

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-486600-0010
DATE: 06 November 2013

A. SUBJECT: Summary and results of the Commercial Technologies for Maintenance Activities (CTMA), Model Based Definition (MBD) for Aircraft Launch, Recovery, and Support Equipment Project

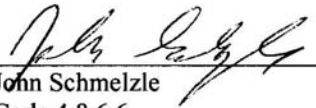
B. OBJECTIVE: The Naval Air Warfare Center Aircraft Division (NAWCAD), Lakehurst, NJ has been exploring the possibility of moving to a model based solution for its acquisition of Technical Data Packages (TDPs). The objective of this paper is to document the results of the subject project.

C. SUMMARY: At this time, the technology exists to implement a MBD solution at NAWCAD Lakehurst. As documented in this report, this implementation of MBD should generate significant savings.

D. REFERENCES: See section 7.0, References, for a complete list of references.

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

PREPARED BY:


John Schmelzle

Code 4.8.6.6
SE Design & Analysis Branch Head

REVIEWED BY:



Erik Merk
Code 6.8.4.1
Logistics Management Specialist

CHECKED BY:



Eric Kline
Code 4.8.8.2
Mechanical Engineer

APPROVED BY:



John Martenak
Code 4.8.6
Division Head, SEED

REPORT DOCUMENTATION PAGE			<i>Form Approved</i> <i>OMB No. 0704-0188</i>		
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY) 06-11-2013		2. REPORT TYPE Summary Report		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Summary and results of the Commercial Technologies for Maintenance Activities (CTMA), Model Based Definition (MBD) for Aircraft Launch, Recovery, and Support Equipment			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) J. Schmelzle			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Support Equipment and Aircraft Launch and Recovery Equipment Dept. Naval Air Systems Command Lakehurst, NJ 08733			8. PERFORMING ORGANIZATION REPORT NUMBER NAWCADLKE-DDR-486600-0010		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Support Equipment and Aircraft Launch and Recovery Equipment Dept. Naval Air Systems Command Lakehurst, NJ 08733			10. SPONSOR/MONITOR'S ACRONYM(S)		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Technology permits engineers to manufacture and inspect parts directly from three-dimensional (3D) models. The dimensions and other engineering information can be applied directly to these models. These models can then be used as an input into Computer Aided Manufacturing (CAM) equipment such as Computer Numeric Control (CNC) machines and water jet machines as well as into Quality Assurance (QA) equipment such as Coordinate Measuring Machines (CMMs) to directly inspect the part. Additionally, these models can be used for logistics, contracting, and any other department that currently uses engineering drawings. Working directly from a 3D model would reduce cost, increase quality, and decrease the product development schedule. Along with industry leaders, the Naval Air Warfare Center Aircraft Division (NAWCAD) Lakehurst has conducted a project to determine the feasibility of this. The purpose of this report is to document and to summarize this project.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES 27	19a. NAME OF RESPONSIBLE PERSON John Schmelzle
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED			19b. TELEPHONE NUMBER (include area code) 732-323-1945

TABLE OF CONTENTS

- 1.0 Executive Summary 1**
 - 1.1 Purpose..... 1
 - 1.2 Main Findings 1
 - 1.3 Outcome/Results 1
 - 1.4 Benefits 1
 - 1.5 Technology Transition with Deployment Recommendations..... 2
- 2.0 Introduction..... 3**
 - 2.1 Background 3
 - 2.2 Authorization 3
 - 2.3 Benefits 4
 - 2.4 Scope..... 5
 - 2.5 Program Budget 5
- 3.0 Narrative..... 6**
 - 3.1 TDP Requirement 6
 - 3.2 Verification Requirement..... 7
 - 3.3 Solution 7
 - 3.4 Project Execution 8
- 4.0 Conclusion 11**
- 5.0 Benefits..... 12**
 - 5.1 Monetary Benefits..... 12
 - 5.2 Non-monetary Benefits 12
 - 5.3 Benefits to Industry..... 12
- 6.0 Recommendations 13**
 - 6.1 Gather Further Metrics 13
 - 6.2 PLM Integrated Software..... 14
 - 6.3 Automated Workflow 14
 - 6.4 3D PDF Graphics Validation 14
 - 6.5 Work Instructions..... 15
 - 6.6 3D PDF Inspection Documents..... 15
 - 6.7 Expansion of MBD 15
- 7.0 References..... 16**
- Appendix A: Figures A-1 through A-4..... 17**

LIST OF FIGURES

Figure 1: Fairing I/R Stand..... 9
Figure 2: MQ-8C Handler Adapter Assembly 10
Figure 3: E-2D Rotodome Antenna Maintenance Stand with Rotodome Installed 13
Figure 4: E-2D Rotodome Antenna Maintenance Stand without Rotodome Installed 14
Figure A-1: Sheet 1 of the 3D TDP Format 18
Figure A-2: Last Sheet of the 3D TDP Format (Sheet 2 for Components and Sheet 3 for Assemblies) 19
Figure A-3: Sheet 2 of the 3D TDP Assembly Format..... 20
Figure A-4: Verification Certificate 21

LIST OF TABLES

Table 1: Expected Savings Generated through MBD..... 12

1.0 Executive Summary

1.1 Purpose

Technology permits artisans to manufacture and inspect parts directly from three-dimensional (3D) models. The dimensions and other engineering information can be applied directly to these models. These models can then be used as an input into Computer Aided Manufacturing (CAM) equipment such as Computer Numeric Control (CNC) machines and water jet machines as well as into Quality Assurance (QA) equipment such as Coordinate Measuring Machines (CMMs) to directly inspect the part. Additionally, these models can be used for logistics, contracting, and any other department that currently uses engineering drawings. Working directly from a 3D model would reduce cost, increase quality, and decrease the product development schedule. The purpose of this project is to determine the extent of these savings.

1.2 Main Findings

This implementation of the Model Based Definition (MBD) solution at the Naval Air Warfare Center Aircraft Division (NAWCAD) in Lakehurst, NJ should realize significant saving in the manufacture and development of new equipment. These savings can be summarized as follows:

- Significant labor savings can be generated though the implementation of MBD, including:
 - 30 percent reduction in complex part fabrication
 - 10 percent reduction in other manufacturing costs
- Development time of new equipment can be reduced by 30 percent
- 3D drawings are less ambiguous and provide more clarity to the end user with respect to design intent

1.3 Outcome/Results

This project established new processes utilizing only 3D data versus the traditional two-dimensional (2D) representations of the 3D data. To accomplish this, three sets of documents had to be generated — a standard 3D drawing practices document, 3D drawing templates/formats, and a model verification certificate. Following the creation of these documents, two projects were vetted through the new process. These projects were the P-8A Wing Pylon Fairing Removal and Installation Stand and a key component of the MQ-8C Handler Adapter Assembly.

Both projects showed very positive results. The new 3D TDP conveyed the design intent to the manufacturing artisans with significantly greater fidelity, and feedback provided by NAWCAD Lakehurst QA personnel indicated that they would also expect to see a reduction in time required to inspect new items utilizing these technological advancements. In particular, significant savings are generated when machining parts with a 3D TDP. A full 30 percent of the labor required for part fabrication can be eliminated if a 3D Standard for the Exchange of Product model data (STEP) file is provided to the CNC programmers.

1.4 Benefits

There are numerous benefits that an organization can realize through the implementation of MBD. The most obvious benefits (and easiest to track) are the direct monetary benefits through the labor savings achieved by reducing duplicate work in the current process. Based on preliminary data obtained through two developmental projects, a savings of more than \$3M will be generated annually by implementing MBD at NAWCAD Lakehurst. Since this project will continue to run in parallel with the legacy process, almost all variables can be compared to the existing ways of doing business. There are also numerous other benefits realized when moving to an MBD environment. A 33 percent reduction in the development schedule of new items is expected. This

ability to rapidly respond to new requirements is particularly important in the Defense industry. Furthermore, MBD shall facilitate an increase in communication and collaboration between engineering and manufacturing personnel as well as between all other project stakeholders. MBD shall also create a significant reduction in manufacturing errors, which should result in a decrease in the amount of rework, thus providing significant cost-savings. Synergies between engineering and manufacturing (producibility analysis) will not only help to reduce the costs of new designs but it will also aid in providing feedback to engineers with regard to manufacturing deviations and inspection results. Furthermore, MBD shall promote improved coordination between NAVAIR and its contractors.

1.5 Technology Transition with Deployment Recommendations

1.5.1 Change Management

As with the deployment of any new technology, the deployment of MBD into the workforce will require a significant cultural change to take place. An analogy has been made that the change from using 3D data vice 2D data is similar to the change from paper drawings to electronic Computer Aided Design (CAD) data. Consequently, educating the workforce on this upcoming change will be essential.

1.5.2 Infrastructure

An infrastructure upgrade will be required to provide the artisans with the capability to view the 3D data as they perform their machining/manufacturing tasks. Prior to the start of this project, a Capital Improvement Project (CIP) was approved for \$300K to make the necessary enhancements. These funds are expected to be executed during the first quarter of FY14.

1.5.3 PLM Integrated Software

The software packages required to create the 3D Portable Document Formats (PDFs) and validate the models were procured by Commercial Technologies for Maintenance Activities (CTMA) and evaluated in a local desktop environment. Although this works well on a small scale, to truly realize the potential savings MBD can bring to the U.S. Navy, enterprise versions that can be integrated into the Product Lifecycle Management (PLM) system currently used to manage engineering data should be procured. This will allow automatic publishing and storage of 3D PDF TDP documents. The metadata associated with the 3D TDP can also be incorporated into the PLM as searchable parameters.

1.5.4 Automated Workflow

Having an automated workflow within the PLM would provide several benefits to the organization. It would simplify the process for the engineers as well as help to ensure that all approved processes are followed. This automation could be accomplished through workflows established in the PLM or alternatively as the Customer/Supplier Interoperability (CSI) process proposed by ITI TranscenData.

1.5.5 3D PDF Graphics Validation

The current process validates the engineer's intent by comparing the STEP files to the CAD models. Although this is sufficient, validating the graphics would provide the manufacturer with the ability to query the model.

1.5.6 Other Opportunities

The 3D PDF solution could also be used to create process planning work instructions (with 3D animation) as well as inspection documents utilizing the Anark Core software. This makes it possible to use the MBD data as an input to these other documents which could generate significant savings for other activities.

2.0 Introduction

MBD is the practice of using 3D digital data (such as solid models and associated metadata) within 3D CAD software to provide specifications for individual components and product assemblies as opposed to utilizing conventional 2D drawings. NAWCAD Lakehurst is the Center of Excellence for Aircraft Launch and Recovery Equipment (ALRE) as well as naval aviation Support Equipment (SE). As such, engineers at the facility are constantly supporting fleet maintenance activities with the design of replacement parts and new maintenance equipment. In the current environment, engineering designs use 3D software. Although these designs are constructed in 3D models, the designs are documented in 2D engineering drawings for prototype/production. When manufacturing and inspecting these prototype/production items, only the 2D drawings are used. Currently, the technology to manufacture and inspect directly from the 3D data is available; however, many challenges still exist.

2.1 Background

NAWCAD Lakehurst is responsible for the design and development of ALRE and SE. ALRE refers to the equipment on naval ships that is used to launch and recover aircraft. Examples of ALRE include catapults, arresting engines, barricades, and aircraft visual landing aids currently on aircraft carriers and air capable ships. SE refers to the equipment required to test, repair, and maintain the aircraft. The introduction of new aircraft, obsolescence issues, and engineering investigations often lead to requirements that could change fleet deployed ALRE and SE systems. Engineers work to design equipment or components of equipment to address these new requirements. The designs are usually completed utilizing Creo Parametric software, which creates a computer model of the design. These models are then imported into a drawings file where they are dimensioned and converted into full engineering drawings. The engineering drawings are then converted to PDF and are sent to the Prototype Manufacturing Division (PMD), AIR-4.8.8. The PMD artisans use a variety of CAD/CAM software packages to recreate a representative model from the drawings and generate tool paths to achieve the requirements of a specific manufacturing process operation. The new model is then used as an input into a CNC machine that manufactures the part. After the part is manufactured, it is sent to NAWCAD Lakehurst's QA Department for inspection. QA personnel compare the part to the original 2D drawing to ensure the part conforms to the applicable dimensioning and tolerancing required. Next, the prototype part is tested to ensure it was correctly designed. After a successful test, the engineering drawings are released to the Contracts Department. Finally, a commercial machine shop is contracted to manufacture the production of the new parts.

This current process can be documented as follows:

- 1) Engineers design in 3D models
- 2) Engineers document their design in 2D drawings
- 3) Artisans recreate a 3D model and manufacture the part
- 4) QA checks the part against a 2D drawing
- 5) 2D drawings sent to Contracts Department
- 6) Machine shop selected and 2D drawings converted back into 3D models. This step is repeated every time the item is procured.

This timely process lacks in efficiency. Valuable time and effort is wasted converting data back and forth between the 3D and 2D environments.

2.2 Authorization

The DoD has been moving toward a model based solution for several years. In recent years, the DoD has led an effort to revise MIL-STD-31000 (specification for TDPs) to include 3D TDPs. The American Society of

Mechanical Engineers (ASME), with assistance from the DoD, has approved a 3D drawing specification (ASME Y14.41). 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 U.S. Air Force already implements this requirement through a product delivery specification that they developed and shared with the DoD community. This MBD project will not only implement this requirement for NAVAIR in-house design, but is the logical next step in TDP development. This project has received approval from AIR-4.8.6.

2.3 Benefits

Working directly from a 3D model would offer the following benefits:

- 1) **Reduction in Cost:** There is a significant amount of rework in the current process. The modeling process that is completed by the engineers is recreated by the PMD artisans. By not having the model available during the QA process, cost is significantly increased in order to inspect the manufactured parts. Furthermore, artisans often spend significant amounts of time interpreting the 2D drawings. Similarly, this entire 2D to 3D model recreation is repeated at the private machine shop, which increases the cost that the supplier must charge and increases the delivery time to the DoD. Using this MBD technology, Boeing has documented a 50 percent reduction in their fabrication costs and a 30 percent reduction in assembly hours. Toyota documentation has shown a 50 percent reduction in development costs (Pezel, 2011). Due to the nature of the work performed by this activity, NAWCAD Lakehurst does not expect to see reductions of this magnitude. However, an analysis by a producibility expert has shown that a significant reduction in total fabrication costs should be realized.
- 2) **Increase in Quality:** Converting from a 3D environment to a 2D environment and back again increased the possibility of translation errors. Moreover, the documentation of some engineering designs in 2D formats can be extremely difficult and confusing. Some components with complex 3D curved surfaces can only be approximated on a 2D engineering drawing. Furthermore, since some of the modeling processes are redone by the PMD artisans, there are additional opportunities for errors to be inserted into the process. A 3D model offers a significantly clearer medium to document the parts to be manufactured. Industry leaders have realized the benefits of increased quality utilizing the MBD process. Boeing showed a 50 percent reduction in rework due directly to MBD, and Toyota documented a 33 percent reduction in engineering changes (Pezel, 2011).
- 3) **Decrease in Schedule:** Studies have shown that the implementation of MBD will reduce the development schedule by up to 50 percent. Toyota showed a 33 percent reduction in overall developmental time. BAE Systems documented an 83 percent reduction in their time to market (Pezel, 2011). In a military environment, rapid response to the fleet is essential. NAWCAD Lakehurst's analysis has shown that an MBD will achieve 25 percent reduction in the developmental schedule. A significant percentage of this schedule reduction can be linked directly to the unambiguous nature of the captured design intent, which makes it easy for manufacturing and inspection groups to clearly and correctly understand what the design engineer considered key and critical design characteristics. This fact alone eliminates the time consuming requests by downstream production users when engineering design intent is not clear.

These benefits are substantial; however, to realize these benefits, a new process must be developed. This process must insure that the master engineering data is secure, is accessible to all, and is immune to errors.

2.4 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. The use of these 3D TDPs shall initially be limited to the 4.8.6.6 SE In-house Design Branch. However, any and all design branches within NAVAIR can use the information and best practices piloted in this project as a path forward in migrating away from their current 2D based environment. It is anticipated that this limited scope shall be expanded within one year to at a minimum include all of AIR-4.8.

2.5 Program Budget

Below is a summary of the program budget:

- 1) CTMA funds: \$100K
- 2) The NAWCAD Lakehurst team plans to provide 1,220 hours of Government labor (\$118K) to support this project. The team consists of the following:
 - Design: 4 Engineers, 500 hours
 - Manufacturing: 3 Artisans, 240 hours, and 1 Engineer, 80 hours
 - Producibility: 1 Engineer, 160 hours
 - QA: 1 Artisan, 80 hours
 - Information Assurance: 1 Technician, 120 hours
 - Logistics/PLM Administration: 120 hours
- 3) ITI TranscenData: ITI TranscenData supplied \$30K in additional software licenses to support the feasibility study. This investment was completely absorbed by ITI TranscenData.
- 4) Anark: Anark contributed \$34K in software licenses.
- 5) CIP: Prior to the start of this project, a CIP project was approved for \$300K to make the necessary infrastructure improvements required to implement this project throughout NAWCAD Lakehurst. These funds are expected to be executed in the first quarter of FY14. An infrastructure upgrade will be required to provide the artisans with the capability to view the 3D data as they perform their machining/manufacturing tasks. This CIP was approved prior to the conception of this project and is not considered to be part of it; however, the investment will directly affect the project's outcome.
- 6) Total project cost: \$282K

3.0 Narrative

3.1 TDP Requirement

The new process must meet the following constraints:

- 1) **Neutral File Format:** Because NAWCAD Lakehurst is a Government agency, there could be significant legal implications if the file format were in a specific CAD format. For instance, if significant funding of manufacturing work were to be contracted out using a specific CAD file format, it would give companies who also use that CAD software a competitive advantage. The competitors of the company who developed this CAD software would soon challenge this approach as it would be unlawful for the Government to provide such an advantage.
- 2) **Readily Readable Format:** Currently, all Government agencies have Acrobat viewers that can read a PDF file. All 2D engineering drawings are in PDF and must be archived into a database that accepts limited formats (PDF included). PDF is considered a neutral file format; therefore, PDF would meet the above legal requirements. 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) **In Accordance with ASME Y14.41:** ASME Y14.41 is the recognized standard for product definition data sets (PDDS). PDDS is the official term for 3D drawings. Any 3D drawing must be in accordance with ASME Y14.41.

PDF does not itself define a 3D data standard, but it does support the viewing of 3D data. This is achieved through one of two other standards — Universal 3D (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 Parametric, to be imported into a PDF. The PRC format provides support for exact geometry and tessellated data, product structure, and product manufacturing information (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 was submitted for ISO publication in June 2013. Both U3D and PRC are specified by the ISO 32000 standard, and are fully supported by the Acrobat platform.

- 4) **Need to Publish:** As per ASME Y14.41, all PDDS must be approved in accordance with AMSE 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. This approval and publishing activity cannot be accomplished with STEP or native CAD software formats. Publishing is an established process for all TDPs.
- 5) **Compatible Format with CAM:** The file format must be able to be used as an input into CAM and QA equipment. Currently, PDF does not meet this requirement. A neutral file format that can meet this requirement is the STEP file format. A STEP file is a file that complies with ISO 10303. The format was developed for the computer-interpretable representation and exchange of product manufacturing information. Its official title is "Automation systems and integration — Product data representation and exchange," but is known informally as STEP.

The above constraints result in conflicting requirements. The engineers design in CAD software, but the final acquisition and manufacturing data must be in PDF and STEP formats. However, it has been shown that a model created in CAD can be successfully written in PDF with all the required engineering data 3D design intent. A STEP file can be embedded into this file PDF file, which can then be used as a necessary input into the CAM and QA equipment. PDF offers the necessary security and publishing for the entire process

- 6) **Compatible with JEDMICS:** The Joint Engineering Data Management Information and Control System (JEDMICS) is the file technical authority for the release copy of the 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.

- 7) **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.

3.2 Verification Requirement

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 ensured if the models used to machine and inspect the parts are guaranteed to be identical to the model created by the engineer (In truth, it is impossible to ensure these are identical; however, for the purposes of this report, the term “identical” shall be defined to mean that any deviation between these models is negligible, or at least an order of magnitude less, compared to the tolerances specified on the engineering drawings or PDDS). If there was an error in the conversion from the Creo Parametric file to the STEP file, the PMD artisans would produce a nonconforming part. Furthermore, since QA would use the same STEP file to inspect the part, this nonconforming part would pass inspection. Consequently, since the MBD process will require at least three different formats (Creo Parametric, STEP, and PDF), a means is required to ensure that these three files provide an identical definition of the part. Unacceptable manufacturing or quality deviation between these three files could have severe negative consequences. Currently, the U.S. Navy has no way to verify that these three files are identical.

Previously stated is the need to use the PDF as the viewable file format for the annotated model. Currently, this format is the only one that meets all of the requirements stated above. However, simply printing the Creo Parametric models to a 3D PDF would not meet the requirements of the engineering drawings specifications. A template would need to be developed to serve as a format. This template would be the equivalent of a NAVAIR drawing format. Furthermore, the standard Adobe Acrobat software is not capable of successfully converting a 3D model to a native PDF in accordance with the engineering drawing specifications.

3.3 Solution

The proposed solution is to partner with industry leaders to formulate a MBD TDP. The TDP will consist of engineering drawing formats that are compatible with the existing 3D PDF (PRC) solution, and embedding STEP files into these PDF files. A comparison of the Creo Parametric models with the new PRC and STEP model files will be conducted to ensure that these models define an identical geometry. The proposed process will be as follows:

- 1) **Design:** Engineers design, using Creo Parametric software, new or modified SE/ALRE in accordance with approved equipment requirements.
- 2) **Document:** Engineers completely annotate their Creo models into an MBD package in accordance with ASME Y14.41.
- 3) **Producibility:** The design will be reviewed by a producibility engineer who works with the design engineers to optimize the design for manufacturing. The model geometry and PMI shall also be validated utilizing ITI’s CADIQ solution. Following these reviews, the engineer shall update the model.

- 4) **PLM:** Engineers save models to a NAVAIR-approved PLM system (Windchill).
- 5) **Create the 3D Drawing:** Engineers print the models to a PDF file (using PRC). The printing of the file is completed utilizing Anark software. The model will be printed onto a NAVAIR-approved PDF template, which will serve as the new 3D drawing format.
- 6) **Check:** The 3D drawing file (PDF) will then be checked by another engineer and a producibility expert. After corrections are completed, the engineers will recreate the PDF as well as a STEP file of the model.
- 7) **Model Comparison:** Utilizing ITI TranscenData CADIQ software, the engineer will analyze the PRC, STEP, and Creo Parametric models to confirm that the models are the same. Then, the engineer will print and digitally sign a verification certificate from the CADIQ software. The engineer will embed both the STEP file and the certificate into the PDF file.
- 8) **Secure:** The PDF file will be secured and sent to PMD.
- 9) **Manufacture Prototype:** PMD will manufacture a prototype of the proposed equipment. During this prototype phase, the STEP file will be used as an input into the machines (e.g., CNC, water jet). QA will inspect the part against the STEP file using CMM equipment.

3.4 Project Execution

3.4.1 Created Standard 3D Drawing Practices Document

A document was created identifying approved standard practices to be used by AIR-4.8 when creating 3D drawings. This document outlines procedures to annotate models, create 3D PDF drawings in accordance with ASME Y14.41, verify the different models, embed the STEP file and the certificate, and secure and digitally sign the 3D drawings.

3.4.2 Created 3D Drawing Templates

Two NAVAIR 3D drawing formats were designed. The first one was created for components and the second was for assemblies. These formats are to be used for the following drawing types:

- 1) **Component Format:** The component format shall consist of two sheets (see Figures A-1 and A-2 in Appendix A) and will be used for the following drawing types:
 - a. Mono-detail Drawings
 - b. Vendor Item Control Drawing
 - c. Altered Item Drawing
 - d. Source Control Drawing
- 2) **Assembly Format:** The assembly format will use the same first and last sheet as the component format. However, a third sheet shall be inserted between them (see Figure A-3 in Appendix A). This sheet shall show a parts list for the assembly. This format shall be used for the following drawing types:
 - a. Assembly Drawing
 - b. Weldment Drawing

These formats are in the form of PDF templates designed using Adobe Live Cycle Designer. The formats are completely compatible with Adobe Reader.

Creo Parametric start parts were also developed. They were designed such that any model made by the engineer will be able to be written onto the templates.

3.4.3 Created Model Verification Standard and Certificate

A standard for verification/validation of the embedded STEP file, Creo Parametric file, and the PRC was developed. An approved NAVAIR certificate was developed. This certificate certifies the model validation (see Figure A-4 in Appendix A). Additionally, a process was developed to perform a producibility analysis on the 3D model to ensure there are no defects in the model that could impact the manufacturing of these parts. Utilizing this process mitigates any risk of using the model as an input to CAM equipment and ensures maximum benefits when implementing the MBD solution.

3.4.4 Metrics

The new MBD process was used in projects currently under development at NAWCAD Lakehurst. NAWCAD Lakehurst obtained limited metrics that verified utilization of the MBD process should generate significant savings. Furthermore, many lessons were learned that will be used when fully deploying this solution.

3.4.4.1 Projects Developed Utilizing MBD

Two different projects were selected for the MBD process. Each project has unique characteristics, which made them ideal for this process.

3.4.4.1.1 P-8A Wing Pylon Fairing Removal and Installation Stand

This item of SE was designed to brace the inboard and outboard Pylon Fairing Assemblies located on both the port and starboard wings. The stand must brace each Pylon Fairing at or near both the Middle and Aft Mount Assemblies to allow for the removal of bolts parallel to the wing surface. Bracing the Pylon Fairing Middle and Aft Mount locations must be achieved in independent operations and had to allow for ample clearance for the removal of the pin assembly and bolt.

The Fairing Stand (see Figure 1) must provide the required force on the P-8 Wing Pylon Fairing to compress the perimeter mating rubber seal to allow the mount fitting holes to align for the insertion of the pin assembly and bolt. The reason this item was selected was due to the complex geometry required since the SE had to precisely mate with the contour of the P-8 wing. In a standard 2D drawing, the dimensioning of this complex 3D surface would be extremely difficult. However, utilizing MBD, this task was performed with relative ease.



Figure 1: Fairing I/R Stand

3.4.4.1.2 MQ-8C Handler Adapter Assembly

This Handler Adapter (see Figure 2) is required to spot the Vertical Takeoff and Landing Tactical Unmanned Air Vehicle on the flight deck and in the hangar bays of various naval vessels. It mates to an existing aircraft handler utilized in the fleet today. The following requirements were generated for this item:

- 1) The Handler Adapter Assembly shall be capable of engaging the aircraft skids and lifting it off the deck, transferring a portion of its weight to the Handler.
- 2) The Handler Adapter Assembly's skid lifting mechanism shall be manually actuated.
- 3) The Handler Adapter Assembly shall interface with the Bell 407 airframe and provide positive engagement without the use of tools.
- 4) The Handler Adapter Assembly shall engage the skidded landing gear so as to enable the Handler to maneuver the air vehicle from either the forward or aft end.
- 5) The Handler Adapter Assembly shall be capable of withstanding the towing forces imposed upon it when towing up to the heaviest aircraft configuration.

A key component of this item was chosen as a potential MBD candidate due to the short project schedule required to meet the aircraft deployment. One of the documented benefits of MBD is its ability to significantly reduce the development schedule of new items.

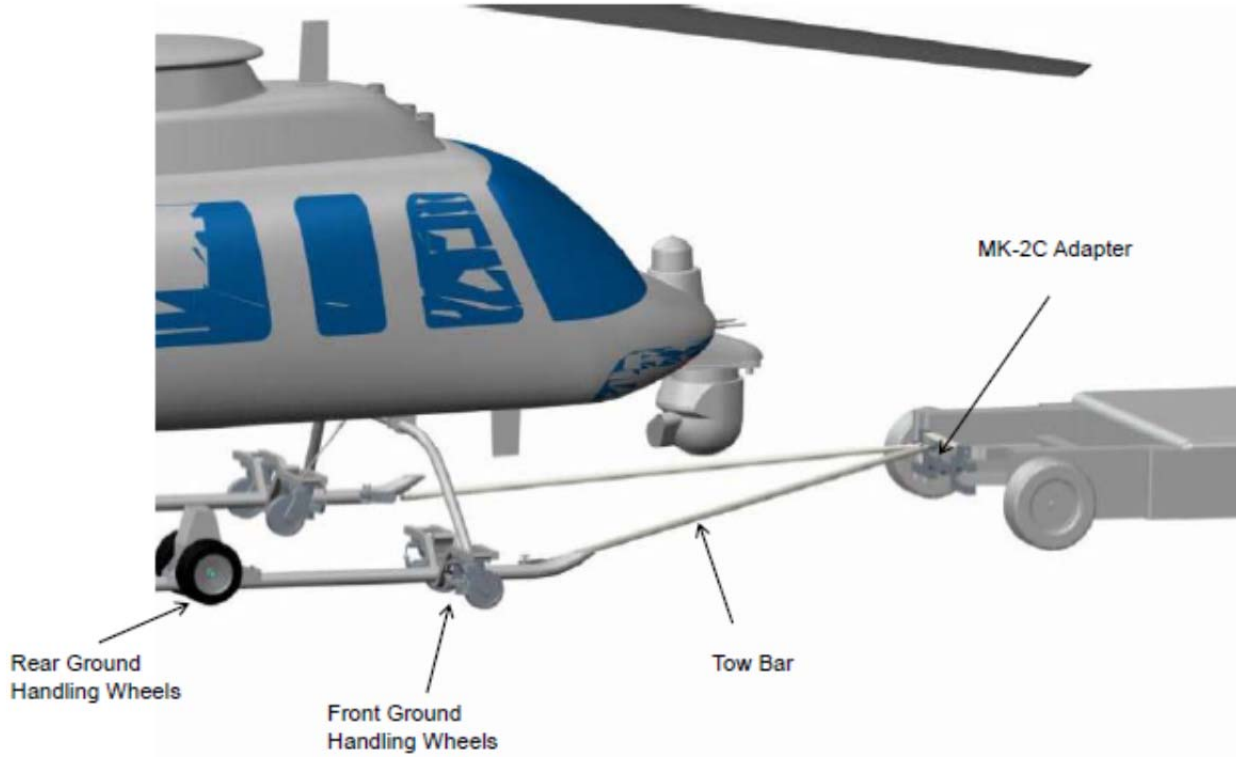


Figure 2: MQ-8C Handler Adapter Assembly

3.4.4.2 Project Results

The projects showed positive results. The new 3D TDP was much clearer for the manufacturing artisans to understand and the feedback provided by NAWCAD Lakehurst QA personnel indicated that they would also see a reduction in time to inspect new items utilizing the new process. In particular, significant savings are generated when machining parts with a 3D TDP. A full 30 percent of the labor required for part fabrication can be eliminated if a 3D STEP file is provided to the CNC programmers. At this time, any savings in design time appears to be limited. This was mostly due to the decision to fully dimension the 3D TDP as opposed to using the model itself as the definition. The decision to fully dimension was made to reduce the culture shock expected during implementation. However, it is still anticipated that in the future, the model itself can be used to replace the dimensions on the TDP.

4.0 Conclusion

Despite the challenges generated by Government furloughs through the summer and a Government shutdown in October, this project has been very successful in accomplishing its objectives. The following key successes should be noted:

- Significant saving can be generated through the implementation of MBD
 - 30 percent reduction in part fabrication
 - 10 percent reduction in other manufacturing costs
- Development time of new equipment can be reduced by 30 percent
- 3D drawings are less ambiguous and provide more clarity to the end user with respect to design intent

5.0 Benefits

Several case studies have been conducted in private industry documenting the savings generated when implementing MBD. Toyota has shown that MBD has led to a 50 percent reduction in development costs, a 33 percent reduction in engineering changes, and a 33 percent reduction in schedule. Boeing and BAE Systems have documented similar savings (Pezel, 2011). NAWCAD Lakehurst has observed smaller savings. However, these savings are still significant.

5.1 Monetary Benefits

Although the data NAWCAD Lakehurst has compiled from this project does not support savings of the magnitude identified by Boeing, BAE Systems, or Toyota, the data does show that a significant reduction in fabrication costs were realized through the implementation of MBD. Additionally, engineering design time shall also be reduced. Table 1 documents the total expected savings by NAWCAD Lakehurst through the implementation of MBD:

Table 1: Expected Savings Generated through MBD

Commodity	Annual Funding	Savings (%)	Savings (\$)
Part fabrication	\$10,000K	30%	\$3,000K
Assembly	\$2,000K	10%	\$200K
QA	\$2,000K	10%	\$200K
Total Savings:			\$3,400K

Based on this data, a savings of more than \$3M will be generated annually by implementing MBD. This will represent a significant return on investment. Since this project will continue to run in parallel with the legacy process, almost all variables can be compared to the existing ways of doing business.

5.2 Non-monetary Benefits

There are numerous other benefits to moving to an MBD environment. Industry has identified a 33 percent reduction in the development schedule of new items. This ability to rapidly respond to new requirements is particularly important in the Defense industry. Although the constraints of this project and the corresponding budgetary challenges made measuring the below benefits impossible, it is reasonable to conclude that these benefits will be realized:

- Improved communication and collaboration of engineering, manufacturing, and all project stakeholders
- Reduction in cycle time for new designs process
- Significant manufacturing error reduction resulting in significant cost-savings in avoidance of rework
- More effective allocation of resources

5.3 Benefits to Industry

Industry partners will learn from the unique requirements of the DoD, providing industry partners with opportunities to adapt their products and services to more closely match the needs of the DoD. Additionally, the new process will promote improved coordination between NAVAIR supply chain vendors.

6.0 Recommendations

6.1 Gather Further Metrics

The potential savings of this project was confirmed by several developmental items being run through the new process; however, due to the Government shutdown and Government furloughs, the number of these items was limited. Consequently, the recognized standard of 95 percent confidence required to confirm the savings of any new process could not be achieved. Therefore, further data should be gathered to support this confirmation of savings. The E-2D Rotodome Antenna Maintenance Stand (see Figures 3 and 4) has been chosen as an ideal project to be used to gather these metrics.

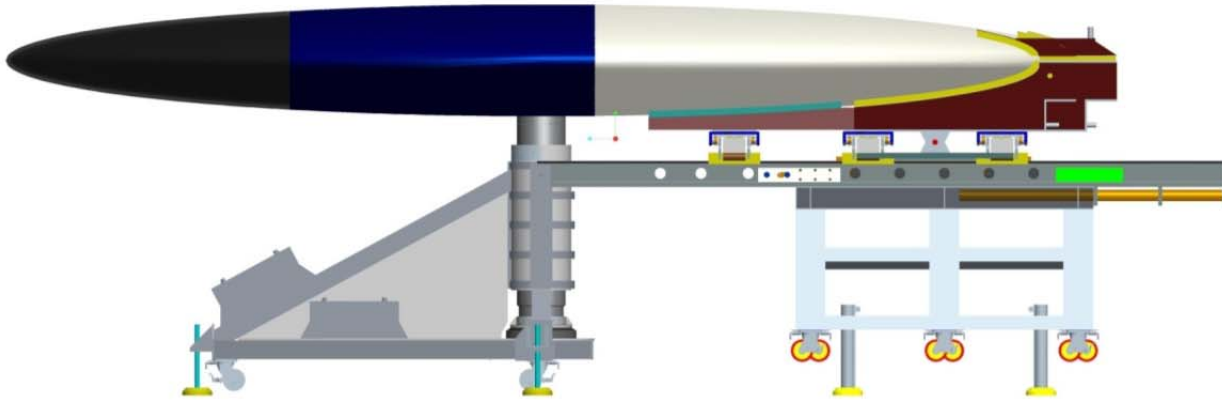


Figure 3: E-2D Rotodome Antenna Maintenance Stand with Rotodome Installed

This item of SE is required to assemble and disassemble the E-2D Rotodome. The fleet has a requirement to separate the Rotodome into its three main components for maintenance purposes. The stand used to do this is itself made of two primary components. One component supports the dome, while the other pulls (or pushes) the dome component apart (or together if assembling). These items have been modeled and the creation of a drawing package is just starting. It has been decided that one of the two primary components shall have its TDP created using MBD. The other component shall utilize the existing 2D drawing process. This project will be the largest project to implement the MBD solution and will have the unique ability to measure the two processes side-by-side. In addition to this project, several other smaller projects will be run through the new MBD process.

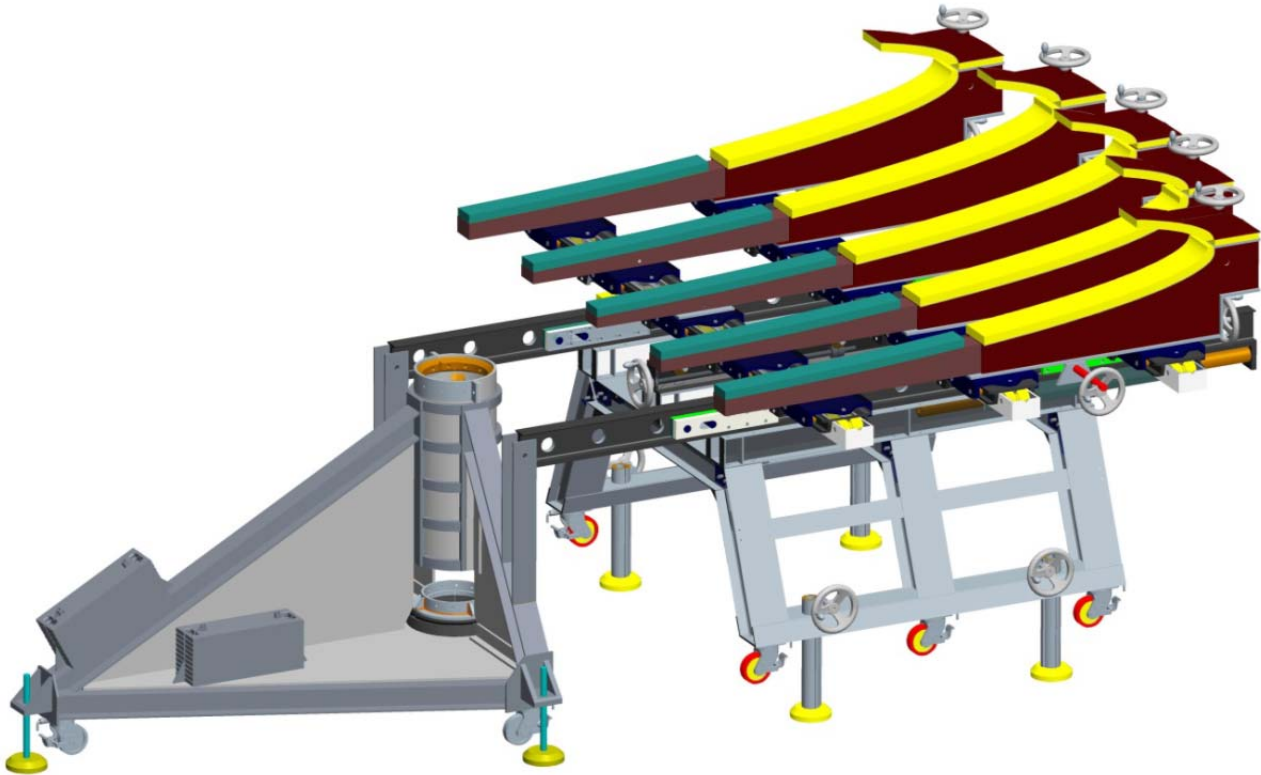


Figure 4: E-2D Rotodome Antenna Maintenance Stand without Rotodome Installed

6.2 PLM Integrated Software

The software packages required to create the 3D PDFs and validate the models were procured by CTMA as desktop versions. Although this works well in a smaller environment, to truly realize the potential savings MBD can bring to the U.S. Navy, enterprise versions that can be integrated into the PLM system currently used to manage the engineering data should be procured. This will allow automatic publishing and storage of 3D PDF TDP documents. The metadata can also be incorporated into Windchill as searchable parameters.

6.3 Automated Workflow

Having an automated workflow would provide several benefits to the organization. It would simplify the process for the engineers as well as help to ensure that all approved processes are followed. This automation could be accomplished through workflow generated in Windchill as well as in a CSI process proposed by ITI TranscenData.

6.4 3D PDF Graphics Validation

The current process validates the engineer intent by comparing the STEP files to the CAD models. Although this is sufficient, validating the 3D PDF graphics would provide the manufacturer with the ability to query the model. This would become important if the model itself were to be used to define the part as opposed to dimensions.

6.5 Work Instructions

The 3D PDF solution could also be used to create process planning work instructions (with 3D animation) using the Anark Core software. This makes it possible to use the MBD data as an input to work instructions (such as assembly, proof loading, welding, etc.) on the factory floor. Furthermore, these work instructions could be sent out to the fleet for use on the aircraft.

6.6 3D PDF Inspection Documents

The 3D PDF solution could also be used to create inspection documents using the Anark Core software. This will allow an operator to perform measurements on product characteristics using 3D MBD.

6.7 Expansion of MBD

The final recommendation would be to expand these processes to the use of other CAD programs and more importantly, across other organizations in the DoD as well as private industry.

7.0 References

American Society of Mechanical Engineers, *Digital Product Definition Data Practices*, ASME Y14.41-2012, New York: ANSI, 2012.

American Society of Mechanical Engineers, *Engineering Drawing Practices*, ASME Y14.100-2013, New York: ANSI, 2013.

Department of Defense Standard Practice: Technical Data Packages, MIL-STD-31000A, 2013.

International Organization for Standardization, *Automation Systems and Integration — Product Data Representation and Exchange*, ISO 10303, Geneva: ISO.

International Organization for Standardization, *Document Management – Portable Document Format – Part 1: PDF 1.7*, ISO 3200-1:2008, Geneva: ISO, 2008.

Pezel, Vladimir, “MBD Overview,” PTC, 2011.

Appendix A: Figures A-1 through A-4

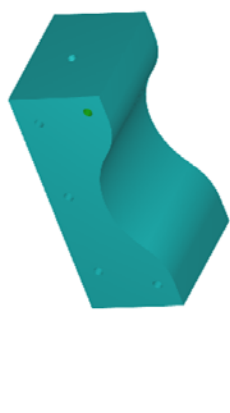

<p>Naval Air Warfare Center, Aircraft Division, Lakehurst, NJ 08733-5000</p>		<p>PRELIMINARY</p>																
Data Set Number:	31 08AS601-2	Rev:	-															
		Design code:	30003															
<p>ADAPTER</p>																		
<p>PYLON</p>																		
Part Number:	3108AS601-2	Weight:	5.00567															
Design for:	P-8A	Next Assembly:																
Distribution Code: A																		
Approved for public release; distributions unlimited.																		
<p>Unless Otherwise Specified:</p> <ul style="list-style-type: none"> - Dimensioning and tolerancing shall be interpreted in accordance with ASME Y14.5M - 2009. - Product Definition Data set (PDS) to be interpreted in accordance with ASME Y14.41. - Remove burrs and break all sharp edges. - Dimensions are in inches. - Parts are modeled as the mean dimensional condition. - The true geometry of the model defines the theoretically exact size profile orientation, or location of a feature or datum. It is the basis from which permissible variations are established by applied tolerancing. - The precision of the model in this PDS is accurate to 5 significant digits. - CAD data is stored in a Windchill PDM. The web site is https://file-engg.navair.navy.mil/Windchill 																		
<p style="text-align: center;">Classification of characteristics per DOD-STD-2001.</p> <p style="text-align: center;">For each finished part, critical and major characteristics require 100% inspection.</p> <p style="text-align: center;">Critical: _____ To: _____ Major: _____ To: _____</p> <p style="text-align: center;">View for Reference Only</p>																		
																		
<p>Notice(s):</p>																		
<p>Revision Block:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>Rev Code:</td> <td>-</td> </tr> <tr> <td>Rev:</td> <td>-</td> </tr> </table>				Rev Code:	-	Rev:	-											
Rev Code:	-																	
Rev:	-																	
																		
<p>Approved for Release (including revisions):</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="3">Drawing Approval</th> </tr> <tr> <th>Name</th> <th>Date</th> <th>Code</th> </tr> </thead> <tbody> <tr> <td>Design By: W HOCHREPPEL</td> <td>10-OCT-13</td> <td>4.8.6.6</td> </tr> <tr> <td>Checked By: P HALASNIK</td> <td>10-OCT-13</td> <td>4.8.8.2</td> </tr> <tr> <td>Supervisor: J SCHMELZLE</td> <td>10-OCT-13</td> <td>4.8.6.6</td> </tr> </tbody> </table>				Drawing Approval			Name	Date	Code	Design By: W HOCHREPPEL	10-OCT-13	4.8.6.6	Checked By: P HALASNIK	10-OCT-13	4.8.8.2	Supervisor: J SCHMELZLE	10-OCT-13	4.8.6.6
Drawing Approval																		
Name	Date	Code																
Design By: W HOCHREPPEL	10-OCT-13	4.8.6.6																
Checked By: P HALASNIK	10-OCT-13	4.8.8.2																
Supervisor: J SCHMELZLE	10-OCT-13	4.8.6.6																
<p>CAD Program: CREO Version: 2.0 Sheet 1 of 3</p> <p>File Name: ADAPTERBUCK.PUBLIC</p>																		

Figure A-1: Sheet 1 of the 3D TDP Format

PART NUMBER	NOMENCLATURE	QTY
3108AS601-2	PYLON ADAPTER	1
3108AS601-4	U-BRACKET	1
3108AS601-3	ADAPTER BLOCK	1
M45913/1-4FS6	.250-20 UNC, NPT, SLIP	4
MS24693-C108	.250-28 X .963 UNZF, 2	2
MS24693-C108	1/4-20 X 2.50, SCREW, 4	4
MS24693-C108	1/4-20 X 2.50, SCREW, 10	10
MS24693-C108	EXT. 3/16-16 UNC, 3/16	10
MS24693-C108	EXT. 3/16-16 UNC, 3/16	10
3108AS601-1	PYLON ADAPTER ASSEMB	X
3108AS601-5	PISTON ROD	1
3108AS601-6	ROBBER 3/24, STD	1
E-45TH	EPoxy, ADHESIVE	1

Show All

Isolate

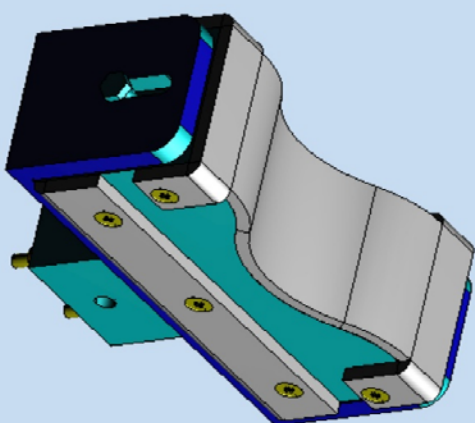
Decimal Tolerances: XXXX ±
(Unless Otherwise Specified) XXX ±

Available Views:
 10 REF_ISO
 20_ANNOTATE_1

Zoom Fit

Select All

Print Selected



Rev:

Design Cage Code: 30003

Title: PYLON ADAPTER, ASSEMBLY

Data Set Number: 3108AS601-1

Sheet 3 of 3

3108AS601-1

Figure A-2: Last Sheet of the 3D TDP Format (Sheet 2 for Components and Sheet 3 for Assemblies)

adapter2 prt_pe_step_CADIQ_compare_report

CADIQ COMPARISON REPORT

CADIQ Ver 1 : 7.1.0, Build Date: July 23, 2013
 CADIQ Ver 2 : 7.1.0, Build Date: July 23, 2013
 CAD System 1 : Creo Parametric Creo 2.0/2012230
 CAD System 2 : STEP AP203
 Oper System 1 : Windows 7 x64 [Service Pack 1] 6.1.7601
 Oper System 2 : Windows 7 x64 [Service Pack 1] 6.1.7601
 CAD Model 1 : C:\CADIQ\7.1.0.0\p-8\adapter2.prt.1
 CAD Model 2 : C:\CADIQ\7.1.0.0\p-8\adapter2.stp
 CAD Part 1 : None
 CAD Part 2 : None
 Config File 1 :
 C:\CADIQ\7.1.0.0\config\config_custom\navair_validate_se_part_transl__capture.cfg
 Config File 2 :
 C:\CADIQ\7.1.0.0\config\config_custom\navair_validate_se_part_transl__compare.cfg
 IQR File 1 : 1XzATHz1HWRQJcdU7rAuqddwTsVd.iqr
 IQR File 2 : JMjbddspEwH6PppmE9NDE1a9a0cX.iqr
 IQR Date 1 : Mon Oct 21 12:40:08 2013
 IQR Date 2 : Mon Oct 21 12:40:19 2013

DIAGNOSTIC LEVEL SUMMARY

Level	P/F	Hot 1	Hot 2	Values 1	Values 2	Run Time 1	Run Time 2
Surface Add/Remove	PASS				190		00:00:00
Major Shape Changes	PASS				287		00:00:00
Integrity Defects	PASS			1436	1436	00:00:00	00:00:00
Minor Shape Changes	PASS				188		00:00:00
Property Changes	PASS				15		00:00:00
Tooling Defects	PASS			2	2	00:00:00	00:00:00
Structure Defects	PASS			3	2	00:00:00	00:00:00
Design Information	PASS			65		00:00:00	
Totals:		0	0	1506	2120	00:00:00	00:00:00

DIAGNOSTIC COMPARISON

Level	Diagnostic	Hot 1	Hot 2	Warm 1	Warm 2
Errors 1	Errors 2	Values 1	Values 2	Extreme Value 1	Extreme Value 2
Label					Units

Figure A-4: Verification Certificate

(THIS PAGE INTENTIONALLY LEFT BLANK)

DISTRIBUTION LIST

INTERNAL

EXTERNAL

4823 (1)
6853:Tech Data (1)

National Center for Manufacturing Sciences (1)
245 Fourth Street
Suite 405
Bremerton, WA 98337

ITI TranscenData (1)
5303 DuPont Circle
Milford, Ohio 45150

Anark Corporation (1)
1434 Spruce Street, Suite 200
Boulder, Colorado 80302

REVISION LIST

REVISION	PAGES AFFECTED	DATE OF REVISION