time to complete	Estimated cost for contractor support
Near-term actions (begin within next 0–2 months)				
1	Conduct 3D PDF demonstration project	DLA J3, J7, and a military service ESA (TBD)	18 months (includes production lead-time)	$300,000–$600,000 (cost may deviate from this range depending on the specific parts and software procured)
2	Monitor M2A1 Program use of 3D PDF TDPs	DLA J3	12 months	$70,000
3	Continue engagement with DoD MBE activities/groups	DLA J3, J7	24 months	$70,000
6	Specify and codify 3D technical data content necessary for procurement	DLA J3	4 months	$45,000
7	Revise DLA procurement policy in reference to 3D TDPs	DLA J7, J3	6 months	$45,000
8	Develop contract language addressing use of 3D TDPs in the procurement process	DLA J7, J3	6 months	$45,000
9	Continue the DLA MBE Technology Roadmap activity	DLA J3, J6, J7	12 months	$140,000
Mid-term actions (begin within next 6–12 months)				
10	Update DLAD to reflect new policy/requirements with regards to 3D TDPs	DLA J3, J7	6 months	$45,000
Far-term actions (begin within next 12–15 months)				
4	Update service PBAs regarding TDPs	DLA, military services	6 months	$50,000
5	Accept new program items only when the TDP is in 3D PDF (PRC) format	DLA	12 months	$70,000
11	Update DLA TQ Deskbook	DLA J3, J7	6 months	$45,000
12	Inform DLA supplier base of impending transition from 2D to 3D technical data	DLA J7, J3	12 months	$150,000
13	Educate DLA personnel on 3D PDF and STEP file formats	DLA J7, J3	12 months	$75,000–$2,200,000 exclusive of any travel

RISK

Positioning DLA so it can routinely use 3D technical data is not without risk. The following are foreseeable risks.

1. The military services and ESAs do not adopt or use the vendor-neutral 3D PDF (PRC) file format.
2. Some portion of DLA's supply base is incapable or unwilling to work with 3D technical data.
3. PDF software is modified by Adobe or "compromised" such that it is no longer allowed on DoD information technology (IT) networks.
4. New software and industry trends lead to different types of vendor-neutral file formats.

The first, second, and fourth risks can be mitigated by implementing the recommended actions described earlier in this section. In particular, the 3D PDF demonstration project, continued engagement with the JDMTP, DEDMWG, and other DoD MBE-related efforts in concert with the awareness campaign (to inform the commercial marketplace of DLA's transition to 3D TDPs) will provide a hedge against these risks.

Actions are currently under way to mitigate the third risk (i.e., a compromise of the PDF software). Specifically, various MBE forums within DoD have identified potential security and version control issues associated with 3D viewing software. Those forums are also investigating contingencies to deal with those issues.

Appendix A
Technical Data Checklist

We interviewed personnel who use technical data in their daily activities at each of the DLA supply chains—Troop Support, Land and Maritime, and Aviation. We asked them to identify specific information and information attributes the PDS and PS review and use when building a TDP for inclusion in a procurement bidset.

The following is a summary list of the data elements and attributes identified during those interviews.

- Legibility
- Completeness
- Restrictions
- Document approval
- Document title
- Document number
- Revision and date
- Revision type
- Expiration date
- Document data code
- Size of drawing, number of sheets, frames
- Call outs
- Sources
- First Article Test requirements
- Inspection requirements
- Higher level contract quality requirements
- Part number

- NSN
- Export control
- Commercial and government entity (CAGE) code
- Specifications
- Dimensions
- Tolerances
- Welding requirements
- Materials (ballistics)
- Temper
- Heat treatments
- Finishes
- Rights in Data
- License Agreement
- Distribution Statement
- Document Type–Parts List, Detailed Drawing, Assembly List, Quality Assurance Provision, etc.
- Security code
- Tech data availability code
- Foreign secure
- Nuclear
- Subsafe
- Control code.

Appendix B
CAD Platform Price Ranges

Table B-1 provides a summary of the approximate costs to purchase and maintain various CAD platform software packages. The ranges are based on the prices for the different editions of each CAD software package. The prices were obtained from technical representatives at each CAD software company.

Table B-1. CAD Platform Costs

	SolidWorks	CREO 2 (Pro-E)	NX	CATIA
Software price range	$3,995–$7,995	$5,990–$27,600	$5,724–$25,584	$10,500–$17,860
Annual maintenance price range	$1,295–$1,995	$1,600–$5,610	$1,547–$5,373	$1,890–$3,570

Appendix C
CAD Training Price Estimates

Table C-1 provides information regarding estimated prices for training on the major CAD platforms. These estimates are based on the experience of a CAD subject matter expert.

Table C-1. Training Price Estimates

Type of training	Estimate for training on a single CAD platform	Estimate for training on all four major CAD platforms	Notes
Beginner 1-week course	$2,500–3,000 per student	$10,000–$12,000 per student	The price estimates do not include any travel expenses for students or the instructors.
Advanced 1-week course	$2,500–3,000 per student	$10,000–$12,000 per student	

Appendix D
CAD Software Compatibility Matrix

This appendix provides information regarding the compatibility of various CAD software programs and file formats with each other and with the Imagenation 3D Viewer currently used by DLA. Compatibility refers to the ability to access all of the information contained in the native CAD file; it does not refer to whether sufficient information is present to manufacture a part. Partial compatibility may or may not provide sufficient information for manufacturing. This determination can only be made on a case by case basis.

All major CAD platforms have embedded translators to export files in software formats different than the native format.[1] These translators also provide capability to import and view data created by other CAD platforms.

Compatibility between CAD platforms is based on the ability of the embedded translator to import and access all the information resident in the native CAD file. In other words, if CAD platform A has partial compatibility with CAD platform B, when CAD platform A imports a native file from CAD platform B it will only be able to access a fraction of the information and data in the native file created by CAD platform B (the information or data not available varies between CAD platforms).

Compatibility between a CAD platform and the files it exports is based on the translator's ability to export all of the information in the native file. In other words, partial compatibility between CAD platform A and an exported STEP file means the STEP file does not contain all of the information in the native file produced by CAD platform A.

Compatibility between a file exported by one CAD platform and then imported by another CAD platform is based on the translator's ability to export all of the information contained in the native file. In other words, partial compatibility between a STEP file exported by CAD platform A that is read by CAD platform B means the STEP file does not contain all of the information in the native file produced by CAD platform A; partial compatibility may also mean that CAD platform B could not access all of the information contained in the STEP file.

Table D-1 identifies compatibility between four major CAD software platforms and the various file types they can export. The table also identifies compatibility of the native files and exported files with the Imagenation Viewer software currently used by DLA to access 3D files.

[1] The native format is what the CAD platform software used to create the original model.

The top row of Table D-1 lists the Imagenation 3D Viewer and each CAD software package. The first column lists the four major CAD software packages, the associated native file format, and the files they can export. The AutoCAD Product Design Suite software package is included because it is common in the commercial sector and its inclusion helps illustrate the level of compatibility across CAD software packages. The remaining rows that form the matrix indicate the level of compatibility when a file listed in the first column is imported by the Imagenation Viewer or one of the CAD packages listed in the first row. The legend for interpreting the level of compatibility follows:

- T Total compatibility—when the file is imported all the data recorded in the native file is available.
- P Partial compatibility—the file will import and can be read, but all the data recorded in the native file is not available.
- N No compatibility—the file will not import.
- ? Unknown—sufficient information unavailable to confirm compatibility.

Table D-1. CAD Platform Compatibility Matrix

	Imagenation 3D Viewer[a] (current DLA 3D viewing capability)	SolidWorks	CREO 2 (Pro-E)	NX	CATIA	AutoCAD Product Design Suite
SolidWorks						
native (.sldprt)	P	T	P	P	P	P
DWG	P	P	P	P	P	P
IGES	P	P	P	P	P	P
CREO/Pro-E	P	P	P	P	N	P
STEP	P	P	P	P	P	P
Parasolid	N	P	P	N	P	N
JT	P	P	P	P	P	P
DXF	P	P	P	P	P	P
ACIS	P	P	P	?	?	?
VDA	P	P	P	?	?	?
CATIA	P	P	N	?	?	?
CREO 2 (Pro-E)						
native (.prt)	P	P	T	?	N	?
DWG	P	P	P	P	P	P
IGES	P	P	P	P	P	P
STEP	P	P	P	P	P	P
Parasolid	N	P	P	P	P	P
JT	P	N	P	N	P	P
DXF	P	P	P	P	P	P
VDA	P	P	P	?	?	?
ACIS	P	P	P	?	?	?
AutoCad Inventor	P	P	P	?	?	?

Table D-1. CAD Platform Compatibility Matrix

	Imagenation 3D Viewer[a] (current DLA 3D viewing capability)	SolidWorks	CREO 2 (Pro-E)	NX	CATIA	AutoCAD Product Design Suite
NX						
native (.prt)	N	P	?	T	P	P
DWG	P	P	P	P	P	P
IGES	P	P	P	P	P	P
CREO (.prt)	P	P	N	P	P	P
STEP	P	P	P	P	P	P
Parasolid	N	P	P	P	P	P
JT	P	P	N	P	P	P
DXF	P	P	P	P	P	P
CATIA 4	P	?	?	P	P	?
CATIA 5	P	?	?	P	P	?
CATIA						
native (.CATPart)	P	P	P	N	T	P
DWG	P	P	P	P	P	P
IGES	P	P	P	P	P	P
CREO (.prt)	P	P	P	P	P	P
STEP	P	P	P	P	P	P
Parasolid	N	P	P	P	P	P
JT	P	P	P	P	P	P
DXF	P	P	P	P	P	P
AutoCAD Product Design Suite						
native (.dwg)	P	P	P	P	P	T
DWG	P	P	P	P	P	P
IGES	P	P	P	P	P	P
CREO (.prt)	P	P	P	P	P	P
STEP	P	P	P	P	P	P
Parasolid	N	P	P	P	P	P
JT	P	N	P	P	P	P
DXF	P	P	P	P	P	P

[a] Imagenation is an information sharing tool. It has 3D viewing capability; however, it does not allow for full native file definition and does not allow for driving a manufacturing process.

Appendix E
3D PDF as the Solution for Model-Based Definition

Naval Air Warfare Center Aircraft Division, Support Equipment Engineering Division, in Lakehurst New Jersey, explored the possibility of moving to a model-based solution for its acquisition TDPs. Before doing so, it identified the preferred file format for TDP files. The attached is a copy of the paper that documented why the 3D PDF solution was chosen as the format to be used in the AIR-4.8.6.

DEPARTMENT OF THE NAVY
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
SUPPORT EQUIPMENT ENGINEERING DIVISION
LAKEHURST, NEW JERSEY 08733-5091

DESIGN DATA REPORT NO.
NAWCADLKE-DDR-486600-0008
DATE: 10 July 2013

A. SUBJECT: Three-dimensional (3D) Portable Document Format (PDF) as the solution for Model Based Definition (MBD).

B. OBJECTIVE: The Naval Air Warfare Center in Lakehurst, NJ is exploring the possibility of moving to a model based solution for its acquisition technical data packages (TDPs). The objective of this paper is to document the reasons as to why the 3D PDF solution has been chosen as the format to be used in the AIR-4.8.6. evaluation of its 3D MBD project.

C. SUMMARY: At this time, the best way to implement a 3D TDP is through the use of 3D PDF, utilizing the Product Representation Compact (PRC) format, with an embedded Standard for the Exchange of Product model data (STEP) file and certificate of comparison. This provides all the capability required and has the additional advantage of being viewable through Adobe Reader, which exists on most computers today. The file format is neutral, complying with ASME Y14.41, and is compatible with the Joint Engineering Data Management Information and Control System (JEDMICS).

D. REFERENCES: See section 2.0, References, for a complete list of references.

E. ENCLOSURE: None.

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14. ABSTRACT: Engineering designs use three-dimensional (3D) modeling software. Although these designs are constructed in 3D, they are documented in two-dimensional (2D) drawings. There is significant effort required to convert the model to the 2D format. When manufacturing/inspecting these items, the process utilizes only the 2D representations. The technology to manufacture and inspect directly from the 3D data is available. Model Based Definition (MBD) is the practice of using 3D digital data to provide specifications as opposed to 2D drawings. The use of MBD to define a product is becoming the norm with the manufacturers producing systems for Naval Air Systems Command (NAVAIR). There is a lack of standardization for 3D model organization. Programs incur risks in design, manufacturing, and sustainment due to poorly defined product data requirements. A challenge when transitioning to the 3D technical data package (TDP) is the file format. The Naval Air Warfare Center at Lakehurst, NJ is looking to move to a model based solution for its acquisition TDPs. It is essential to identify the proper file format for which this TDP shall exist. This paper documents why the 3D PDF solution has been chosen.			
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1.0 Introduction

1.1 Background: In the current environment, engineering designs use three-dimensional (3D) modeling software. Although these designs are constructed in 3D models, the designs are documented in two-dimensional (2D) engineering drawings for prototype/production. This has been the general practice for more than 20 years. There is significant time and effort required by an engineering design branch to take the existing model and then convert it into the common 2D formats. When manufacturing and inspecting these prototype/production items, commonly the process is fulfilled utilizing only these 2D representations of the models. However, the technology to manufacture and inspect directly from the 3D data is currently available.

Model Based Definition (MBD) is the practice of using 3D digital data (such as solid models and associated metadata) combined with other data, such as 3D dimensions and tolerances in accordance with ASME Y14.5, within 3D Computer Aided Design (CAD) software to provide specifications for individual components and product assemblies as opposed to utilizing conventional 2D drawings. The goal of MBD is to create 3D technical data packages (TDPs) to be used for manufacture, logistics, and acquisition.

The TDP is a key component of a program's strategy for sustaining systems throughout their lifecycle. The use of MBD to fully define a product is becoming the norm rather than the exception with the manufacturers currently producing systems for Naval Air Systems Command (NAVAIR). Despite the push towards MBD (in which the product is completely defined using models, annotations, and associated metadata), there is a lack of standardization within the DoD for 3D model organization. MIL-STD-3100A has recently been revised to address the concept of MBD; however, it still lacks the specific guidance on 3D TDPs and 3D model data necessary to address many concerns. As a result, programs can incur risks in design, manufacturing, and sustainment due to poorly defined product data requirements.

A fundamental challenge when transitioning to the 3D TDP concept is the determination of the file format of the package itself. Significant research has been conducted on this topic in both the private sector and in the Government. Some of this research has been conducted by the 3DPDF Consortium, and is used throughout this paper.

1.2 Purpose: The Naval Air Warfare Center in Lakehurst, NJ is exploring the possibility of moving to a model based solution for its acquisition TDPs. Prior to this transition, it is essential to identify the proper file format for which this TDP shall exist. The objective of this paper is to document the reasons as to why the 3D Portable Document Format (PDF) solution has been chosen as the format to be used in the AIR-4.8.6. evaluation of its 3D MBD project.

1.3 Scope: Although the decision to adopt the 3D PDF solution as the official format for 3D TDPs applies only to AIR-4.8.6, the information documented in this paper is applicable to the entire DoD.

2.0 References

2.1 Military Standards

MIL-STD-31000A Technical Data Packages

2.2 ASME Drawing References

ASME Y14.100	Engineering Drawing Practices
ASME Y14.26	Digital Representation for Communication of Product Definition Data
ASME Y14.41	Product Definition Data Practices
ASME Y14.5	Dimensioning and Tolerancing Standard

2.3 Other Reference Documents

ISO 10303	Industrial automation systems and integration -- Product data representation and exchange
ISO 14306	Industrial automation systems and integration -- JT file format specification for 3D visualization
ISO 32000-1	Document Management -- Portable Document Format -- Part 1: PDF 1-7
NBSIR 80-1978	Digital Representation for Communication of Product Definition Data

D. Opsahl, "Positioning 3DPDF in Manufacturing: How to Understand 3DPDF when Compared to Other Formats," 3DPDF Consortium, Jan. 2013.

Memorandum from the Assistant Secretary of the Navy, "DON Policy on Digital Product/Technical Data," Oct. 23, 2004.

3.0 Requirements

3.1 Mandatory Requirements: The requirements of any 3D TDP supporting the U.S. Government are documented in sections 3.1.1 and 3.1.2 of this paper.

3.1.1 Neutral File Format: Utilization of a neutral file format eliminates the risk of a legal challenge to a procurement that could arise if a file format were in a specific CAD format for the purposes of acquisition that was not in accordance with an ISO standard. For instance, if significant funding of manufacturing work were to be contracted out using a proprietary 3D modeling format, it could give companies who also use this format a competitive advantage. Competitors of the company that owns the proprietary format may argue that this is an unfair advantage .

3.1.2 In Accordance with ASME Y14.41: ASME Y14.41 is the recognized standard for Product Definition Data Sets (PDDSs). PDDS is the official term for what many in industry refer to as 3D drawings. Any PDDS must be in accordance with ASME Y14.41.

- **Need to Publish/Approve:** As per ASME Y14.41, paragraph 4.3.2 (Approval): "The data set shall be approved in accordance with ASME Y14.100." As per ASME Y14.100, an approval indicator shall be electronically affixed. An approval indicator must be unique to an individual, capable of verification, and under the individual's sole control. Publishing is an established process for all TDPs.

  This is required not only because it is documented in the ASME specifications, but it is required for the very reason that the ASME decided to make it a requirement. Without an approval indicator on the document, it becomes impossible to verify its authenticity. Although a Product Lifecycle Management (PLM) system could be used to verify authenticity, it could only do this while the document is in the PLM system. Once the document is removed from the PLM system, there would no longer be any configuration control over the document. Furthermore, for all practical purposes, a drawing is a legal document that legally defines a specific part or component and its acceptable tolerance requirements. As such, it must be handled like any other legal document, including approval processes.

  It is this need for an approval indicator that becomes a driving requirement for the PDDS file format. Without this approval indicator, the PDDS would not be considered a complete legal document and would compromise configuration control of the item.

3.2 Additional Preferred Considerations (Non-Mandatory): Additional factors that any 3D TDP supporting the U.S. Government should include are described in sections 3.2.1 through 3.2.4 of this paper.

3.2.1 Compatible Format with CAM: The file format must be able to be used as an input into Computer Aided Manufacturing (CAM) and Quality Assurance (QA) equipment. There are a limited number of file formats that meet these criteria. One neutral file format that can meet this requirement is the Standard for the Exchange of Product model data (STEP) file format, which complies with ISO 10303. The STEP format was developed for the computer-interpretable representation and exchange of product manufacturing information. Its official title is "Industrial automation systems and integration -- Product data representation and exchange," but is known informally as STEP. Potential other file formats that can be read from some CAM equipment are Initial Graphics Exchange Specification (IGES) and JT formats.

3.2.2 Readily Readable Format: Currently, all Government agencies have viewers that can read a PDF file. Most 2D engineering drawings are converted to PDF from their native design environment and must be archived into a database that accepts limited formats (PDF included, see section 3.3.3). PDF is considered a neutral file format; therefore, PDF would meet the previously described legal considerations. PDF offers the required security options in addition to a 3D environment. Currently, no other neutral file format can meet all of the requirements.

3.2.3 Compatible with JEDMICS: The Joint Engineering Data Management Information and Control System (JEDMICS) is the file technical authority for TDPs. Although JEDMICS can store any form of data, it has limited viewer capability. For the purposes of this paper, "compatible" shall be defined as the ability to view and store the data.

3.2.4 Output Design Capable Natively (or with Add-ons): When designing an item in a standard 3D CAD modeling tool, one of the primary benefits of remaining in 3D is the overall reduction in time to manufacture or inspect this part when compared to starting with a 2D TDP equivalent. Conversions from 2D to 3D would no longer be required, thus, affording time savings. The ability of the user to export from an approved design within the CAD client with minimal intervention is important to the decision of which available 3D file format should be utilized. All currently utilized 3D software design packages contain the ability to output their source files to a STEP based solution. Some of the clients also have the ability to output a file to IGES and JT formats. Publishing to PDF is another possibility; however, this method requires third-party tools to serve as an intermediary between the 3D CAD and the 3D PDF.

3.3 Editable Source Code (Additional Requirement): When procuring a TDP, it is typical to procure the native CAD files as well. It is important to note that the TDP should be able to stand on its own as an acquisition package (without the dependency on a proprietary native CAD format) and, thus, allow any qualified manufacturer to use the package to produce and inspect the part. There are many solid reasons for the Government to procure these native CAD files and there shall be no dispute that this is a good practice and is required. However, this requirement for the CAD files shall be considered as an additional requirement to the 3D TDP.

4.0 3D File Formats

4.1 Currently Available 3D File Formats: All 3D file formats will fall within one of the following two categories: proprietary/open and neutral/international.

4.1.1 Proprietary and Open Formats

4.1.1.1 Proprietary: Proprietary formats are generally regarded as intellectual property and are protected appropriately. Proprietary formats provide the developers with the means to enable rapid innovation within their products, which benefit the community at the product realization stage.

4.1.1.2 Open: Open formats have been developed by many of the software developers. These developers provide authoring tools that are accessible to third-party application developers and customers who wish to do their own application development.

4.1.1.3 The Problem with Proprietary and Open Formats: Both proprietary and open formats encounter the following problems:

a. The intellectual property belongs to the developer regardless of how much detail is provided to the third-party application providers.
b. The developer has control over the definition of the standard, and can change it at will with or without the advice and consent of the user community.
c. The developer can also determine who has access to the format and for what purpose, regardless of the value to the user community.

4.1.2 Neutral/International Standards: Vendor neutral/international standards are standards in which all relevant information, data, and intellectual property are in the hands of the marketplace, and development of the standard is driven by the community itself. International standards by their nature are stable and can be slow to evolve, but protect the investment in tools and processes of the community by ensuring that the data is capable of being used and recovered from an archive repository. Consequently, for the purposes of a Government furnished 3D TDP, only international standards can be considered. These include: STEP, JT, IGES, and PDF.

4.2 STEP: STEP is an international standard (ISO 10303) that consists of several hundred parts and is the largest standard in the ISO community. The purpose for STEP is application data exchange. STEP was always envisaged as an international standard containing no proprietary intellectual property. It was developed as a community effort (originating in the aerospace industry) as a means to exchange information between manufacturers and suppliers.
STEP can represent an enormous variety of data including:

- Geometric information
- Product manufacturing information
- Product lifecycle support information
- Computer Numerical Control (CNC) manufacturing information
- Electrical systems information

The types of information STEP can represent is matched by no other format in existence, and it is ideal for archiving purposes. The DON memorandum, “DON Policy on Digital Product/Technical Data,” dated October 23, 2004, specifically states that “product model data should be delivered in a data definition format for neutral file exchange in accordance with” STEP. However, the approval and publishing activity described in this document cannot be accomplished with the STEP data.

STEP AP203e2 (the current ISO Standard, approved in 2011) also has limitations. There is no associativity between the Geometric Dimensioning and Tolerancing (GD&T) feature control frames and the geometry that the GD&T controls. This associativity is defined in ASME Y14.41 and is required for any PDDS. Furthermore, without this associativity, it becomes very difficult to properly interpret the tolerances of the geometry within the PDDS.

4.3 JT: JT was originally developed by Engineering Animation, Inc. (EAI) and Hewlett Packard. EAI was purchased by UGS Corp., and JT became a part of UGS Corp.'s product suite. In 2007, UGS announced the publication of the JT data format, easing the adoption of JT as a master 3D format. UGS was acquired by Siemens AG and became Siemens PLM Software. JT is the common interoperability format in use across all of Siemens PLM Software product suites. With Siemens' support, JT was approved as an ISO standard in 2012.

JT focuses on the geometric representation of the product or object to be built and the attribute information associated to the product, including product and manufacturing inspection (PMI). JT also contains definitions of both exact geometry and tessellated data.

JT, developed as a proprietary format, was later changed with the assistance of the JT Open community, permitting customers and developers to contribute to the evolution of JT while allowing Unigraphics/Siemens PLM to retain control of the intellectual property and distribution. By releasing control, JT can be considered for adoption as an international standard. However, approval and publishing activity cannot be accomplished with JT formats. JT version 9.5 successfully reached the international standard status in December 2012 as ISO 14306, "JT file format specification for 3D visualization" (also known as "JT Edition 1").

4.4 IGES: The IGES is a file format that defines a vendor neutral data format that allows the digital exchange of information among CAD systems. The official title of IGES is "Digital Representation for Communication of Product Definition Data," first published in January 1980 by the U.S. National Bureau of Standards as NBSIR 80-1978. Many documents referred to it as ASME Y14.26M, the designation of the American National Standards Institute (ANSI) committee that approved IGES Version 1.0.

Due to its growing international popularity, several countries, including Australia and the U.K., adopted IGES as their own national standards. Consequently, although IGES is generally not thought of as an international standard, it is used internationally and, for the purpose of this paper, shall be considered as such.

Using IGES, a CAD user can exchange product data models in the form of circuit diagrams, wireframe, freeform surface, or solid modeling representations. Applications supported by IGES include traditional engineering drawings, models for analysis, and other manufacturing functions.

The IGES project was started in 1979 by a group of CAD users and vendors, including Boeing, General Electric, Xerox, Computervision, and Applicon, with the support of the National Bureau of Standards (now known as the National Institute of Standards and Technology (NIST)) and the U.S. DoD. The name was carefully chosen to avoid any suggestion of a database standard that would compete with the proprietary databases that were then used by the different CAD vendors.

Since 1988, digital PMI for weapons systems contracts have been delivered to the DoD in an electronic form such as the IGES format. As a consequence, computer-aided technologies (CAx) software vendors who wanted to market their products to DoD subcontractors and their partners needed to support the import and export of IGES format files. On October 23, 2004, the DON issued a memorandum requiring the acceptance of technical data to be only in digital formats for contracts awarded after 2004.

An ANSI standard since 1980, IGES has been used in the automotive, aerospace, and shipbuilding industries. It has been used for weapons systems from the Trident missile guidance systems to entire aircraft carriers. These part models may have to be used years after the vendor of the original design system has gone out of business. IGES files provide a way to access the data decades from now. Today, viewers for web browsers allow IGES files created 20 years ago to be viewed from anywhere in the world.

After the initial release of STEP in 1994, interest in further development of IGES declined, and Version 5.3 (1996) was the last published standard. A decade later, STEP has yet to fulfill its promise of replacing IGES, which remains the most widely used standard for CAx and PMI interoperability. However, IGES still faces all the same challenges as STEP in terms of the required approval and publishing capability.

4.5 PDF: The PDF was initially a proprietary format before it became an international standard. PDF is a file format used to represent documents in a manner independent of application software, hardware, and operating systems. While Adobe made the PDF specification available free of charge in 1993, PDF remained a proprietary format, controlled by Adobe, until it was officially released as an open standard on July 1, 2008, and published by the International Organization for Standardization as ISO 32000-1. In 2008, Adobe published a Public Patent License to ISO 32000-1, granting royalty-free rights for all patents owned by Adobe that are necessary to make, use, sell, and distribute PDF compliant implementations. PDF is a standard that defines how renditions of data are to be made, such that they are universally consumable via Adobe Reader. It can use all of the features that are unique amongst the various formats discussed in this paper, such as digital signatures, templates, forms, and rights management. In 2005, Adobe released support for 3D by referencing in the PDF standard, prior to its public release, a standard called Universal 3D (U3D).

PDF does not itself define a 3D data standard, but it does support 3D data. This is achieved through one of two other standards — U3D and Product Representation Compact (PRC). The PRC format permits a large number of data formats, including the major MBD applications (such as CATIA, NX, and Creo) to be imported into a PDF. The PRC format provides support for both exact geometry data and tessellated data, product structure, and PMI, and is in accordance with ASME Y14.41. PRC is in the final stages of becoming an international standard in its own right, and is expected to be published and publicly available in July of 2013. Both U3D and PRC are specified by the ISO 32000 standard, and are fully supported by the Acrobat platform.

An advantage of using PDF is for the publishing of product data including TDPs. Publishing is an established process in most if not all organizations; adding 3D support leverages those processes and the associated investment. Moving forward, the capability and the availability of Acrobat Reader on most Government computers makes 3D PDF very attractive.

5.0 Format Comparison

As seen in Table 1, the PDF format can meet all of the mandatory and non-mandatory requirements with the exception of CAM compatibility. However, since a STEP file can be exported from the PRC file, and STEP is CAM compatible, this requirement can be met through a two-step process. This export leads to another issue with the PDDS: Can it be guaranteed that the export STEP file is identical to the PRC, and if it is not, should this be a concern?

Table 1: Format Comparison

File Format	Neutral	ASME Y14.41 Including Approval	CAM Compatible	Readily Readable	JEDMICS	Output Design Capable
PDF (PRC)	Yes	Yes	No	Yes	Yes	Yes
JT	Yes	No	No	No	No	Yes
STEP	Yes	No	Yes	No	No	Yes
IGES	Yes	No	Yes	No	No	Yes

6.0 PDDS vs. MBD

A PDDS is a collection of one or more computer file(s) that discloses (directly or by reference), by means of graphic or textual presentations, or combinations of both, the physical and functional requirements of an item. The types of information included are GD&T, component level materials, assembly level bills of materials, engineering configurations, design intent, etc. By contrast, other methodologies have historically required accompanying use of 2D drawings to provide such details. The PDDS is used as a means to document the design of an item. PDDS, the official term of a 3D drawing, must be in accordance with ASME Y14.41. However, the use of PDDS leaves open the possibility of several methods to define a design in a 3D TDP. Many of these different methods are used in industry today. These methods are described in sections 6.1 through 6.3 of this paper.

6.1 Fully Annotated Model: In this case, the model is used very similarly to the conventional 2D drawing, and is fully dimensioned. The part itself is not defined by the model, but is defined by the dimensions on the model. Any QA on the part would involve the inspection of these dimensions in the same way a part with a 2D drawing would be inspected.

6.2 2D Drawing with an Associated Model: This case is very similar to the fully annotated model; however, it is a 2D drawing with an associated model. Often, this model is embedded as a STEP file into a 2D PDF drawing. The model is used for manufacturing and QA purposes; however, as with the fully annotated model, the part is really defined by the dimensions on the 2D drawing. This also reduces the efficiencies involved with a true 3D process, as the time and effort involved in the conversion to 2D must still be performed under this option.

6.3 MBD: MBD is different from the fully annotated model and the 2D drawing with an associated model in that the model itself defines the part as opposed to annotated dimensions. In true MBD, dimensions are optional and only used at the discretion of the cognizant engineer. The model is toleranced geometrically often using surface profile tolarancing. It is in this case where the accuracy of the model itself becomes critical.

One of the most important requirements of any engineering data process is that the process not lead to a nonconforming part being accepted. This requirement can only be insured if the models used to machine and inspect the parts are guaranteed to be identical to the model created by the engineer. If, for example, there was an error in the conversion from the Pro/ENGINEER (Pro/E) file to an MBD file, manufacturing artisans could produce a nonconforming part. Furthermore, since QA would use the same MBD file to inspect the part, this nonconforming part would pass inspection. Consequently, since the MBD process will require different formats, a means is required to insure that these files provide an identical definition of the part. Any deviation between these files could have severe negative consequences.

As stated above, a STEP file can be exported from the PRC file for the purposes of CAM compatibility; however, any conversion process is currently subject to errors. It would also be necessary to ensure that the PRC file itself defined the part that the engineer originally intended when it was designed in the CAD software.

7.0 Embedding Files in the PDF: One advantage to the STEP file is that it is CAM compatible and known to be produced by most CAD software. It is also ideal for long-term archiving purposes. The STEP file was developed as a neutral file format and it is this format that was referenced in the DON memo as the Navy’s preferred file format. However, the STEP file lacks the important capability of approval/publishing. In industry, the answer to this limitation often involves the embedding of the STEP file into the PDF. This gives all the advantages of approval/publishing inherent in the PDF format and the CAM compatibility of the STEP format. Although this combination of STEP and PDF solves all the problems of the fully annotated model and the 2D drawing with an associated model, it does not address the requirement to ensure that the different formats provide an identical definition of the part.

8.0 Need for Verification in MBD: Regardless of the final format used to document the design, if true MBD is to be implemented, there is a need to verify that the file in the TDP and the files used to inspect the part represent the identical definition of the part that the engineer intended when the part was designed in the native CAD software.

This problem was investigated by the U.S. Army Armament Research, Development, and Engineering Center at the Picatinny Arsenal in New Jersey. Through a partnership with a third-party software vendor, a solution was devised. A software program was made with the capability to open the parts in their native CAD software, the PRC format, and the STEP format, and then compare the geometry of each. Upon a successful comparison, a certificate is generated to document the results. Under this scenario, the TDP is generated using a PDF with two embedded files — the STEP file of the model and the certificate of comparison. This effectively solves all the problems with MBD TDPs.

An argument could be made that if the STEP file (or other format) was used throughout the entire process (design, manufacturing, QA, and testing), that the STEP file in and of itself could then accurately define the part. This logic has two potential problems. The first is the inability of the STEP file to offer the publishing/approval as noted earlier. The second involves concerns regarding revisions of the part. Since the CAD software itself will undoubtedly be revised over time, a means would be needed to verify that the new revised model did not contain any unintended modifications during the revision process. Therefore, regardless of the process used to create the 3D TDP, the verification step is essential when implementing true MBD.

9.0 Managing the Configuration: A challenge with the proposed MBD solution is maintaining the configuration control of multiple files. This solution involves using the combination of a STEP file, a PDF, a certificate, as well as the native CAD file that the part was designed in. However, it should be noted that this is not significantly different than the current process utilized when generating 2D drawings. These 2D drawings also have multiple files (the model, the CAD drawing file, the PDF, and a CAM file that is often generated later in the process). The configuration control (in the 2D as well as 3D) shall be managed in an approved PLM system and JEDMICS. The process shall be handled through an automated workflow. After the engineer is ready for the 3D TDP to be approved, the STEP and PDF files shall be generated and verified. A certificate shall be generated and embedded along with the STEP files into the applicable PDF. When the approving authority signs the PDF, the CAD file shall be placed into an approved status in the PLM system. The PDF with the embedded files shall then be submitted to JEDMICS. Through this process, all of the files shall be maintained at the same revision level. The PDF file shall contain a note on it identifying the web address of the PLM system and the CAD file name. Consequently, a search of the JEDMICS database shall return not only the PDF PDDS, but the embedded STEP file and the location of the CAD source data as well.

10.0 Summary

Although there are many file format options for a 3D TDP, these options essentially fall into three categories. The first of these is the native file format in which the model was created. The second would be an international or neutral file format other than PDF. The STEP file format offers all of the advantages of the other non-PDF neutral file formats, and, consequently, would be the best option if one of these formats were chosen. The third category for the 3D TDP is the 3D PDF using PRC combined with an embedded CAM compatible STEP file.

As discussed earlier, the first two categories are unacceptable for reasons that are summarized in paragraphs 10.1 and 10.2, below.

10.1 Summary of STEP Limitations for use as the 3D TDP

1) As per ASME, an approval indicator shall be electronically affixed. STEP cannot support this requirement.
2) No means exists to verify that the STEP file is identical to the source data. This problem is magnified if the file is to ever be revised.
3) STEP does not offer the associativity as defined in ASME Y14.41
4) Requires special viewer software, which is not available throughout the Navy without additional cost and infrastructure being put into place, nor is available in JEDMICS.

10.2 Summary of the Native File Format Limitations for use as the 3D TDP

1) The intellectual property belongs to the developer regardless of how much detail is provided to the third-party application providers.
2) The developer has control over the definition of the standard, and can change it at will with or without the advice and consent of the user community.
3) The developer can also determine who has access to the format and for what purpose, regardless of the value to the user community.
4) Requires special viewer software, which is not standard or readily available throughout the Navy or in JEDMICS.
5) Cannot universally import data into CAM/Coordinate Measuring Machine (CMM) equipment, meaning a conversion to a STEP file would be required. No means exists to verify that the STEP file is identical to the source data. This problem is magnified if the file is to ever be revised.
6) Not a neutral file format. Any Government agency could encounter legal challenges if a file format were in a specific CAD format for the purposes of acquisition. This could provide an unfair advantage to any company that used the same software that the Government used to generate the design. Since many services are currently providing 3D data in neutral format, it would be difficult for any other service to justify giving this advantage.

10.3 NAVAIR Requirement: The currently proposed Joint (AIR-6.8/4.1) Interim Policy regarding 2D and 3D TDP acquisition states that Program Managers should require that the TDP be delivered in: 1) native CAD format, 2) neutral STEP ISO 10303 format, and 3) a commonly viewable format like 3D PDF, JT, or other third-party viewing format. The Air Force already implements this requirement through a Product Delivery Specification that they developed and shared with the DoD community. It should be noted that the proposed AIR-4.8.6 policy described herein, shall comply with this policy.

10.4 Conclusion

In an ideal environment, a file format that could support every aspect of MBD would exist. This format would meet all of the requirements listed in this paper and would be guaranteed to permit a conversion both to and from every CAD software program available with perfect accuracy 100 percent of the time. However, currently this file format does not exist and will not exist at any time in the foreseeable future. Consequently, to implement an MBD solution, multiple files or different formats will be required such that all the requirements can be addressed.

At this time, the best way for AIR-4.8.6 to implement a 3D TDP is through the use of PDF using PRC with an embedded STEP file and certificate of comparison. This provides all the capability required and has the additional advantage of being viewable through Adobe Reader, which is the standard viewer within the DoD and exists on most computers today. The file format is neutral, complying with ASME Y14.41, and is compatible with JEDMICS. The embedded STEP file offers CAM/QA compatibility and a means for retrieving the data from an archived database. The certificate of comparison ties up the entire process to ensure the data is accurate. Additionally, the CAD source file shall be available in an approved PLM system.

As stated previously, it is the need for an approval indicator that becomes a driving requirement for the 3D TDP file format. Additionally, PDF offers several other obvious advantages such as its current compatibility with JEDMICS and its viewer availability. None of these benefits are available in the IGES, JT, or STEP formats. The U.S. Army, U.S. Air Force, and the Defense Logistics Agency (DLA) have begun moving toward the 3D PDF solution and have piloted several initiatives. AIR-4.8.6 is building upon those successes and is utilizing the 3D PDF PDDS to truly enable the transformation of naval design and accompanying manufacturing capabilities into modern and future best practices.

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Appendix F

3D PDF Details and Supporting Information

A 3D PDF file using PRC format permits the import of major CAD applications (such as CATIA, NX, and CREO) into a PDF. The PRC format supports exact geometry data and tessellated data, product structure, and PMI.

MIL-STD 31000A (26 February 2013) cites the use of 3D PDF with PRC as one example of the importance of providing sufficient technical detail when specifying 3D TDP format. 3D PDF currently is the only format that meets the ASME Y14.41publishing approval requirements.[1] It also is the only format that is fully viewable within the Joint Engineering Data Management Information and Control System (JEDMICS).[2]

3D PDF files are read using Adobe Acrobat or Adobe Reader. Adobe Acrobat is already installed on DLA computers, so there is no additional cost to DLA for purchasing new software. Since Adobe Reader software is available free of charge to anyone via the Internet, DLA suppliers who don't already have the software can easily obtain it at no extra cost. In addition, there is little to no unique training required to open and navigate a 3D PDF file, because it follows the standard rules for all PDF documents.

What makes the 3D PDF file different from a standard PDF file is the (intuitive) interactive 3D model embedded in the 2D page, which allows the reader to manipulate (rotate, query) the model.

A number of DoD programs are currently using the 3D PDF format to document their TDP and manufacturing work instructions (MWI):

- A-10 Wing Replacement Program—Hill Air Force Base, DLA, and Boeing are using 3D PDF for complete wing design and provisioning data
- PM-SW M2A1 Quick Change Barrel—3D PDF TDP is being used for procurement actions

[1] ASME Y14.41 is the standard for product definition data sets (PDDS), which is the official term for 3D drawings. A PDDS must be in accordance with ASME Y14.41. Per ASME Y14.41, paragraph 4.3.2 (Approval): "The data set shall be approved in accordance with ASME Y14.100." Per ASME Y14.100, an approval indicator must be electronically affixed. An approval indicator must be unique to an individual, capable of verification, and under the individual's sole control. Reference Naval Air Warfare Center Aircraft Division, Support Equipment Engineering Division, Lakehurst NJ, Design Data Report No. NAWCADLKE-DDR-486600-0008, 10 July 2013.

[2] JEDMICS is the file technical authority for TDPs. JEDMICS can store any form of data, but it has limited viewer capability and cannot fully view neutral file formats except 3D PDF. Reference Naval Air Warfare Center Aircraft Division, Support Equipment Engineering Division, Lakehurst NJ, Design Data Report No. NAWCADLKE-DDR-486600-0008, 10 July 2013.

- M153 Common Remote Weapon Station—3D PDF interactive technical repair manual is fielded to reduce mean time to repair (MTTR)
- TOW-GPK—3D PDF digital work instructions (DWI) interactive electronic technical manual (IETM) has been fielded with each system to reduce assembly times
- Max-Pro—3D PDF DWI assembly and weld processes to reduce manufacturing risk for industry
- SPARK II—3D PDF IETM has been fielded with system to reduce assembly times
- Bradley Fighting Vehicle Protection Roller Interface Brackets—assembly and weld processes are provided as 3D PDF DWI
- PM-Armed Scout Helicopter KIOWA Nose Mounted Sensor—3D PDF DWI assembly and installation processes fielded with depots.

In general, DoD programs are increasingly adopting 3D PDF as their preferred format for sharing technical data internally and externally. In addition to the programs above, NAVAIR Lakehurst performed and documented a comprehensive study regarding its decision to use 3D PDF as its TDP standard (see Appendix E for a copy of NAVAIR Lakehurst's report).

Surveys of commercial companies provided additional positive feedback regarding the direct use of 3D PDF TDPs as part of the bidding, planning, and manufacturing process. Specifically, in 2012, Model Based Enterprise[3] stakeholders and partners, including NIST, the U.S. Army Armament Research, Development and Engineering Center (ARDEC), and Catalyst Connection conducted a study to gather feedback on the 3D PDF TDP[4] from a sample of decision makers at companies within the Army supply chain.[5] Forty-six respondents reviewed a 3D PDF TDP with CAD and STEP files attached prior to answering questions about the TDP. The following are among the study's key findings:

- 89 percent of the respondents said the 3D TDP has all of the information that is needed to make a part.

[3] MBE is an integrated and collaborative environment, founded on 3D product definition shared across the enterprise, enabling rapid, seamless, and affordable deployment of products from concept to disposal http://model-based-enterprise.org/model-based-enterprise.html.

[4] 3D PDF is a neutral file format that offers complete product data. A 3D PDF cannot be used to drive manufacturing like a CAD file, but it can complement the manufacturing process by providing data not normally available in other platform-neutral file formats.

[5] See http://model-based-enterprise.org/mbe-2012-supplier-assessment.html.

- 89 percent of the respondents feel the 3D TDP is better or much better than 2D drawings for conveying design intent.
- 84 percent of respondents plan to use the 3D TDP in their manufacturing planning.

As part of this R&D task, we conducted live demonstrations at the three defense supply centers (Aviation, Troop Support, Land and Maritime), where we provided a 3D PDF file for their viewing and comment. We asked the participants (who were selected by their management specifically because of their intimate knowledge and use of technical data in daily procurement operations) to assess the PDF format relative to its use as part of a TDP. In general, the participants agreed the example file was easy to navigate and interpret and that it appeared to contain most of the information they looked for when conducting the required completeness and consistency checks of technical data before it is released as part of a solicitation.

We documented all instances where they did not see a specific type of data they considered necessary for the completeness and consistency checks and have included it in the list of data elements and attributes we gathered from them during earlier meetings (see Appendix A, Technical Data Checklist).

Appendix G
Conversion and Training Providers for 3D Technical Data

The following companies offer services for conversion of 2D technical data to 3D CAD or conversion of 3D CAD to 3D PDF neutral file format.

- Anark (http://www.anark.com/) offers products and services for creating 3D Model-Based Definition (MBD[1]) in CAD tools, 3D PDF technical data packages, and 3D PDF digital work instructions.
- Booz Allen Hamilton (http://www.boozallen.com/) does 2D data to 3D data conversions for large government contractors.
- CAD/CAM Services (http://www.cadcam.org/) offers CAD drafting, and raster to vector conversions, paper to CAD conversions and scanning services.
- ImageCom (http://www.aspire3d.com/) does 2D data to 3D data conversions.
- Lattice Technology (http://www.lattice3d.com/company/about-us/) provides solutions for leveraging 2D and 3D data beyond design and development, throughout the extended manufacturing enterprise, including 3D PDF conversion.
- Rigid Concepts Engineering and Design (http://www.rigidconcepts.com/) can take a sketch, picture, or an existing 2D drawing and convert it to a 3D solid model. They support most CAD file types, whether they are 2D or 3D file formats.
- SCRA (http://www.scra.org/) has converted data from 2D to 3D for a variety of government projects.
- Tetra4D (http://www.tetra4d.com/) provides solutions for integrating 3D PDF into engineering, manufacturing, technical publication, and AEC workflows.

Most any CAD software reseller can also offer 2D to 3D conversions.

[1] MBD is an annotated 3D CAD Model that contains all the information needed to define a product http://model-based-enterprise.org/model-based-definition.html.

The following companies offer training services to support the use of CAD and 3D PDF files.

- Anark (http://www.anark.com/) offers training for creating 3D MBD in CAD tools, MBD best practices, 3D PDF technical data packages, and 3D PDF digital work instructions.
- EOS (http://3eos.com/ and http://3dPDFit.com/) provides consulting, services and support for companies implementing 3D PDF across their enterprise.
- Informative Graphics Corporation (IGC, http://www.infograph.com/) provides viewing, collaboration, redaction, and document transformation software.
- Lattice Technology (http://www.lattice3d.com/company/about-us/) provides solutions for leveraging 2D and 3D beyond design and development, throughout the extended manufacturing enterprise.
- OpenText (http://www.opentext.com/) has taken the Imagenation product over from Spicer Corp. The product is now called OpenText Viewer. OpenText can provide training on both products.
- SCRA (http://www.scra.org/) offers training on how to create 3D MBD in CAD tools, MBD best practices, 3D PDF technical data packages and 3D PDF digital work instructions.
- Tech Soft 3D (http://www.techsoft3d.com/) provides a variety of tools and training designed to support the MBE.
- Tetra4D (http://www.tetra4d.com/) provides best-in-class solutions for integrating 3D PDF into engineering, manufacturing, technical publication, and AEC workflows.

CAD training is also offered by any of the CAD resellers in a customer's local geographic area. Whenever a CAD reseller does not offer training, they can normally direct customers to training resources.

Appendix H
3D PDF Conversion Software Price Ranges

Table H-1 provides estimated price ranges for 3D PDF conversion software workstation solutions. Table H-2 provides estimated price ranges for 3D PDF conversion software server solutions. The ranges are based on the different options available with each of the 3D PDF conversion software packages. It is important to note the appropriate options for a given situation will depend on the user's requirements. All of the options included in these ranges provide PMI, which is needed for procurement. The prices were obtained from technical representatives at each 3D PDF conversion software company.

Table H-1. Price Ranges for 3D PDF Conversion Software Workstation Solutions

	Anark	Lattice Technology	Tetra4D
Software price range	$12,879–$15,741	$7,350–$21,837	$500
Annual maintenance price range	$3,220–$3,935	$1,470–$4,367	Not applicable

Table H-2. Price Ranges for 3D PDF Conversion Software Server Solutions

	Anark	Lattice Technology	Tetra4D
Software price range	$92,925–$114,741	$25,900–$115,107	Not applicable
Annual maintenance price range	$23,231–$28,685	$5,180–$23,021	Not applicable

Appendix I

Abbreviations

2D	two-dimensional
3D	three-dimensional
API	application programming interface
ARDEC	Armament Research, Development and Engineering Center
CAD	computer-aided design
CAGE	commercial and government entity
CAM	computer-aided manufacturing
CNC	computer numerical control
CONOPs	concept of operations
DEDMWG	Department of Defense Engineering Drawing and Modeling Working Group
DIBBS	DLA Internet Bid Board System
DLA	Defense Logistics Agency
DLAD	Defense Logistics Acquisition Directive
DMS	Document Management System
DWI	digital work instructions
EBS	Enterprise Business System
EDL	engineering data list
ESA	engineering support activity
FAR	Federal Acquisition Regulations
GD&T	geometric dimensioning and tolerancing
GPK	gunner protection kit
HTML5	hypertext markup language 5
IETM	interactive electronic technical manual
IGC	Informative Graphic Corportation
IGES	initial graphics exchange specification
IT	information technology
JDMTP	Joint Defense Manufacturing Technology Panel

JEDMICS	Joint Engineering Data Management Information and Control System
MBD	Model-Based Definition
MBE	Model-Based Enterprise
MEDALS	Military Engineering Data Asset Locator System
MTTR	mean time to repair
MWI	manufacturing work instructions
NIST	National Institute for Standards and Technology
NSN	national stock number
OSD	Office of the Secretary of Defense
PBA	performance-based agreement
PDDS	product definition data set
PDF	portable document format
PDS	product data specialist
PM	Program Manager
PMI	product and manufacturing information
PR	purchase request
PRC	product representation compact
PS	product specialist
QA	quality assurance
R&D	research and development
STEP	Standard for the Exchange of Product Model Data (ISO 10303)
SW	Soldier Weapons
TBD	to be determined
TDP	technical data package
TDPL	technical data package list
TOW	tube-launched, optically-tracked, wire command-link guided
TQ	technical and quality
WebGL	Web Graphics Library