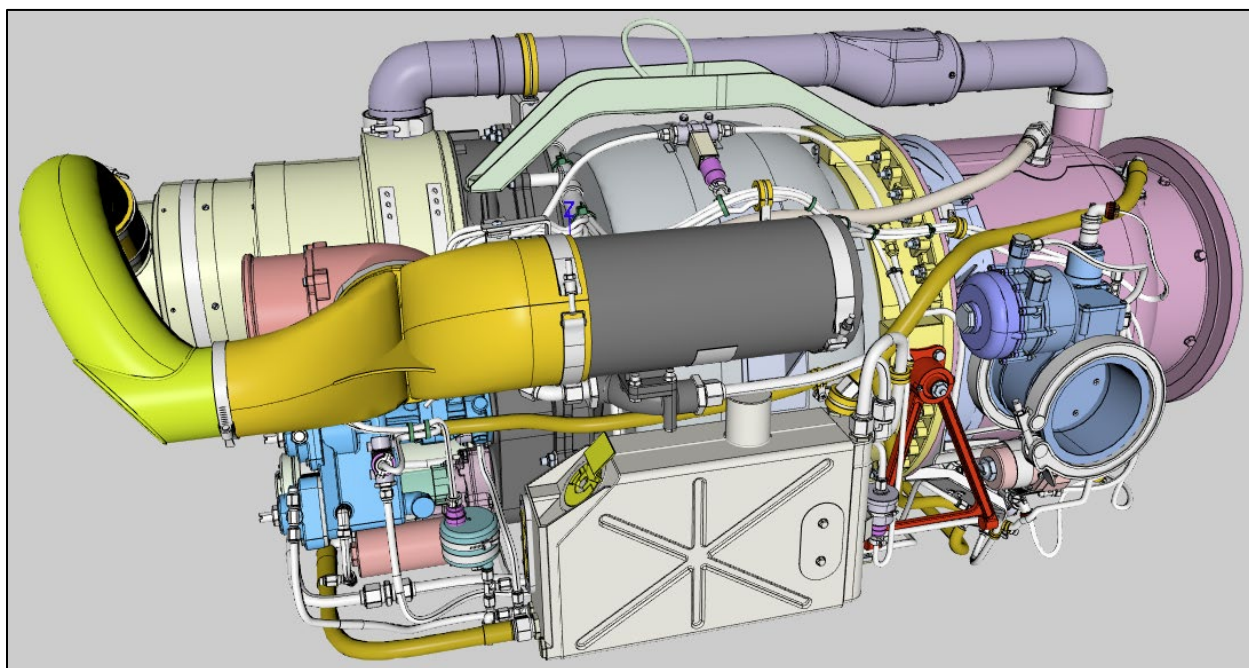


NIST Advanced Manufacturing Series 200-12

STEP File Analyzer and Viewer User Guide (Update 7)

Robert R. Lipman
Soonjo Kwon

This publication is available free of charge from:
<https://doi.org/10.6028/NIST.AMS.200-12>



NIST
**National Institute of
Standards and Technology**
U.S. Department of Commerce

NIST Advanced Manufacturing Series 200-12

STEP File Analyzer and Viewer User Guide (Update 7)

Robert R. Lipman
*Systems Integration Division
Engineering Laboratory*

Soonjo Kwon
Kumoh National Institute of Technology

This publication is available free of charge from:
<https://doi.org/10.6028/NIST.AMS.200-12>

October 2021



U.S. Department of Commerce
Gina M. Raimondo, Secretary

National Institute of Standards and Technology
*James K. Olthoff, Performing the Non-Exclusive Functions and Duties of the Under Secretary of Commerce
for Standards and Technology & Director, National Institute of Standards and Technology*

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

This software was developed by employees of the National Institute of Standards and Technology (NIST), an agency of the Federal Government and is being made available as a public service. Pursuant to title 17 United States Code Section 105, works of NIST employees are not subject to copyright protection in the United States. This software may be subject to foreign copyright. Permission in the United States and in foreign countries, to the extent that NIST may hold copyright, to use, copy, modify, create derivative works, and distribute this software and its documentation without fee is hereby granted on a non-exclusive basis, provided that this notice and disclaimer of warranty appears in all copies.

THE SOFTWARE IS PROVIDED 'AS IS' WITHOUT ANY WARRANTY OF ANY KIND, EITHER EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING, BUT NOT LIMITED TO, ANY WARRANTY THAT THE SOFTWARE WILL CONFORM TO SPECIFICATIONS, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND FREEDOM FROM INFRINGEMENT, AND ANY WARRANTY THAT THE DOCUMENTATION WILL CONFORM TO THE SOFTWARE, OR ANY WARRANTY THAT THE SOFTWARE WILL BE ERROR FREE. IN NO EVENT SHALL NIST BE LIABLE FOR ANY DAMAGES, INCLUDING, BUT NOT LIMITED TO, DIRECT, INDIRECT, SPECIAL OR CONSEQUENTIAL DAMAGES, ARISING OUT OF, RESULTING FROM, OR IN ANY WAY CONNECTED WITH THIS SOFTWARE, WHETHER OR NOT BASED UPON WARRANTY, CONTRACT, TORT, OR OTHERWISE, WHETHER OR NOT INJURY WAS SUSTAINED BY PERSONS OR PROPERTY OR OTHERWISE, AND WHETHER OR NOT LOSS WAS SUSTAINED FROM, OR AROSE OUT OF THE RESULTS OF, OR USE OF, THE SOFTWARE OR SERVICES PROVIDED HEREUNDER.

**National Institute of Standards and Technology Advanced Manufacturing Series 200-12
Natl. Inst. Stand. Technol. Adv. Man. Ser. 200-12, 87 pages (October 2021)**

**This publication is available free of charge from:
<https://doi.org/10.6028/NIST.AMS.200-12>**

PREFACE

This guide describes how to use the STEP File Analyzer and Viewer, a software tool that analyzes and generates a spreadsheet or a set of CSV (comma-separated value) files from an ISO 10303 STEP (STandard for the Exchange of Product model data) file. The spreadsheets simplify inspecting information in the STEP file at an entity and attribute level. STEP files can also be checked for conformance to recommended practices for Product and Manufacturing Information (PMI) representation, PMI presentation, and validation properties.

The STEP File Analyzer and Viewer also generates views of part geometry, graphical PMI annotations, tessellated part geometry, sketch geometry, supplemental geometry, datum targets, and finite element models.

More information about the software and sample spreadsheets and views can be found at <https://www.nist.gov/services-resources/software/step-file-analyzer-and-viewer>. The source code for the software is available at <https://github.com/usnistgov/SFA>.

In this report the acronym **SFA** will be used for the STEP File Analyzer and Viewer.

UPDATES

For update 7, in addition to some updated figures, new content is found in sections: (3.4) Options tab, (3.5) Spreadsheets tab, (4.2.1) Saved Views, (4.2.3) Holes, (4.5) Augmented Reality, (5.5.2) Text String and Numbers, (6.1.3.1) Rounding, and (6.3.1) Semantic Text. The old section 10 was merged into the renamed section 2.4 Crash Recovery. Some figures are from older versions of SFA.

DISCLAIMERS

Any mention of commercial products in SFA and this User Guide is for information purposes only; it does not imply recommendation or endorsement by the National Institute of Standards and Technology (NIST). For any of the web links in the software and this User Guide, NIST does not necessarily endorse the views expressed, or concur with the facts presented on those web sites.

NIST-developed software is provided by NIST as a public service. You may use, copy and distribute copies of the software in any medium, provided that you keep intact this entire notice. You may improve, modify and create derivative works of the software or any portion of the software, and you may copy and distribute such modifications or works. Modified works should carry a notice stating that you changed the software and should note the date and nature of any such change. Please explicitly acknowledge the National Institute of Standards and Technology as the source of the software.

Please also refer to the [NIST Disclaimer](#) and the [NIST Software Disclaimer](#).

ACKNOWLEDGEMENTS

Dr. Soonjo Kwon, a former guest research at NIST now at the Kumoh National Institute of Technology in South Korea, developed the software that converts STEP to X3D [1] for viewing part geometry as described in Sec. 4.1.

The image on the cover page was generated by SFA from a STEP file downloaded from GrabCAD <https://grabcad.com/library/gtcp85-98d-1>.

TABLE OF CONTENTS

1	INTRODUCTION	1
2	GETTING STARTED.....	2
2.1	INSTALL SFA.....	2
2.2	RUN SFA	2
2.2.1	<i>Install IFCsvr</i>	<i>2</i>
2.3	GENERATE OUTPUT	3
2.4	CRASH RECOVERY.....	3
2.5	UNINSTALL SFA.....	4
3	USER INTERFACE	5
3.1	MENU BAR.....	6
3.1.1	<i>File Menu</i>	<i>6</i>
3.1.2	<i>Websites Menu.....</i>	<i>7</i>
3.1.3	<i>Examples Menu</i>	<i>7</i>
3.1.4	<i>Help Menu.....</i>	<i>8</i>
3.2	TABS BAR.....	9
3.3	STATUS TAB	9
3.4	OPTIONS TAB.....	10
3.4.1	<i>Generate.....</i>	<i>10</i>
3.4.2	<i>Selectively Process Entity Types.....</i>	<i>11</i>
3.4.3	<i>Analysis Reports.....</i>	<i>12</i>
3.4.4	<i>View Options.....</i>	<i>12</i>
3.4.5	<i>Open STEP File in App</i>	<i>12</i>
3.4.5.1	<i>Tree View for Debugging.....</i>	<i>13</i>
3.5	SPREADSHEET TAB	14
4	VIEWER	15
4.1	PART GEOMETRY.....	15
4.1.1	<i>Part Quality and Normals</i>	<i>19</i>
4.1.2	<i>Sketch Geometry.....</i>	<i>20</i>
4.1.3	<i>Supplemental Geometry.....</i>	<i>21</i>
4.2	GRAPHICAL PMI.....	22
4.2.1	<i>Saved Views.....</i>	<i>23</i>
4.2.2	<i>Datum Targets.....</i>	<i>25</i>
4.2.3	<i>Holes</i>	<i>26</i>
4.3	AP242 TESSELLATED PART GEOMETRY	26
4.4	AP209 FINITE ELEMENT MODEL	27
4.4.1	<i>Finite Element Mesh.....</i>	<i>27</i>
4.4.2	<i>Boundary Conditions, Loads, and Displacements</i>	<i>29</i>
4.5	AUGMENTED REALITY.....	32
5	SPREADSHEETS.....	33
5.1	SUMMARY WORKSHEET	33
5.2	HEADER WORKSHEET.....	34
5.3	ENTITY WORKSHEETS	34
5.4	SKIPPED ATTRIBUTES	36
5.5	OPTIONS	36
5.5.1	<i>Maximum Rows</i>	<i>36</i>

5.5.2	<i>Text Strings and Numbers</i>	36
5.5.3	<i>Tables</i>	38
5.5.4	<i>Number Format</i>	38
5.6	ANCHOR SECTION	39
6	ANALYSIS REPORTS	40
6.1	PMI REPRESENTATION (SEMANTIC PMI)	42
6.1.1	<i>Visual Presentation of PMI Representation</i>	43
6.1.2	<i>Datum Reference Frame</i>	43
6.1.3	<i>Dimensional Tolerance</i>	44
6.1.3.1	<i>Rounding</i>	46
6.1.4	<i>Geometric Tolerances</i>	47
6.1.5	<i>Associated and Toleranced Geometry</i>	49
6.1.5.1	<i>Multiple Dimensions</i>	51
6.1.6	<i>PMI Representation Summary</i>	52
6.1.7	<i>PMI Representation Coverage Analysis</i>	53
6.2	PMI PRESENTATION (GRAPHICAL PMI)	55
6.2.1	<i>PMI Presentation Coverage Analysis</i>	57
6.3	VALIDATION PROPERTIES	58
6.3.1	<i>Semantic Text</i>	59
6.4	INVERSE RELATIONSHIPS	60
6.5	SYNTAX ERRORS	61
6.6	COLOR-CODING RESULTS FOR NIST CAD MODELS	65
6.6.1	<i>Representation Summary</i>	65
6.6.2	<i>Representation Coverage Analysis</i>	68
6.6.2.1	<i>Color-coding Expected PMI</i>	68
7	SYNTAX CHECKER	70
8	MULTIPLE STEP FILES	71
8.1	SUMMARY WORKSHEET	71
8.2	COVERAGE ANALYSIS WORKSHEETS	72
8.2.1	<i>PMI Representation Coverage Analysis</i>	73
8.2.2	<i>PMI Presentation Coverage Analysis</i>	75
9	COMMAND-LINE VERSION	76
10	REFERENCES	78

LIST OF TABLES

Table 1: Icons for constrained DOF	29
Table 2: All PMI Elements for PMI Representation Coverage	54

LIST OF FIGURES

Figure 1: IFCsvr installation dialogs	3
Figure 2: What to do if the STEP File Analyzer and Viewer crashes	4
Figure 3: User interface	5
Figure 4: File menu	6
Figure 5: Websites menu	7
Figure 6: Examples menu	7

Figure 7: Help menus.....	8
Figure 8: Tooltip help	9
Figure 9: Options tab	10
Figure 10: Tooltip help for Shape Aspect entities	11
Figure 11: Open STEP File in other applications.....	12
Figure 12: Tree View output.....	13
Figure 13: Spreadsheet tab.....	14
Figure 14: Part geometry view.....	16
Figure 15: Part geometry view with edges switched off	16
Figure 16: Part geometry view with rod-assembly switched off	17
Figure 17: Part geometry view with bracket assembly and plate switched off.....	17
Figure 18: Part geometry view with approximate transparency	18
Figure 19: Part geometry view with edges only	18
Figure 20: Part geometry view with low quality	19
Figure 21: Part geometry view with high quality and normals.....	19
Figure 22: Part geometry view with sketch geometry	20
Figure 23: Part with supplemental geometry.....	21
Figure 24: Graphical PMI	22
Figure 25: Graphical PMI with multiple saved views	23
Figure 26: Graphical PMI with multiple saved view viewpoints	24
Figure 27: Graphical PMI with a datum target.....	25
Figure 28: AP242 tessellated part geometry	26
Figure 29: AP209 FEM of ultra-lightweight glider.....	27
Figure 30: AP209 FEM, no mesh	28
Figure 31: AP209 FEM, nodes only.....	28
Figure 32: AP209 FEM.....	29
Figure 33: AP209 nodal boundary conditions.....	30
Figure 34: AP209 nodal load vectors.....	30
Figure 35: AP209 displacement vectors.....	31
Figure 36: AP209 mode shape displacements	31
Figure 37: Augmented reality application of SFA output	32
Figure 38: Summary worksheet	33
Figure 39: Header worksheet	34
Figure 40: datum_system entities.....	34
Figure 41: Entity worksheet (datum_system).....	35
Figure 42: Entity worksheet (draughting_model)	35
Figure 43: Entity worksheet (b_spline_surface_with_knots)	36
Figure 44: Maximum rows example	36
Figure 45: Entity worksheet with Unicode characters.....	37
Figure 46: Entity worksheet (shape_aspect) with tables for sorting.....	38
Figure 47: Rounding numbers example	38
Figure 48: ANCHOR section in a STEP file.....	39
Figure 49: ANCHOR section worksheet.....	39
Figure 50: ANCHOR ID reported on datum worksheet.....	39
Figure 51: NIST test case CTC 3	41
Figure 52: Summary worksheet with entities highlighted for PMI.....	42
Figure 53: Entity worksheet (datum)	43
Figure 54: Entity worksheet (datum_reference_compartment)	43
Figure 55: Datum reference frame example.....	44
Figure 56: Dimensional tolerance example (columns A-C)	45
Figure 57: Dimensional tolerance example (columns A, D-I).....	46

Figure 58: Flatness tolerance example (columns A-H)	47
Figure 59: Flatness tolerance example (columns I-K).....	47
Figure 60: Position tolerance example (columns A-G)	48
Figure 61: Position tolerance example (columns H-J)	48
Figure 62: Position tolerance feature control frame	49
Figure 63: Toleranced geometry for position tolerance.....	49
Figure 64: Associated geometry for dimensional tolerance	50
Figure 65: Associated geometry for datum feature	50
Figure 66: Warning message for multiple dimensions	51
Figure 67: Multiple dimensions example (columns D-H).....	51
Figure 68: Multiple dimensions example (column K).....	51
Figure 69: PMI Representation Summary worksheet.....	52
Figure 70: PMI Representation Coverage worksheet.....	53
Figure 71: PMI presentation example (columns A-D)	55
Figure 72: PMI presentation example (columns E-H).....	56
Figure 73: PMI presentation example (columns I-K).....	56
Figure 74: PMI Presentation Coverage worksheet	57
Figure 75: Validation properties example (columns A-D)	58
Figure 76: Validation properties example (columns E-O).....	59
Figure 77: Validation properties example with expanded columns (columns E-J).....	59
Figure 78: Entity worksheet (shape_aspect_relationship).....	60
Figure 79: Inverse Relationships and Used In example (columns A-F)	60
Figure 80: Inverse Relationships and Used In example (columns G-H)	61
Figure 81: Syntax error related to annotation_curve_occurrence.....	61
Figure 82: Warning message related to dimensional_characteristic_representation.....	61
Figure 83: Entities with errors or warnings highlighted on Summary worksheet.....	62
Figure 84: Syntax error on (characterized_representation)(draughting_model)	63
Figure 85: Warning message on dimensional_characteristic_representation	63
Figure 86: Cell comment for dimensional tolerances.....	64
Figure 87: Color-coded PMI Representation Summary worksheet for CTC 5	66
Figure 88: Feature from NIST CTC 5.....	67
Figure 89: Color-coded PMI Representation Coverage worksheet	69
Figure 90: Syntax Checker results	70
Figure 91: File Summary worksheet, multiple files (rows 31-56).....	72
Figure 92: PMI Representation Coverage worksheet, multiple files (rows 1-34).....	73
Figure 93: PMI Representation Coverage worksheet, multiple files (rows 35-62).....	74
Figure 94: PMI Presentation Coverage worksheet, multiple files	75
Figure 95: Command-line version options.....	76
Figure 96: Command-line version output	77

1 Introduction

The STEP File Analyzer and Viewer [2] processes STEP (ISO 10303 – informally known as the STandard for Exchange of Product model data) [3, 4] files. A STEP file refers to a file that is typically exported by CAD (Computer-Aided Design) software in a format described by ISO 10303-21 and known as a Part 21 file [5, 6].

In this report the acronym **SFA** is used for the **STEP File Analyzer and Viewer**.

SFA supports current and some older editions of the following STEP Application Protocols (AP), also known as STEP schemas. An AP is the implementable part of ISO 10303 upon which STEP import and export translators are based on for a particular engineering domain. A complete list of supported APs can be found in the SFA Help menu under Supported STEP APs.

- AP203 – Configuration Controlled 3D Design of Mechanical Parts and Assemblies [7], the older version of AP203 is known as Config Control Design
- AP209 – Multidisciplinary Analysis and Design [8, 9], the older version of AP209 is known as Structural Analysis Design
- AP210 – Electronic Assembly Interconnect and Packaging Design [10]
- AP214 – Automotive Design [11]
- AP238 – Model Based Integrated Manufacturing Schema [12, 13], the older version of AP238 is known as Integrated CNC Schema
- AP239 – Product Life Cycle Support (PLCS) [14, 15]
- AP242 – Managed Model Based 3D Engineering [16-18]

Some other schemas are also supported.

- ISO 13399 Cutting Tools Data [19]
- ISO 13584 Parts Library (PLIB) [20]
- IFC (Industry Foundation Classes) [21-23]
- CIS/2 (CIMsteel Integration Standards) [24, 25]

There are four main features of SFA.

1. SFA is a viewer for parts, sketch and supplemental geometry, graphical PMI annotations, tessellated part geometry, datum target, and finite element models. The viewer is described in section 4.
2. SFA generates a spreadsheet or a set of CSV (comma-separated value) files from a STEP file. The spreadsheets or CSV files simplify inspecting information from the STEP file at an entity and attribute level. Spreadsheets are described in section 5.
3. SFA can also analyze a STEP file for conformance to recommended practices for Product and Manufacturing Information representation (semantic PMI), PMI presentation (graphical PMI), and validation properties. Recommended practices are defined by the CAX Interoperability Forum (CAX-IF) [26]. Checking recommended practices is described in section 6.
4. SFA can check for basic syntax errors and warnings in STEP files related to missing or extra attributes, incompatible and unresolved entity references, select value types, illegal and unexpected characters, and other problems with entity attributes. Some errors might prevent SFA and other software from processing a STEP file. The syntax checker is described in section 7.

2 Getting Started

2.1 Install SFA

SFA runs on Windows 7 or higher computers. The viewer for part geometry (Sec. 4.1) requires a 64-bit computer. Microsoft Excel is required to generate a spreadsheet. Excel 2007 and higher is supported. If Excel is not installed, then CSV files will be generated instead of a spreadsheet.

The link to the download request form for SFA can be found on <https://www.nist.gov/services-resources/software/step-file-analyzer-and-viewer>. You will receive instructions about where to download SFA after submitting the download request. SFA is downloaded as a zip file named SFA-n.nn.zip where n.nn is the version number.

The installation process does not require anything more than unzipping SFA-n.nn.zip. The zip file contains six files:

1. STEP-File-Analyzer.exe – Graphical user interface (GUI) version of SFA
2. STEP-File-Analyzer-CL.exe – Command-line version (Sec. 9)
3. SFA-User-Guide-v7.pdf – User Guide
4. SFA-README-FIRST.pdf – Readme file
5. STEP-File-Analyzer-changelog.xlsx – Summary of new and updated features
6. nist_ctc_05.stp – Sample STEP AP242 file with semantic PMI

There are no restrictions as to where the files are located on your computer's file system.

2.2 Run SFA

To run SFA, simply double click on the icon for STEP-File-Analyzer.exe. Several setup functions are performed the first time you run SFA:

1. Welcome message is shown in the Status tab.
2. Option to create a shortcut in the Start Menu and an icon on the Desktop.
3. User Guide is opened.
4. Crash Recovery dialog is shown (Sec. 2.4).
5. STEP-File-Analyzer-options.dat is created in your home directory that stores the current state of SFA options. Do not edit this file.
6. Installation of the IFCsvr toolkit.

2.2.1 Install IFCsvr

Although the IFCsvr toolkit¹ was originally written to process IFC files [21] used in the building and construction industry, it has been adapted to read and process STEP files. The IFCsvr installation program is automatically started. You might need administrator privileges to install the toolkit. The installation program might cause antivirus software to respond that there is an issue with the toolkit. The toolkit is safe to install. For example, if the Windows Defender antivirus software responds that there is an issue with the toolkit, select More Info and Run Anyway.

Two of several installation dialogs are shown in Figure 1. Use the default installation folder as shown in the right dialog. You must let the installation process complete before processing any STEP files.

¹ The IFCsvr toolkit used to be available in a Yahoo Group.

<https://web.archive.org/web/20090726182959/tech.groups.yahoo.com/group/ifcsvr-users/>

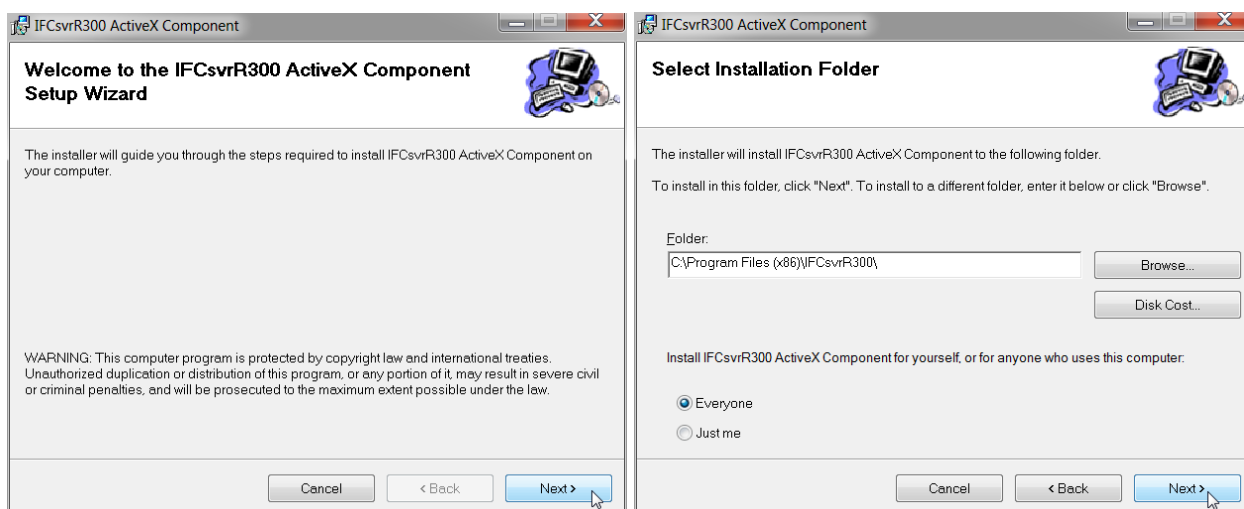


Figure 1: IFCsvr installation dialogs

Sometimes an updated version of SFA will prompt you to reinstall IFCsvr to update the STEP schemas. This requires removing the existing version of IFCsvr and installing the new version.

If you Cancel the IFCsvr toolkit installation, you will still be able to use the Viewer for Part Geometry (Sec. 4.1). Select View and Part Only in the Generate section of the Options tab (Sec. 3.4.1).

2.3 Generate Output

After the IFCsvr toolkit is installed, you can generate a spreadsheet and view from a STEP file. Go to the File menu, select Open STEP File(s), select a STEP file on your computer, click Open in the dialog, and then click on the Generate Spreadsheet and View button.

Feedback will appear in the Status tab indicating the progress of processing the STEP file. The spreadsheet will be opened after it has been generated and the view will open in the default web browser. If CSV files are generated, the directory where the CSV files were generated will be opened. One CSV file is generated for each entity type.

2.4 Crash Recovery

Sometimes SFA will unexpectedly stop (crash) when processing a STEP file. This is usually due to either bugs in the STEP file or limitations of the IFCsvr toolkit. If this happens, simply restart SFA and process the same STEP file again by using function key F1 or F6 if processing multiple STEP files. SFA keeps track of which entity type caused the crash for a particular STEP file and will not process that type again. A message will be shown in the Status tab if a particular type of entity will not be processed.

Use the Syntax Checker (Sec. 7) to check for syntax errors and warnings related to entities that might have caused the crash.

The entity types that will not be processed again are stored in a file myfile-skip.dat. No matter what the reason is for the crash, that file will always be generated. Even if you stop SFA in the middle of processing a STEP file, the file *-skip.dat will be generated. Therefore, the next time SFA is run, the entity type that was being processed when you stopped SFA will not be processed. In this case, or if the syntax errors related to the bad entity are corrected, the *-skip.dat file can be deleted or edited.

Another way to prevent that entity type from being processed is to deselect, in the Process section of the Options tab, the category of entities that contains the entity that caused the crash. That will prevent that entity from being processed along, however, with all other entities of that category.

SFA might also crash when processing very large STEP files. Popup dialogs might appear that say, “unable to alloc xxx bytes”. In this case, deselect some entity types to process in the Options tab or use a User-Defined List of entities to process (Sec. 3.4.2).

Figure 2 shows the Crash Recovery dialog that is shown the first time SFA is run.

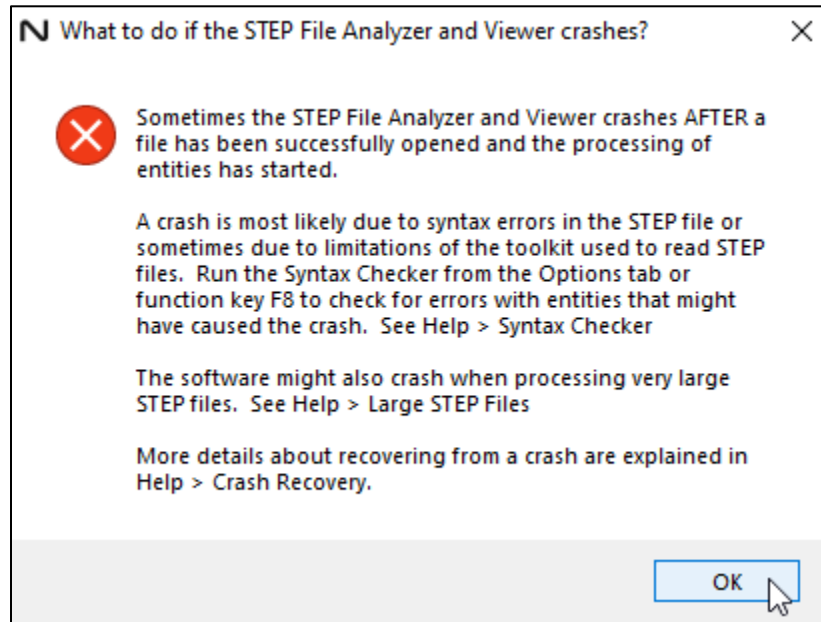


Figure 2: What to do if the STEP File Analyzer and Viewer crashes

2.5 Uninstall SFA

SFA can be uninstalled by manually deleting the two executable files and PDF files, the STEP-File-Analyzer-options.dat file in your home directory, and the desktop icon for SFA. The IFCsvr toolkit can also be deleted from Apps in Windows Settings. Temporary files can also be deleted from C:/Users/username/AppData/Local/Temp/SFA.

3 User Interface

Figure 3 shows the SFA user interface on a computer running Windows 10. At the top of the user interface is the Menu bar with the File, Websites, Examples, and Help menus. Below that is the Tabs bar with tabs for Status, Options, and Spreadsheet. Below that is the Status window that shows text feedback when SFA is running. Clicking on the Options and Spreadsheet tabs will switch to the user interface for those tabs. At the bottom of the user interface is the Generate Spreadsheet and View button, NIST logo, and progress bar.

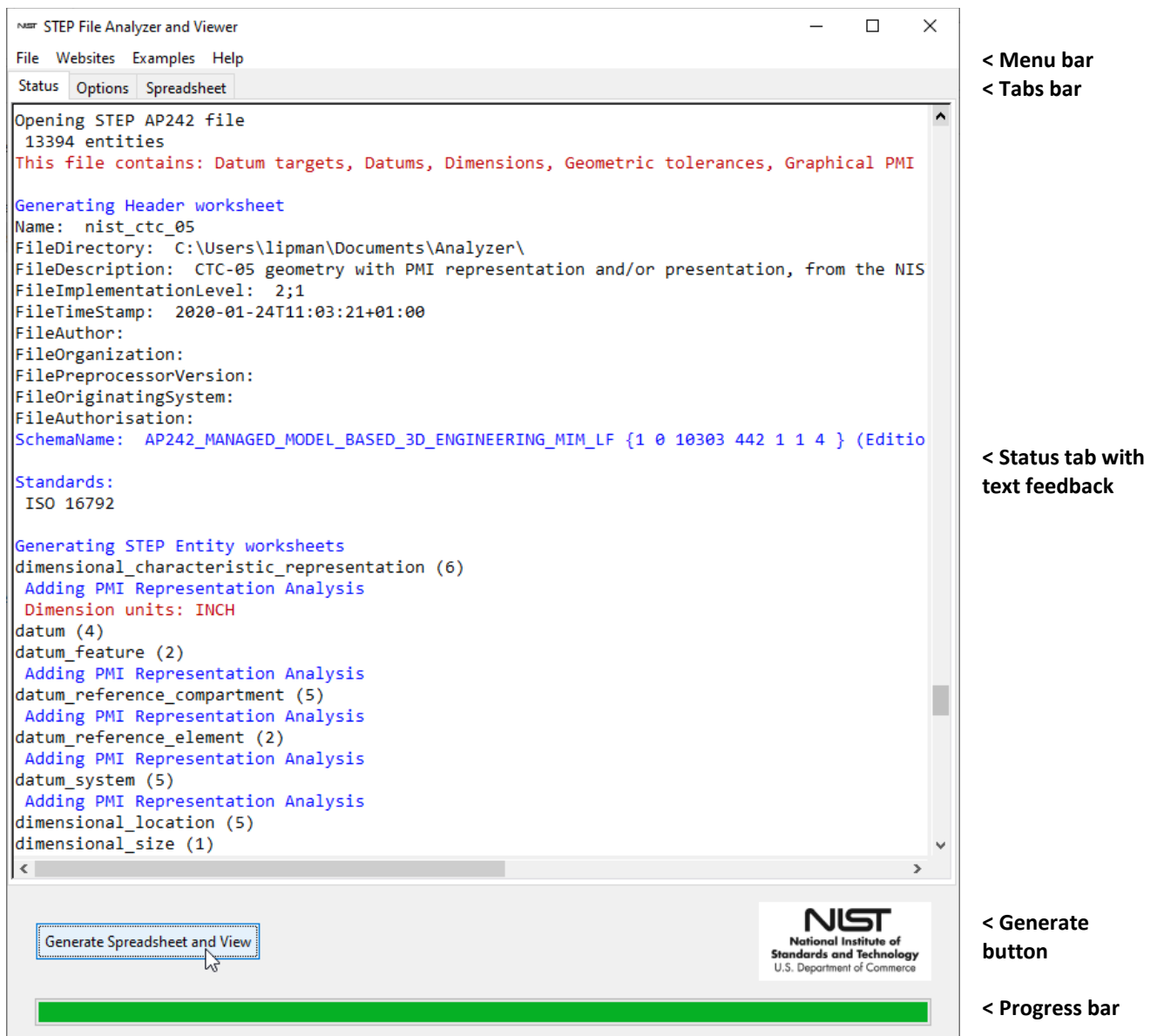


Figure 3: User interface

3.1 Menu Bar

The menu bar contains four items: File, Websites, Examples, and Help menus.

3.1.1 File Menu

From the File menu, shown in Figure 4, you can select a single STEP file to process with Open STEP File(s). STEP files with extensions of .stp, .step, and .p21 are recognized. Compressed STEP files with an extension of .stpZ are also recognized. ISO 10303 Part 21 Edition 3 STEP files are also supported [5, 27] (Sec. 5.6). AP238 files with a .stpnc file extension are supported if the file extension is changed to .stp.

Multiple STEP files can be processed at one time by selecting the Open Multiple STEP Files in a Directory option where you will be asked to select a directory to search for STEP files. The search for multiple files can be restricted to only the selected directory or to include all subdirectories.

Multiple STEP files can also be selected in the Open STEP File(s) dialog by holding down the control or shift key when selecting files. When spreadsheets from multiple STEP files are generated, a File Summary spreadsheet is also generated as described in Sec. 8.1.

Below the first solid line in the File menu is a list of up to 24 of the most recently translated STEP files that can be opened directly. Function keys, defined in the Help menu, can be used to access features of the File menu and other functions.

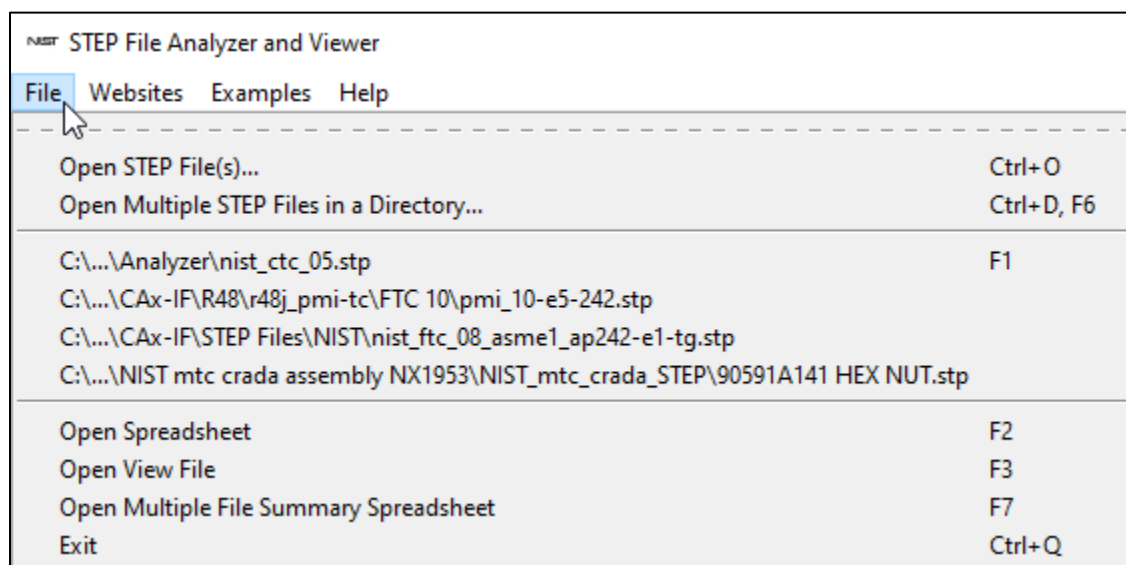


Figure 4: File menu

3.1.2 Websites Menu

The Websites menu, shown in Figure 5, provides links to useful resources related to SFA, NIST research, CAX-IF resources, AP242, related organizations, and the STEP format, schemas, and software.

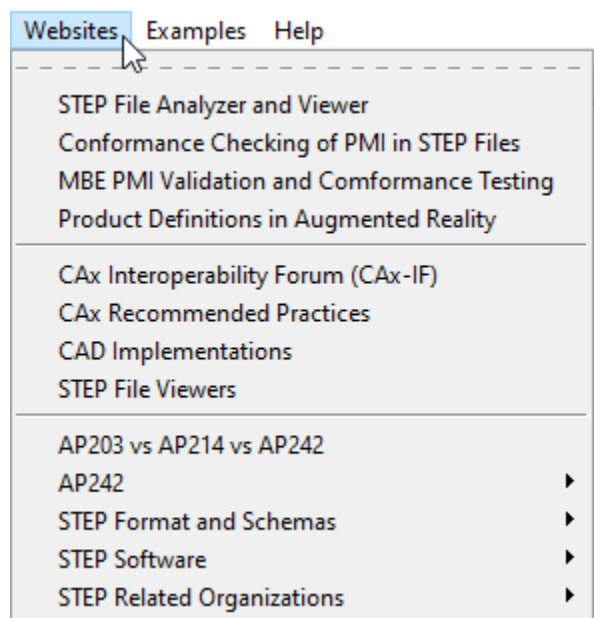


Figure 5: Websites menu

3.1.3 Examples Menu

The Examples menu, shown in Figure 6, has links to several sources of sample STEP files and sample views and spreadsheets generated by SFA.

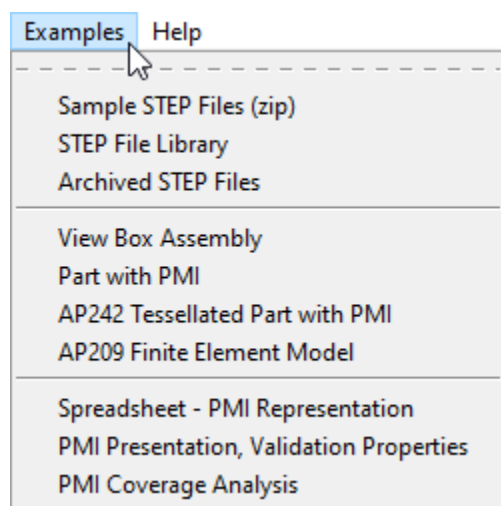


Figure 6: Examples menu

3.1.4 Help Menu

The main Help Menu, shown in Figure 7, has five sections and two submenus. User Guide a link to this document. Changelog opens the spreadsheet of changes for each version of SFA. Check for Update opens up a web page that checks for the latest version of SFA. Follow the instructions on that web page to download a new version of SFA if one is available. This feature runs automatically if an update has not been checked for in the last 30 days.

The other topics in the Help menu show information in the Status tab and are similar to most information in this User Guide. The submenus have information about View and Analyze options.

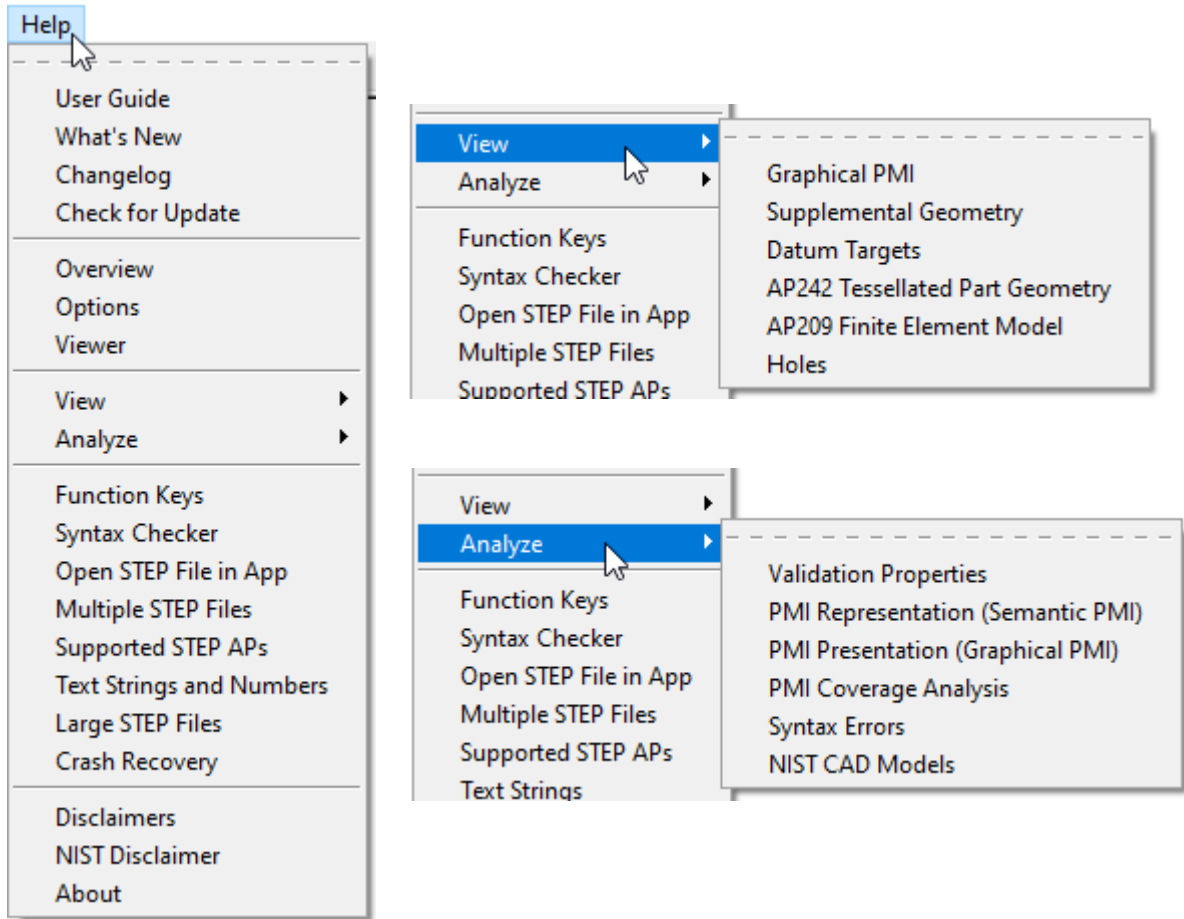


Figure 7: Help menus

Help is also available in the form of tooltips related to some of options in the tabs. Holding the mouse over any text in a tab for a second or two will show a tooltip. The Spreadsheet tooltip help in the Options tab is shown in Figure 8.

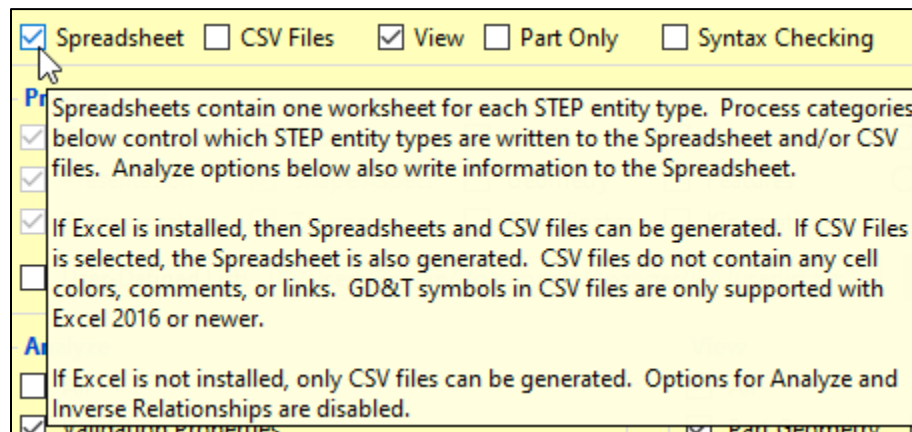


Figure 8: Tooltip help

3.2 Tabs Bar

The Tabs bar is located directly below the menu bar in Figure 3. Clicking on a tab will switch from the current tab to the selected tab. Except for the Status tab, the tabs contain the options that affect how a spreadsheet and view is generated from a STEP file. The Options and Spreadsheet tabs are described in Secs. 3.4 and 3.5, respectively.

3.3 Status Tab

The Status tab shows important feedback during the generation of a spreadsheet from a STEP file. You should not ignore the feedback as it provides useful information related to the success in processing the STEP file. Some of the error, warning, or informational messages in the Status tab have a **yellow background**, **red background**, **red**, **blue**, or **green** text. Syntax error messages highlighted with a red background are for nonconformance of some aspect of the STEP file to a CAX-IF recommended practice [28]. Information in the Status tab is shown in Figure 3 and Sec. 6.5.

3.4 Options Tab

Figure 9 shows the Options tab with five sections to control what type of output is generated from a STEP file.

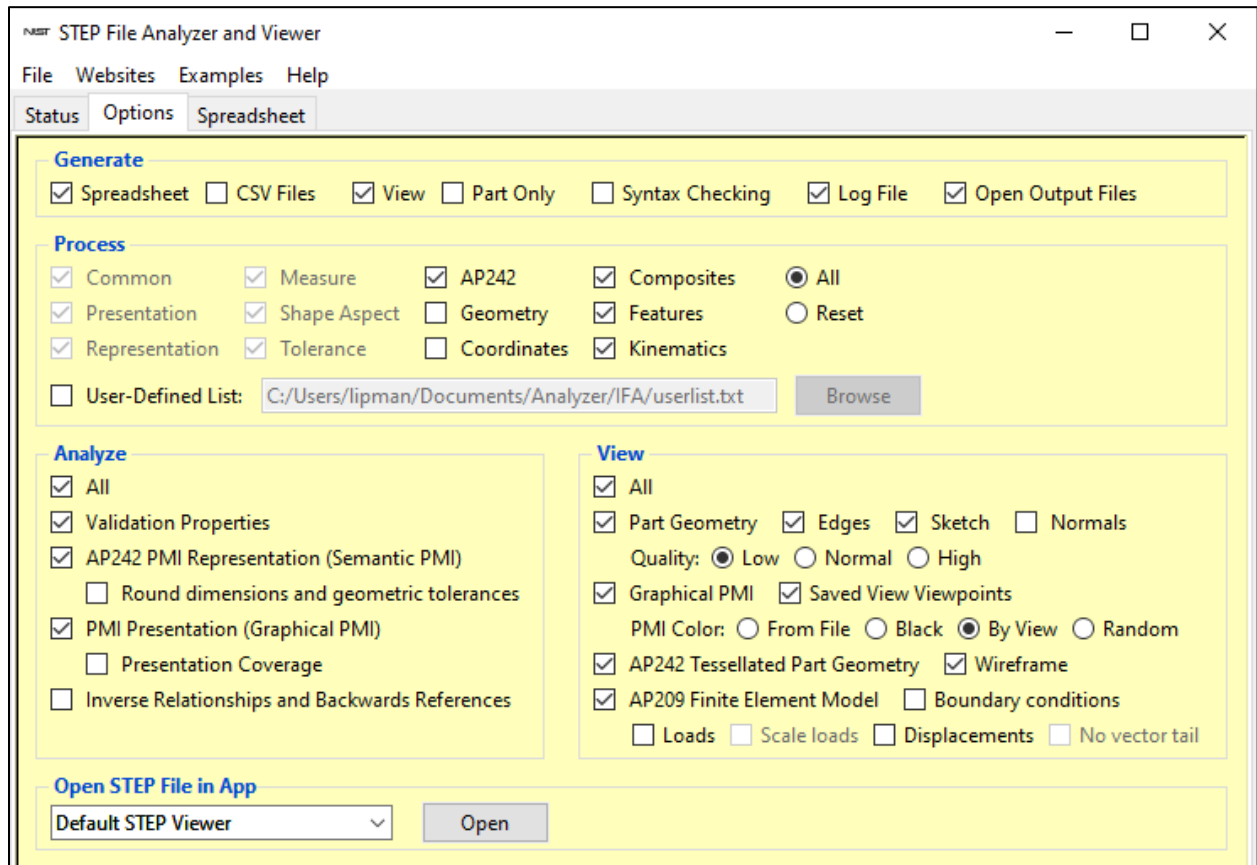


Figure 9: Options tab

3.4.1 Generate

A Spreadsheet (Sec. 5) and/or View (Sec. 4) can be generated from a STEP file.

If Excel is installed, then a spreadsheet and CSV files can be generated. If Excel is not installed, only CSV files can be generated, and some features are not available such as Analysis reports (Sec. 6). CSV files do not contain any cell colors, comments, or links. For CSV files, PMI annotations will look correct only with Excel 2016 or newer.

The Syntax Checker can be run when processing a STEP file (Sec. 7).

Text in the Status tab can be saved in a log file named myfile-sfa.log. In the log file, color-coded messages in the Status tab (Sec. 3.3) are preceded by two or three asterisks (*).

3.4.2 Selectively Process Entity Types

SFA can process any entity type for any schema listed by Supported STEP APs in the Help menu. The checkboxes in the Process section of the Options tab allow you to selectively process different types of entities. Each checkbox corresponds to a category of entities that is also used to group and color-code entities on the File Summary worksheet as shown in Figure 38.

All entities unique to APs and schemas other than AP203, AP214, and AP242 are always processed. The All button selects all categories except Geometry and Coordinates. The Reset button deselects all categories, except Common.

Selecting any Analyze option automatically includes the necessary entity categories related to that analysis. For example, selecting the analysis for AP242 PMI Representation automatically selects the entity categories for Common, Representation, Measure, Shape Aspect, and Tolerance, and disables deselecting them.

Holding your mouse over the checkboxes for a second or two will show a tooltip that lists all of the entities in that category. The tooltip for the Shape Aspect entities is shown in Figure 10 and shows that there are 60 entities in the Shape Aspect category. The first set of entities are found in STEP AP203, AP214, and AP242. The second set of entities is only in AP242 with some only in AP242 edition 2.

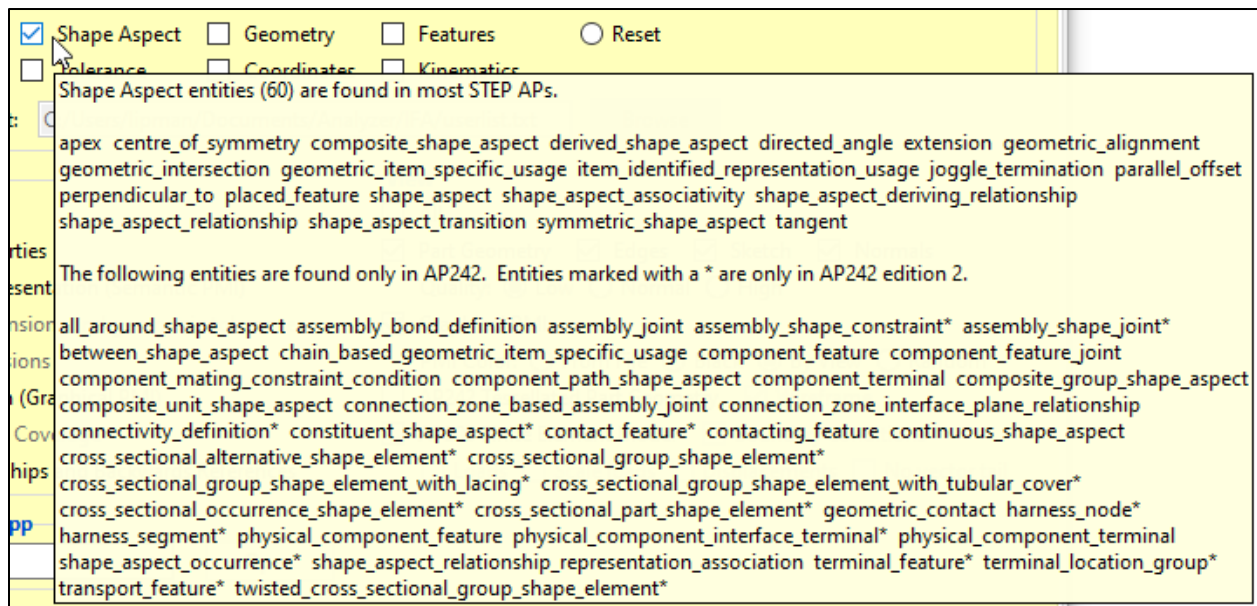


Figure 10: Tooltip help for Shape Aspect entities

A User-Defined List can also be used to set which entities will be processed. The list is defined in a plain text file with the name of one entity type per line in lower case. When the User-Defined List option is selected, the Browse button will be activated to select the file that contains the list of entities. This option allows you more control to process only the required entity types. It is also useful when processing large STEP files that might crash SFA.

3.4.3 Analysis Reports

SFA checks the STEP file for conformance to recommended practices which are specifications that provide common implementation guidance associated with specific functionalities for data exchange. The CAX-IF has published recommended practices for communicating PMI representation, PMI presentation, and validation properties in STEP files [28]. Recommended practices are not part of ISO 10303 EXPRESS schemas [29, 30].

Non-conformance to recommended practices is shown with messages in the Status tab and spreadsheet cells that are highlighted in red.

Section 6.1 discusses the report for PMI representation. Section 6.2 discusses the report for PMI presentation. Section 6.3 discusses the report for validation properties.

3.4.4 View Options

Views for part geometry, graphical PMI annotations, AP242 tessellated part geometry, and AP209 finite element models can be generated. Section 4 describes the view options.

3.4.5 Open STEP File in App

The Open STEP File in App option is a convenient way to open a STEP file in other applications. Figure 11 shows the pull-down menu listing some of the applications that can open a STEP file on the author's computer. The pull-down menu will always contain a text editor, Default STEP Viewer, and Tree View (for debugging) which is described below. The Default STEP Viewer is whichever application is associated with STEP files (.stp file extension). Several STEP file viewers and conformance checkers also appear in the pull-down menu. Applications will appear in the pull-down menu if they are installed in their default location. To open a STEP file in one of the applications, select the application from the pull-down menu and click the Open button.

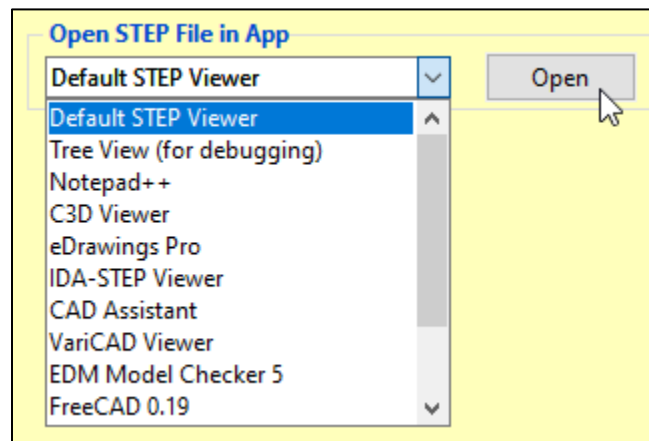


Figure 11: Open STEP File in other applications

3.4.5.1 Tree View for Debugging

The option for the Tree View (for debugging) will show the STEP file in a text editor; however, the STEP entities will be rearranged and indented to show the hierarchy of information in the STEP file. This is a useful feature to help debug a STEP file, however it is not recommended for large STEP files. Figure 12 shows a sample of the tree view output. In this sample, it is easy to see how flatness_tolerance (#5584) refers to length_measure_with_unit (#5585) and datum_feature (#5583). The tree view output of the STEP file starts with entities that will generate useful output and stops with other entities to prevent the tree view file from getting too large. Basic geometric and styled item entities can optionally be included in the tree view file, which will increase the size of the file. The resulting tree view file is named myfile-sfa.txt

```
#5584=FLATNESS_TOLERANCE('GT1',$,#5585,#5583);
  #5585=LENGTH_MEASURE_WITH_UNIT(LENGTH_MEASURE(0.02),#24);
    #24=(LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILLI.,.METRE.));
  #5583=DATUM_FEATURE('F116',$,#37,.T.);
    #37=PRODUCT_DEFINITION_SHAPE('None','None',#36);
      #36=PRODUCT_DEFINITION('None','None',#34,#35);
        #34=PRODUCT_DEFINITION_FORMATION('', 'None',#32);
          #32=PRODUCT('GDT_Test_Part_2011_1-id','', 'None',(#12273));
            #12273=PRODUCT_CONTEXT('part',#29,'');
              #29=APPLICATION_CONTEXT('automotive design');
                #35=PRODUCT_DEFINITION_CONTEXT('part definition',#29,'design');
```

Figure 12: Tree View output

3.5 Spreadsheet Tab

The Spreadsheet tab, shown in Figure 13, contains several more options that affect how information is written to the spreadsheet.

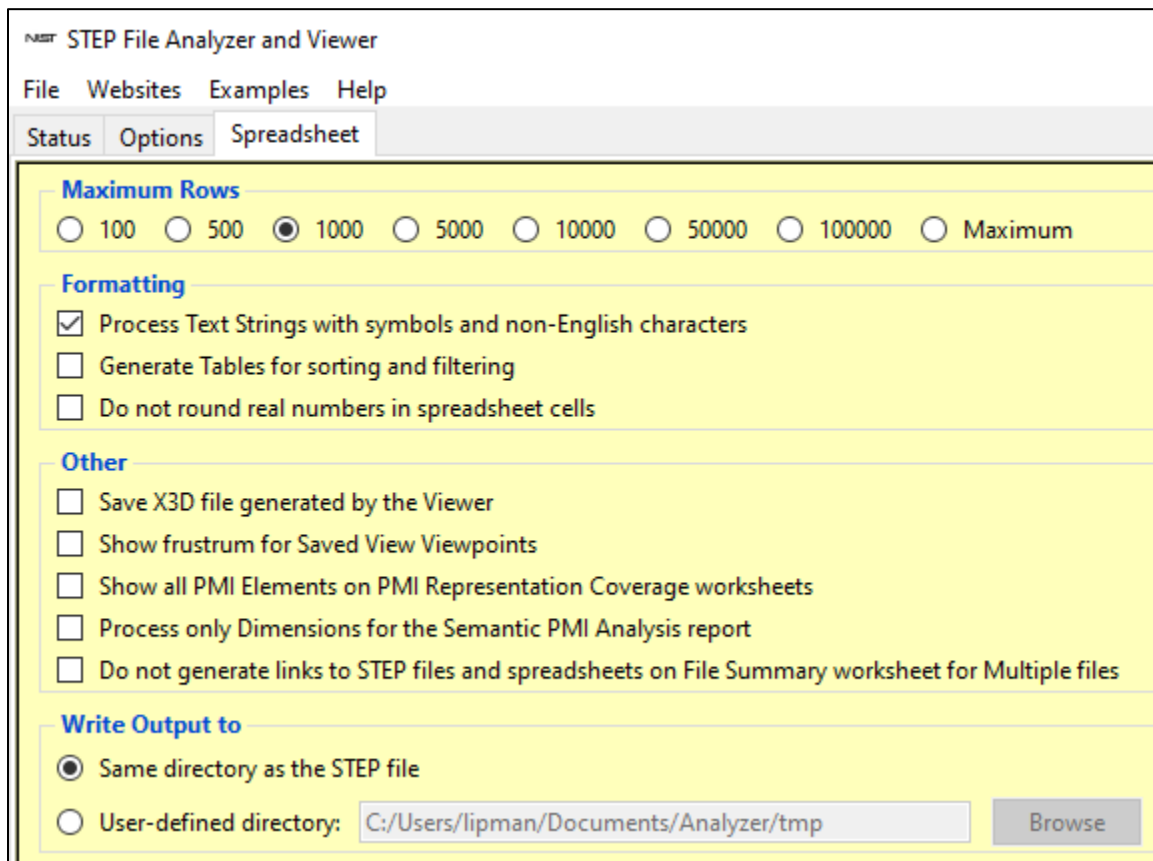


Figure 13: Spreadsheet tab

Section 5.5.1 shows how Maximum Rows can be used to limit the number of rows on any worksheet.

Formatting options:

- Section 5.5.2 describes processing text strings with symbols and non-English characters.
- Section 5.5.3 shows an example of generating tables for sorting and filtering.
- Section 5.5.4 shows an example of not rounding real numbers in spreadsheet cells.

Other options:

- The Viewer generates an X3D file which can be saved and displayed in X3D viewers or processed by other software (Sec. 4.5) [31].
- Section 4.2.1 describes generating viewpoints for graphical PMI saved views.
- Table 2 shows all PMI Elements that can appear on a PMI Representation Coverage worksheet.
- For the semantic PMI analysis report, analyze only dimensional tolerances and no geometric tolerances, datums, or datum targets.
- Not generating links on the File Summary worksheet is useful when sharing spreadsheets.

Output files can be written to the same directory as the STEP file or to a user-defined directory.

4 Viewer

SFA can generate views for part geometry, graphical PMI annotations, AP242 tessellated part geometry, and AP209 finite element models. The views are shown in the default web browser using X3DOM [32]. Internet Explorer is not supported. The resulting view file is named myfile-sfa.html. The HTML file is self-contained and can be shared with other users, including those on non-Windows systems, although an Internet connection is required. Viewer examples are available in the Examples menu.

The origin of the model at '0 0 0' is shown with a small colored XYZ coordinate axis that can be switched off. The background color can be changed between white, blue, gray, and black.

In the view, use key 'a' to view all (+Y axis up) and 'r' to restore to the original view (+Z axis up). Sometimes the model might be located far away from the origin. In this case, turn off the Origin and use 'a' to view all. The function of other keys is described in the link 'Use the mouse'. Navigation uses the Examine Mode. Use PageDown to cycle between front, side, and top viewpoints. The last viewpoint in the cycle is an orthographic projection. Section 4.2.1 describes viewpoints for graphical PMI saved views that can be generated instead of most front, side, and top viewpoints.

4.1 Part Geometry

Figure 14 shows the part geometry view for a simple assembly. Part edges are shown in black. Generating edges can be selected in the View section on the Options tab. If only part geometry needs to be viewed, select Part Only in the Generate section on the Options tab.

There is a list of checkboxes for the parts and/or assemblies in the model. Most assemblies and parts can be switched on and off depending on the assembly structure. The Show/Hide checkbox reverses the checkboxes for the parts and/or assemblies. Some names in the list might have an underscore and number appended to their name. Processing sketch geometry might also affect the list of names. Some assemblies have no unique names assigned to parts, therefore there is no list of part names. Names that use non-English characters might have different or missing characters. In this case, try to convert the encoding of the STEP file to UTF-8 with the Notepad++ text editor² or other software (Sec. 5.5.2).

The bounding box min and max XYZ coordinates are based on the faceted geometry being shown and not the exact geometry in the STEP file. There might be a variation in the coordinates depending on the Quality option described below. The bounding box also accounts for any sketch geometry if it is displayed, but not graphical PMI and supplemental geometry.

Nested assemblies are supported where one STEP file contains the assembly structure with external file references to individual assembly components that contain part geometry.

Clicking on the model shows the part name (rod) in the upper left. A small dot might be visible where the model was clicked. The part name shown may not be in the list of assemblies and parts on the right. The part might be contained in a higher-level assembly that is in the list.

For very large STEP files, it might take several minutes to process the STEP part geometry. The resulting HTML file also might several minutes to display in the web browser. Select 'Wait' if the web browser prompts that it is running slowly when opening the HTML file.

The part geometry viewer is based on the STEP to X3D translator [1] and only runs on 64-bit computers.

² <https://notepad-plus-plus.org/>

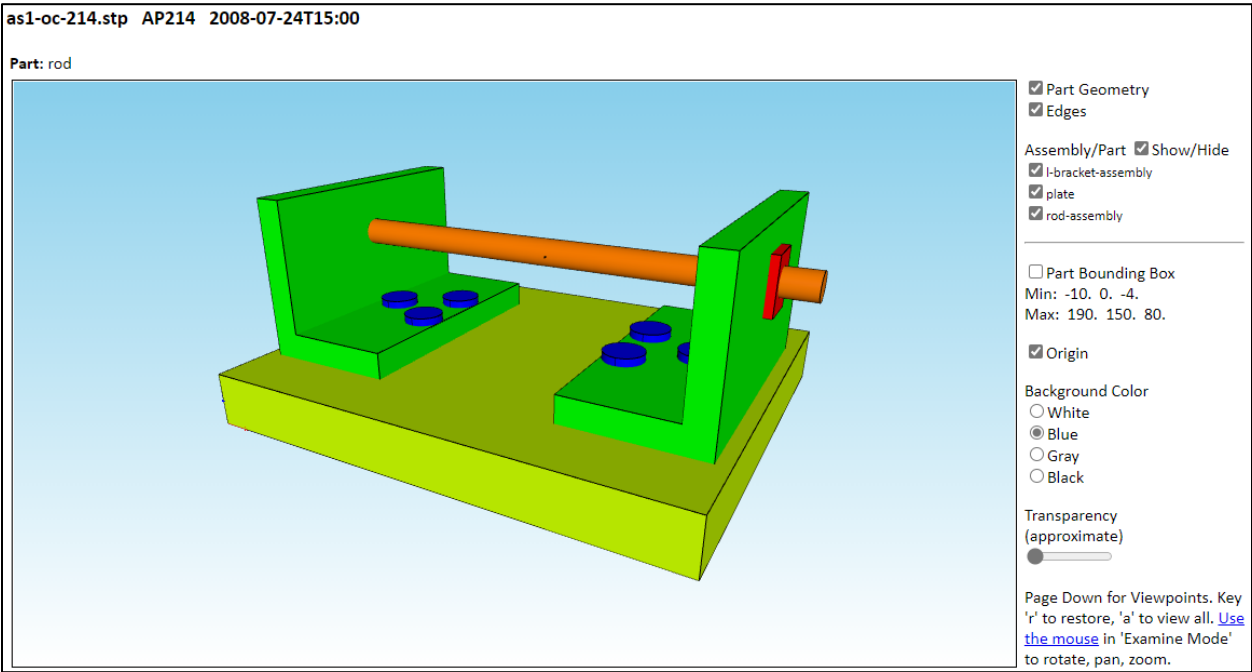


Figure 14: Part geometry view

Figure 15 shows the assembly with edges switched off with a white background.

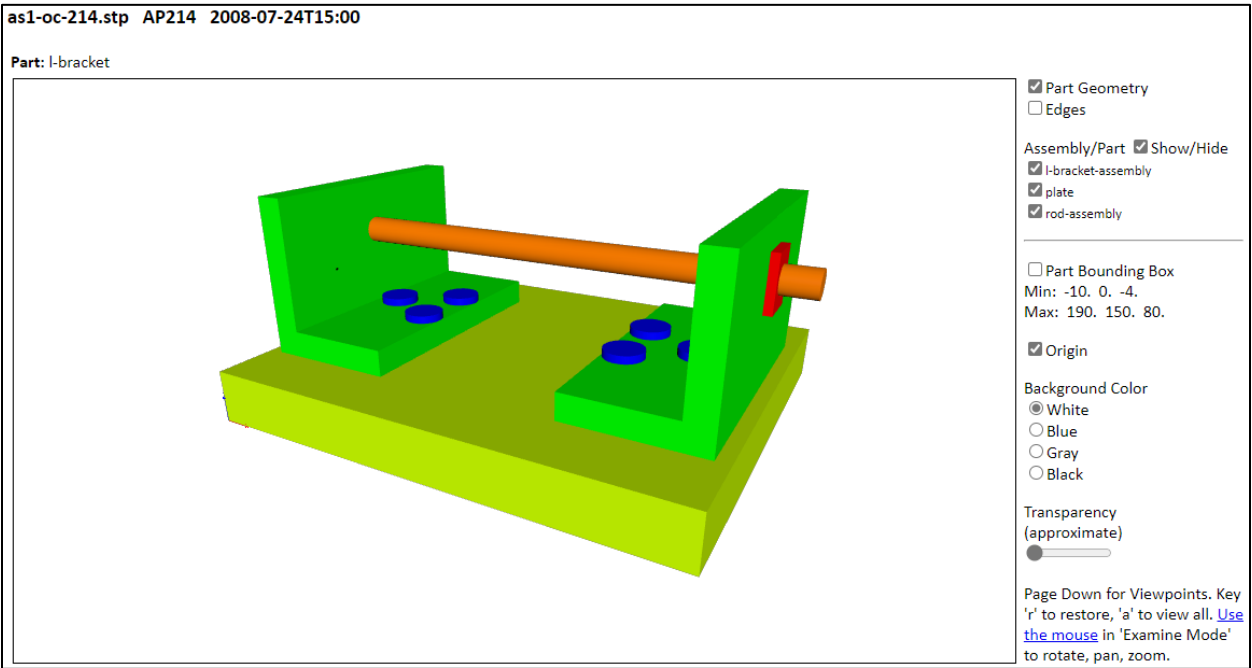


Figure 15: Part geometry view with edges switched off

Figure 16 shows the assembly with the rod-assembly switched off with a gray background.

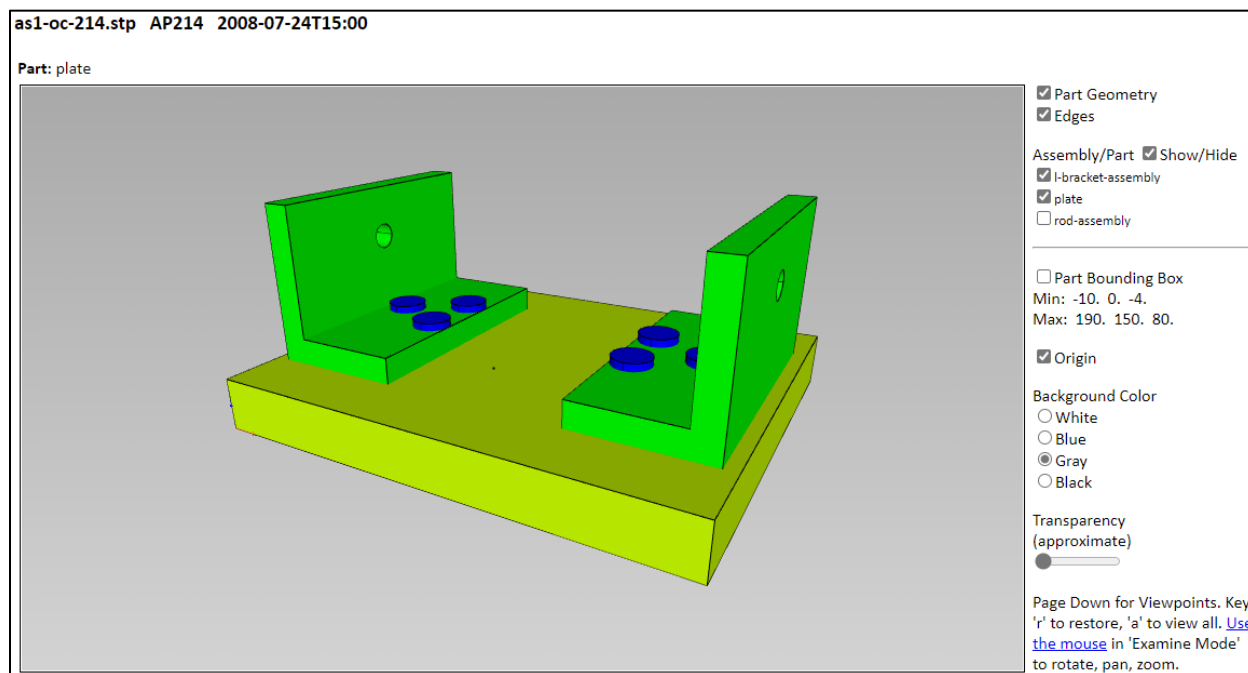


Figure 16: Part geometry view with rod-assembly switched off

Figure 17 shows using the Show/Hide checkbox to switch all parts on or off.

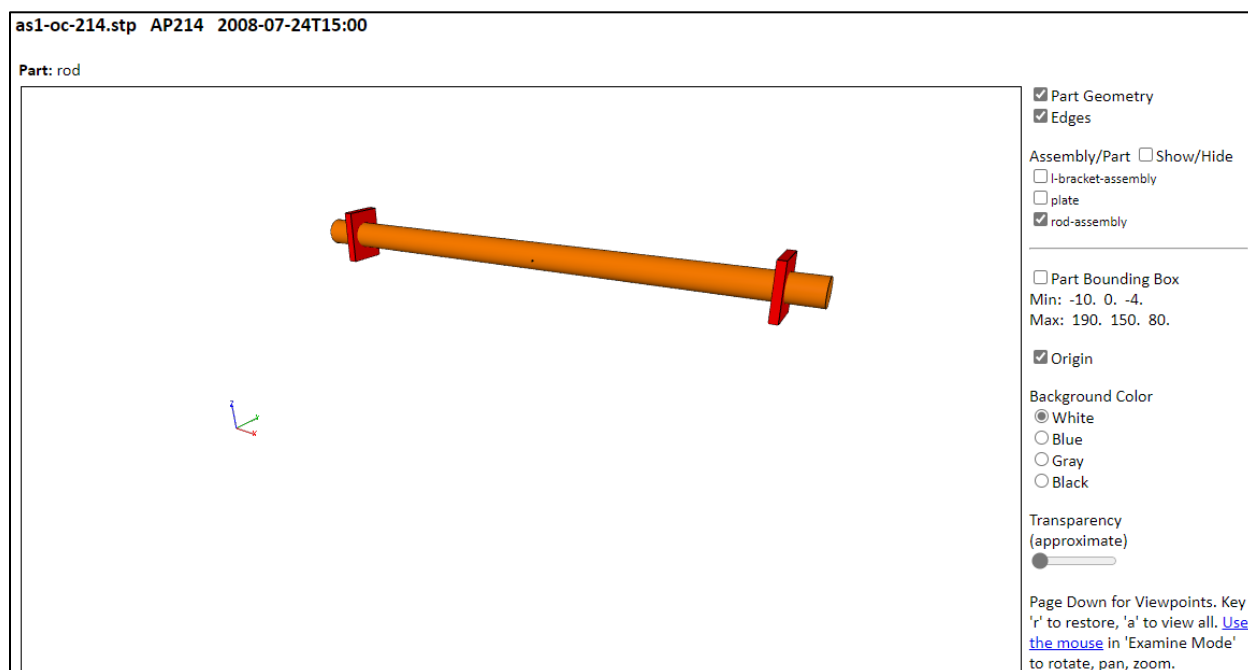


Figure 17: Part geometry view with bracket assembly and plate switched off

Figure 18 shows the assembly partially transparent by using the transparency slider bar. Transparency is only an approximation as shown by the missing three red nuts and the bottoms of the three blue bolts on the right. This limitation might cause parts inside assemblies to be invisible. The approximation is due to how transparency is implemented in X3DOM [32]. The bounding box is also shown.

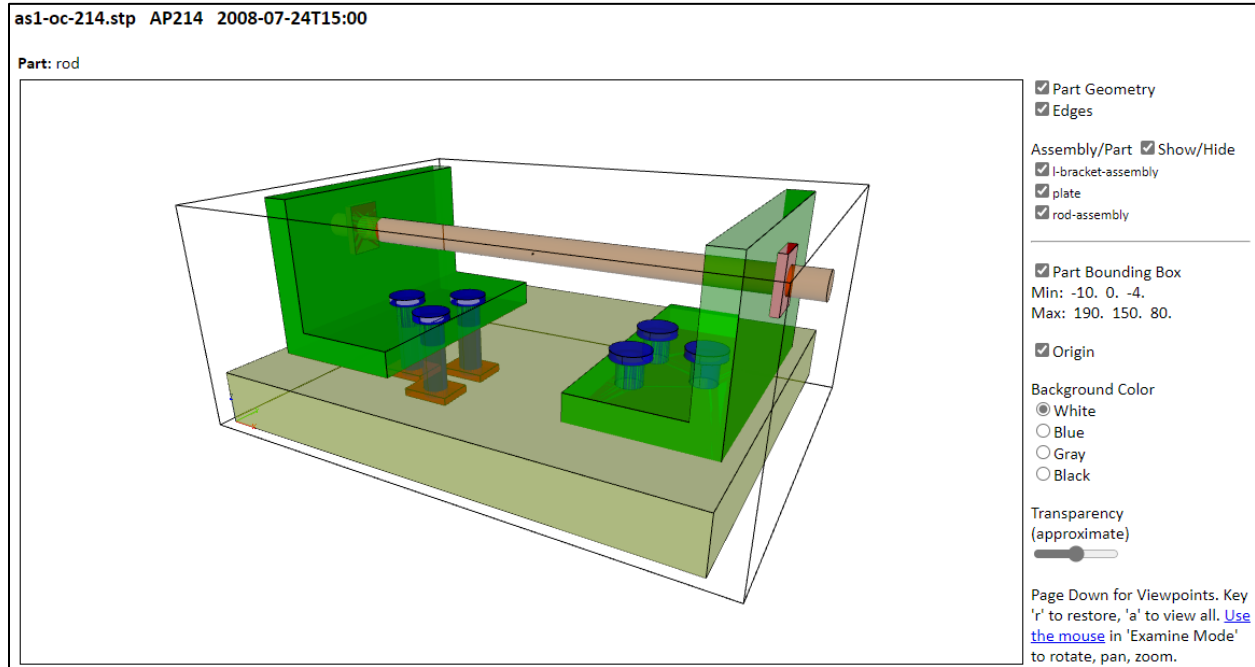


Figure 18: Part geometry view with approximate transparency

Figure 19 shows only part edges by making the assembly completely transparent.

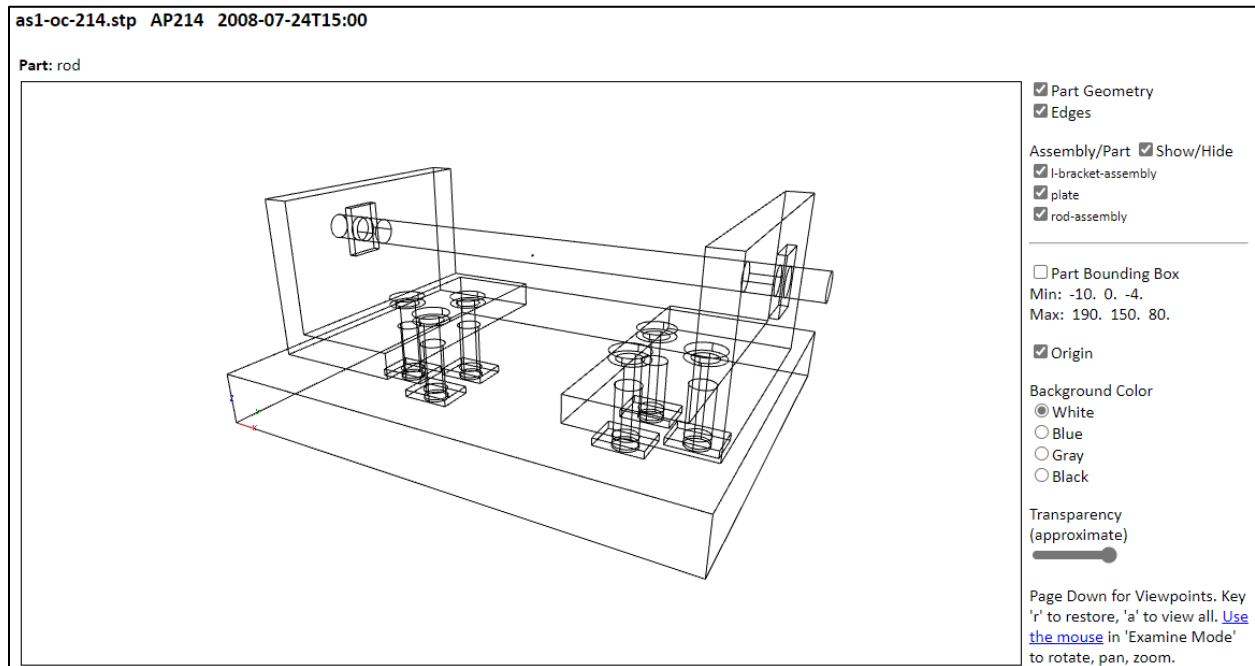


Figure 19: Part geometry view with edges only

4.1.1 Part Quality and Normals

Three levels of part quality (low, normal, high) can be selected in the View section of the Options tab. Quality controls the number of facets used for curved surfaces. For example, the higher the quality the more facets used around the circumference of a cylinder. A part geometry view with low quality selected is shown in Figure 20. The facets around the cylindrical surfaces are clearly visible. Although the part geometry is always displayed by default with smooth shading, a discontinuity in the shading is also apparent. Figure 21 shows the same part with quality set to high and normals selected. Normals improve the smooth shading by explicitly computing surface normals and improves the appearance of curved surfaces.

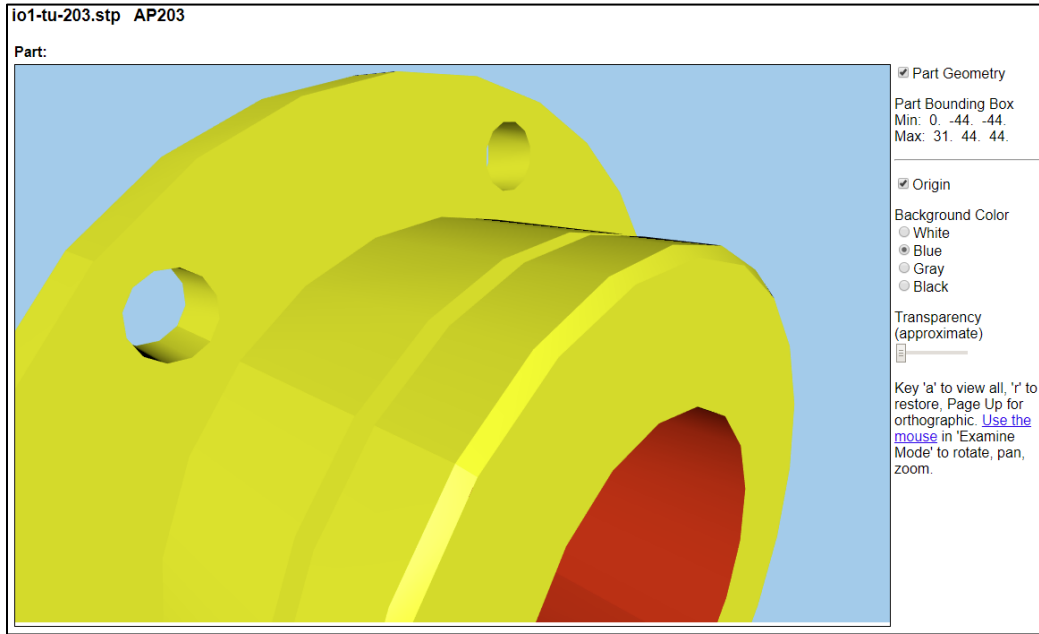


Figure 20: Part geometry view with low quality

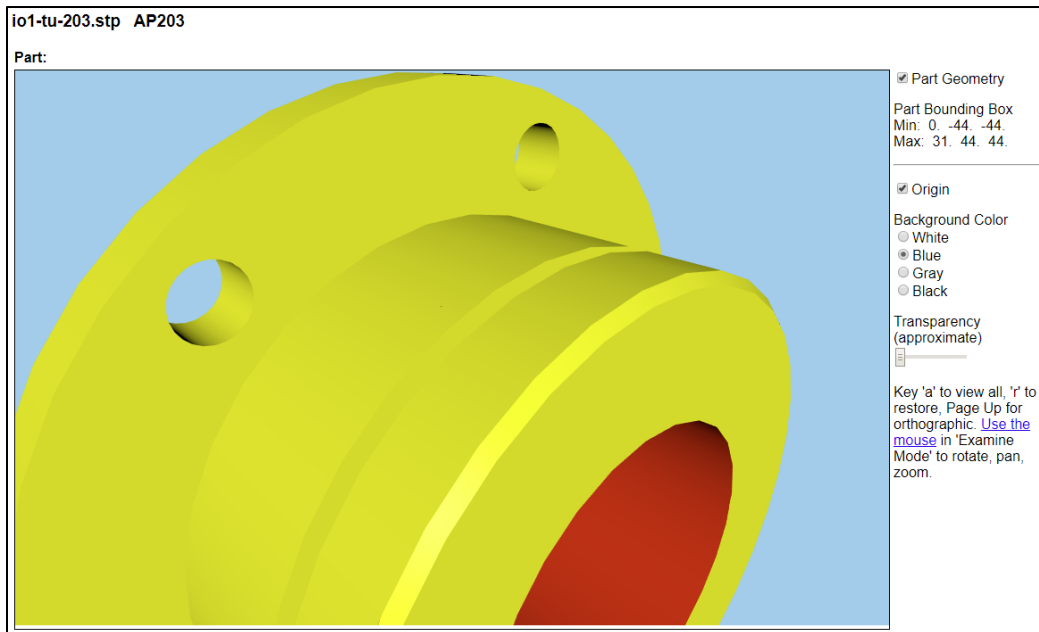


Figure 21: Part geometry view with high quality and normals

4.1.2 Sketch Geometry

The white lines in Figure 22 are an example of sketch geometry that is usually created in a CAD system to aid in modeling geometry. The option for sketch geometry is in the View section of the Options tab. Sketch geometry is not the same as supplemental geometry described below. The assembly³ also has eight different types of parts that can be switched on and off. See the Examples menu to view the assembly⁴.

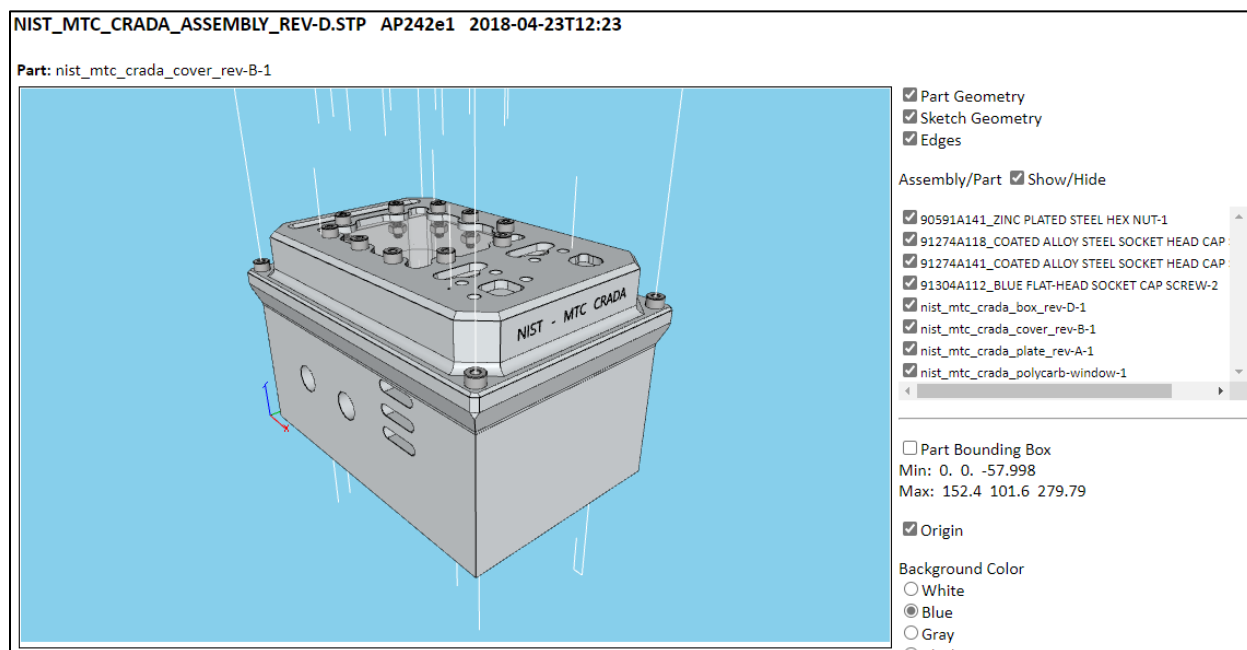


Figure 22: Part geometry view with sketch geometry

³ <https://www.nist.gov/el/systems-integration-division-73400/mbe-pmi-validation-and-conformance-testing-project/download>

⁴ <https://pages.nist.gov/CAD-PMI-Testing/step-file-viewer.html>

4.1.3 Supplemental Geometry

Figure 23 shows a part with supplemental geometry including planes, lines, and coordinate systems. Supplemental geometry is shown only if part geometry or graphical PMI is also viewed. Supplemental geometry is not associated with graphical PMI saved views. Supplemental geometry is not the same as sketch geometry described above.

The following types of supplemental geometry and associated text are supported.

- Coordinate System: red/green/blue axes
- Plane: blue transparent outlined surface
- Cylinder: blue transparent cylinder
- Line/Circle/Ellipse: purple line/circle/ellipse
- Point: black dot
- Tessellated Surface: faces outlined in black

Colors defined in the STEP file override the default colors above. Unbounded planes are shown with a square planar surface.

Supplemental geometry is also counted on the PMI Coverage Analysis worksheet (Sec. 6.1.7) if a View is generated.

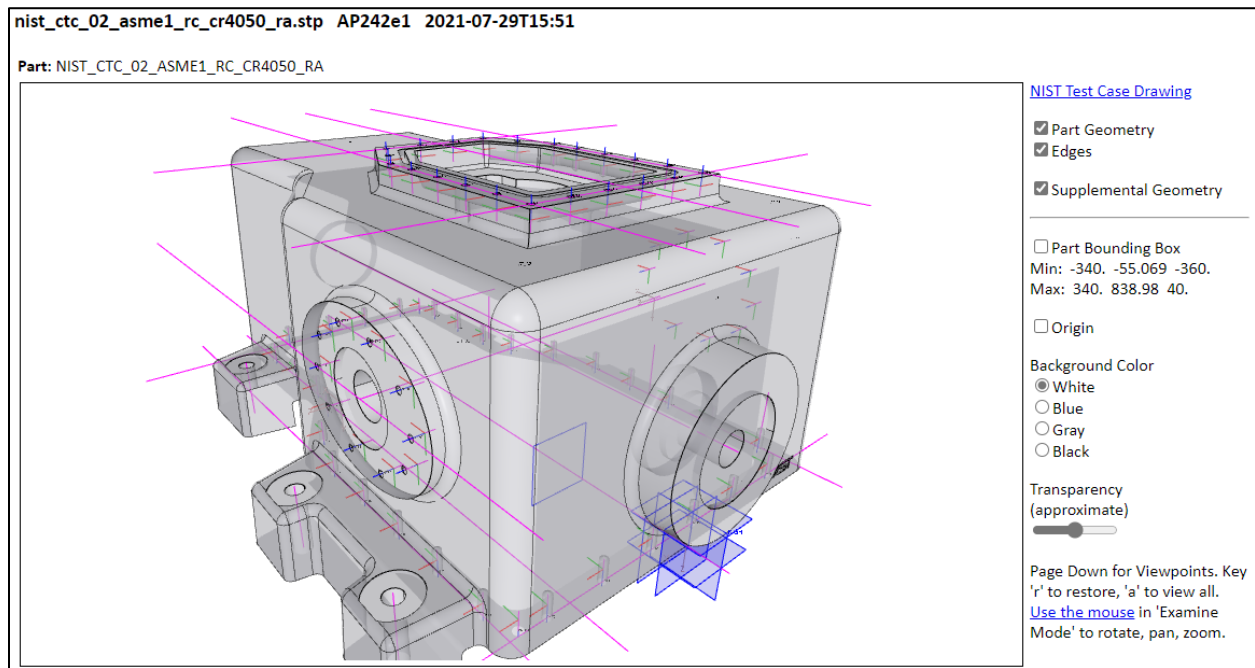


Figure 23: Part with supplemental geometry

4.2 Graphical PMI

Graphical PMI (PMI presentation) can be viewed by selecting the option in the View section of the Options tab. STEP AP203, AP214, and AP242 support graphical PMI.

Figure 24 shows the graphical PMI that corresponds to the annotations shown in Figure 51. The view file contains the line segments defined by the polylines in column F of Figure 72. In this example, each part of the graphical PMI is assigned a different color to help differentiate them from each other.

There is a checkbox for the graphical PMI associated with saved view MBD_0. In this case, there is only one saved view for the PMI.

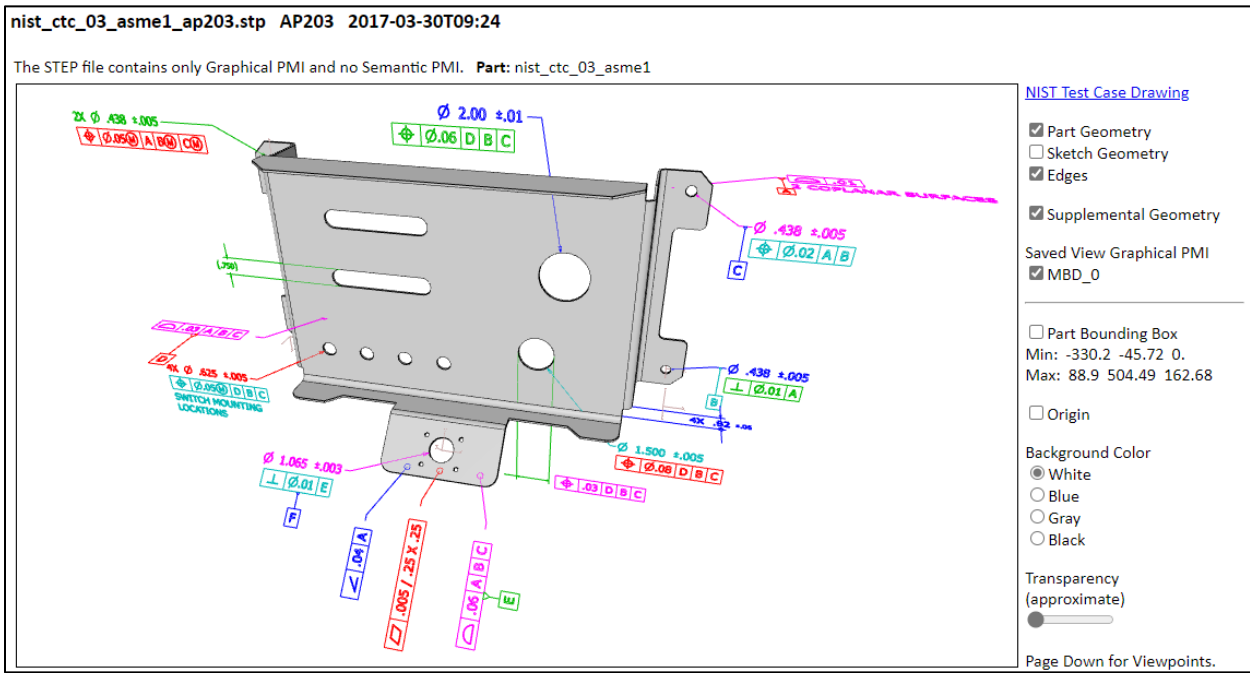


Figure 24: Graphical PMI

4.2.1 Saved Views

A saved view is a subset of all graphical PMI. Multiple saved views will have multiple checkboxes as shown in Figure 25. In this example the graphical PMI in each of the three saved views is assigned a different color.

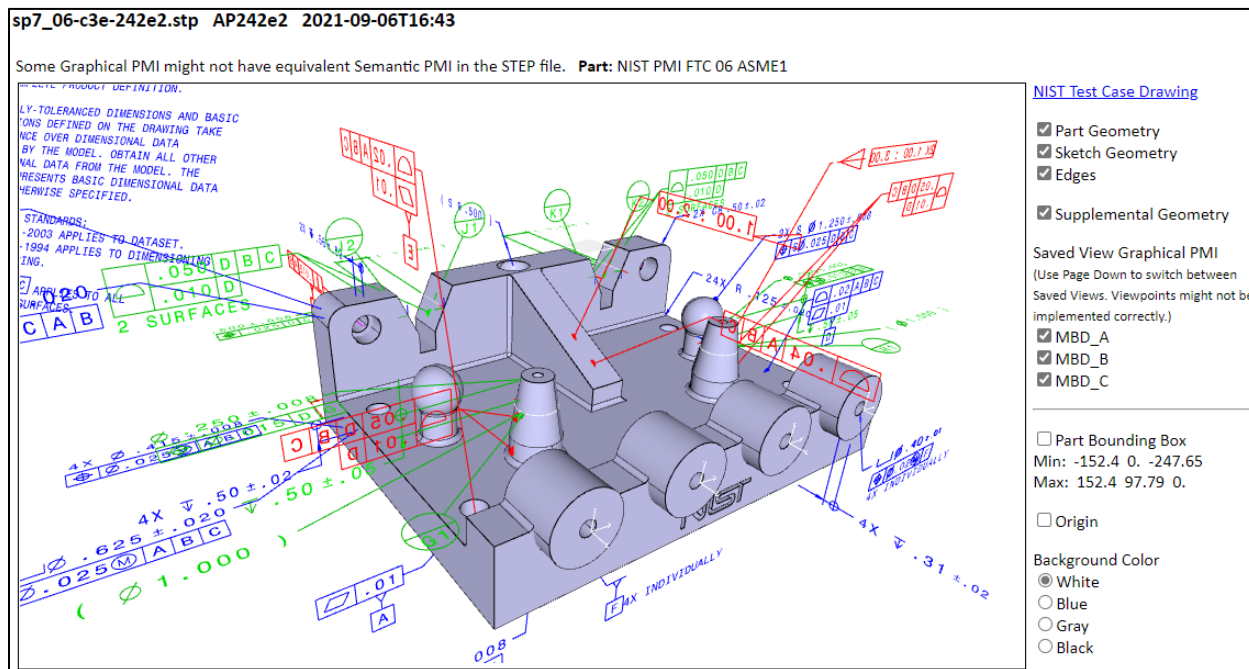
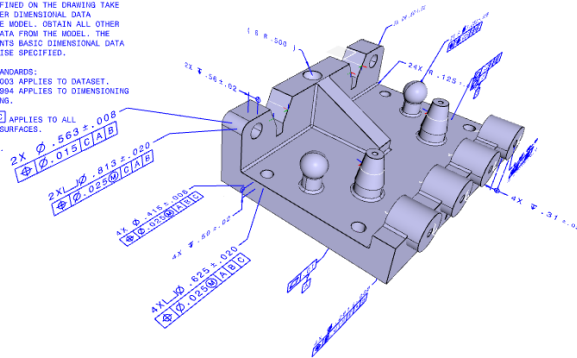


Figure 25: Graphical PMI with multiple saved views

A viewpoint position and orientation can also be associated with a saved view. Saved view viewpoints can be included in the view instead of front, side, and top viewpoints. Using PageDown in the viewer to cycle through the saved views, switches to the associated viewpoint and subset of graphical PMI. Figure 26 shows the saved views for MBD_A, MBD_B, and MBD_C. The saved views correspond to what is shown in the link to the NIST Test Case Drawing. Sometimes some graphical PMI is not in a saved view and will be labeled 'Not In a Saved View' in the list of saved views.

Saved view viewpoints might not be implemented correctly in older versions of software that exports STEP AP242 files. The option on the Spreadsheet tab in the Other section will display the geometry of the view frustum for a saved view viewpoint.

Some Graphical PMI might not have equivalent Semantic PMI in the STEP file. **Part:** NIST PMI FTC 06 ASME1



NIST Test Case Drawing

- ☒ Part Geometry
- ☒ Sketch Geometry
- ☒ Edges
- ☒ Supplemental Geometry

Saved View Graphical PMI

(Use Page Down to switch between Saved Views. Viewpoints might not be implemented correctly.)

- ☒ MBD_A
☐ MBD_B
☐ MBD_C

- ☐ Part Bounding Box
Min: -152.4 0. -247.65
Max: 152.4 97.79 0.

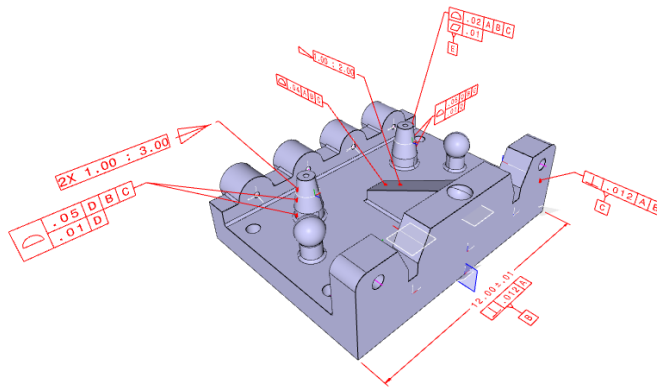
- ☐
- Original

Background Color

- ☒ White
☐ Blue
☐ Gray
☐ Black

sp7_06-c3e-242e2.stp AP242e2 2021-09-06T16:43

Some Graphical PMI might not have equivalent Semantic PMI in the STEP file. **Part:** NIST PMI FTC 06 ASME1



[NIST Test Case Drawing](#)

- ☒ Part Geometry
- ☒ Sketch Geometry
- ☒ Edges
- ☒ Supplemental Geometry

Saved View Graphical PMI

(Use Page Down to switch between Saved Views. Viewpoints might not be implemented correctly.)

- ☐ MBD_A
☒ MBD_B
☐ MBD_C

- ☐ Part Bounding Box
Min: -152.4 0. -247.65
Max: 152.4 97.79 0.

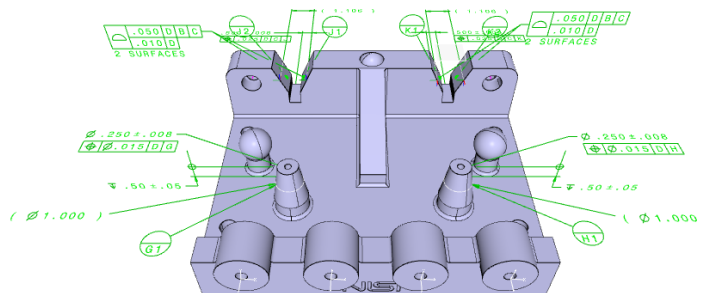
- ☐
- Origin

Background Color

- ☒ White
☐ Blue
☐ Gray
☐ Black

sp7_06-c3e-242e2.stp AP242e2 2021-09-06T16:43

Some Graphical PMI might not have equivalent Semantic PMI in the STEP file. **Part:** NIST PMI FTC 06 ASME1



[NIST Test Case Drawing](#)

- ☒ Part Geometry
- ☒ Sketch Geometry
- ☒ Edges

☒ Supplemental Geometry

Saved View Graphical PMI
(Use Page Down to switch between
Saved Views. Viewpoints might not be
implemented correctly.)

- ☐ MBD_A
☐ MBD_B
☒ MBD_C

- ☐ Part Bounding Box
Min: -152.4 0. -247.65
Max: 152.4 97.79 0.

- ☐
- Origin

Background Color

- ☒ White
☐ Blue
☐ Gray
☐ Black

Figure 26: Graphical PMI with multiple saved view viewpoints

4.2.2 Datum Targets

Datum targets are shown only if a spreadsheet is generated with the analysis for semantic PMI selected and when part geometry or graphical PMI is also viewed. Figure 27 shows an example of a part with a rectangular datum target highlighted in red. The graphical PMI also has a datum target symbol, C1 in the circle, pointing to the datum target.

There are two methods to represent and view the position, orientation, and dimensions of a datum target in a STEP file. For the first method, the position, orientation, and target length, width, and diameter are specified parametrically. Point, line, circle, circular curve, and rectangle datum targets are supported. A small coordinate axes is shown at the origin of a datum target except for point datum targets in addition to the datum target label.

For the second method, the shape and location of arbitrarily shaped area and curve datum targets is specified with geometric entities. Supported geometric entities, that lie in plane, are line, circle, trimmed curves, and faces bounded by lines, circles, or ellipses. If other geometric entities are used, then either the datum target will not be shown or some of the edges of the datum targets will be missing. Datum targets defined by multiple types of curves and non-planar datum targets are not supported.

Both types of datum targets are shown in red and can be switched on and off in the view. Datum target feature geometry, also specified with geometric entities similar to the second method, is shown in green.

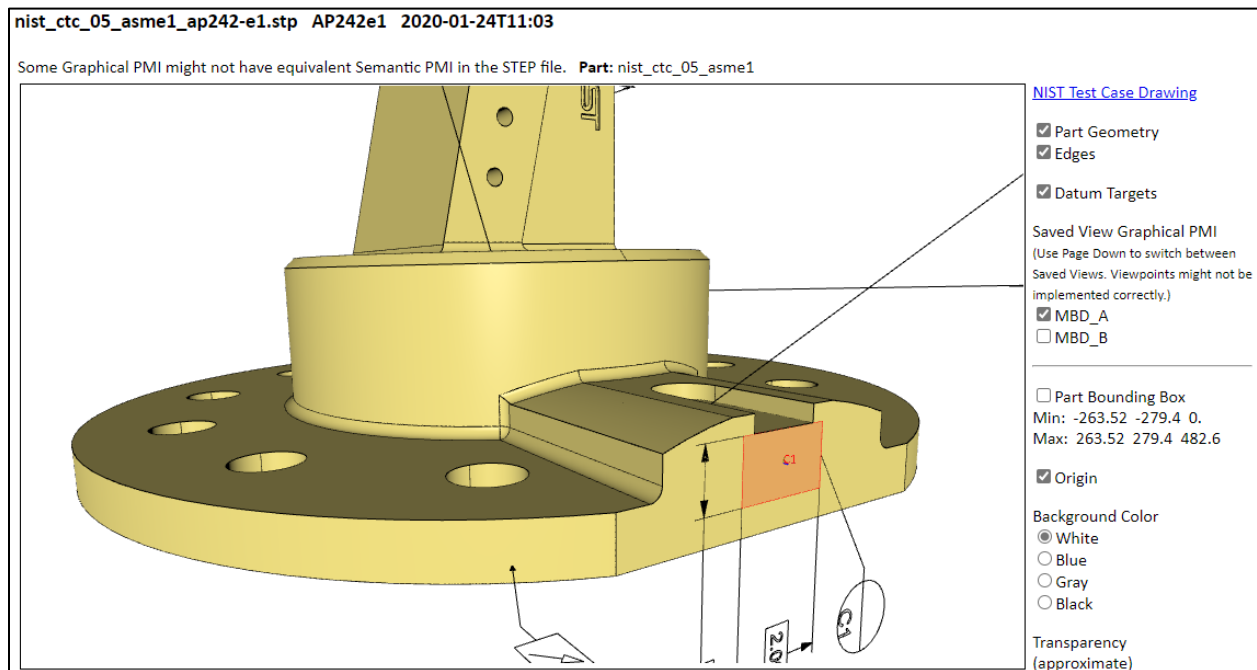


Figure 27: Graphical PMI with a datum target

4.2.3 Holes

Hole features, including basic round, counterbore, and countersink holes, and spotface are supported in AP242 edition 2 but have not been widely implemented. If the semantic PMI analysis report is not generated, then holes are shown only with a drill entry point.

If the report is generated, then cylindrical or conical surfaces are used to view the depth and diameter of the hole, counterbore, and countersink. If there is no depth associated with the hole (a through hole), then a very thin cylindrical surface with the correct diameter is shown. The bottom of a hole is also shown if the hole is not a through hole and the hole has a depth. Usually, only the counterbore or countersink is shown for through holes. Semantic information related to holes is reported on *_hole_definition and basic_round_hole worksheets.

Holes can be switched on and off in the viewer. Cylindrical surfaces are green and conical surfaces are blue. Holes are viewed regardless of whether or not they were explicitly modeled in the part geometry.

4.3 AP242 Tessellated Part Geometry

Tessellated part geometry can be viewed by selecting the option in the View section of the Options tab. STEP AP242 supports tessellated part geometry, but not AP203 and AP214. It is typically written to a STEP file instead of or in addition to b-rep part geometry (Sec. 4.1). Figure 28 shows tessellated part geometry where each tessellated facet is outlined. Individual parts can be switched on and off. Parts in an assembly might be in the wrong position and orientation or be missing.

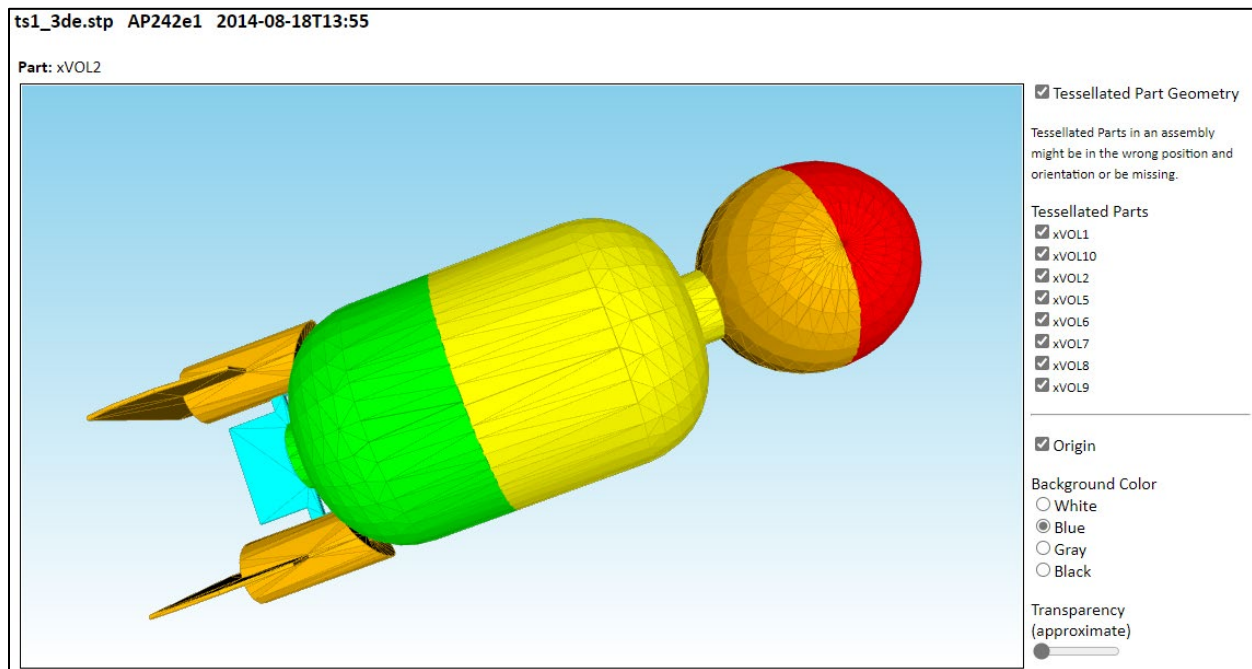


Figure 28: AP242 tessellated part geometry

4.4 AP209 Finite Element Model

The finite element model in a STEP AP209 file can be viewed by selecting the option in the View section of the Options tab. Nodes, 1D elements, 2D elements, and 3D elements are shown along with the finite element mesh. Viewing boundary conditions, loads, and displacements is also supported. Multiple coordinate systems and viewing of stresses and strains is not supported. There might be insufficient memory for SFA to process very large finite element models.

4.4.1 Finite Element Mesh

Figure 29 shows the view of the finite element model (FEM) of an ultra-lightweight glider [9]. 2D elements are cyan, 1D elements are magenta, nodes are blue, and the mesh is black. To the right of the view are checkboxes for Nodes, Mesh, and 1D and 2D Elements. The number of nodes and different element types are also listed.

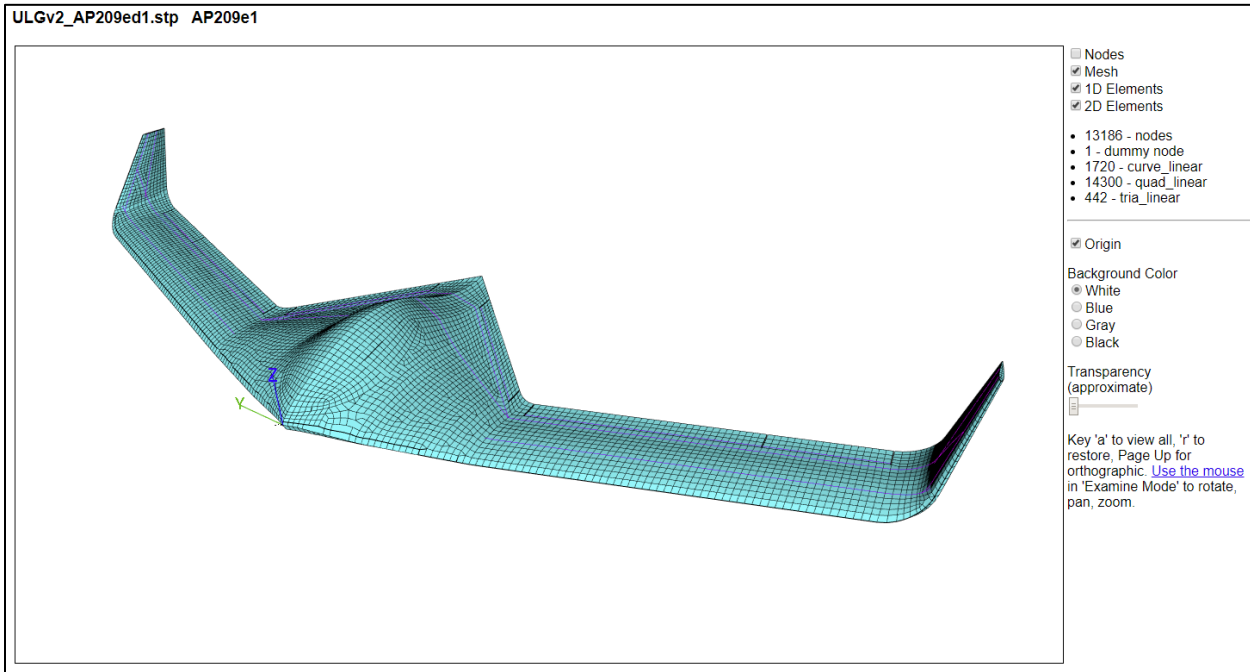


Figure 29: AP209 FEM of ultra-lightweight glider

Figure 30 shows the same FEM without the mesh where the magenta-colored 1D elements are visible because the 2D elements are partially transparent.

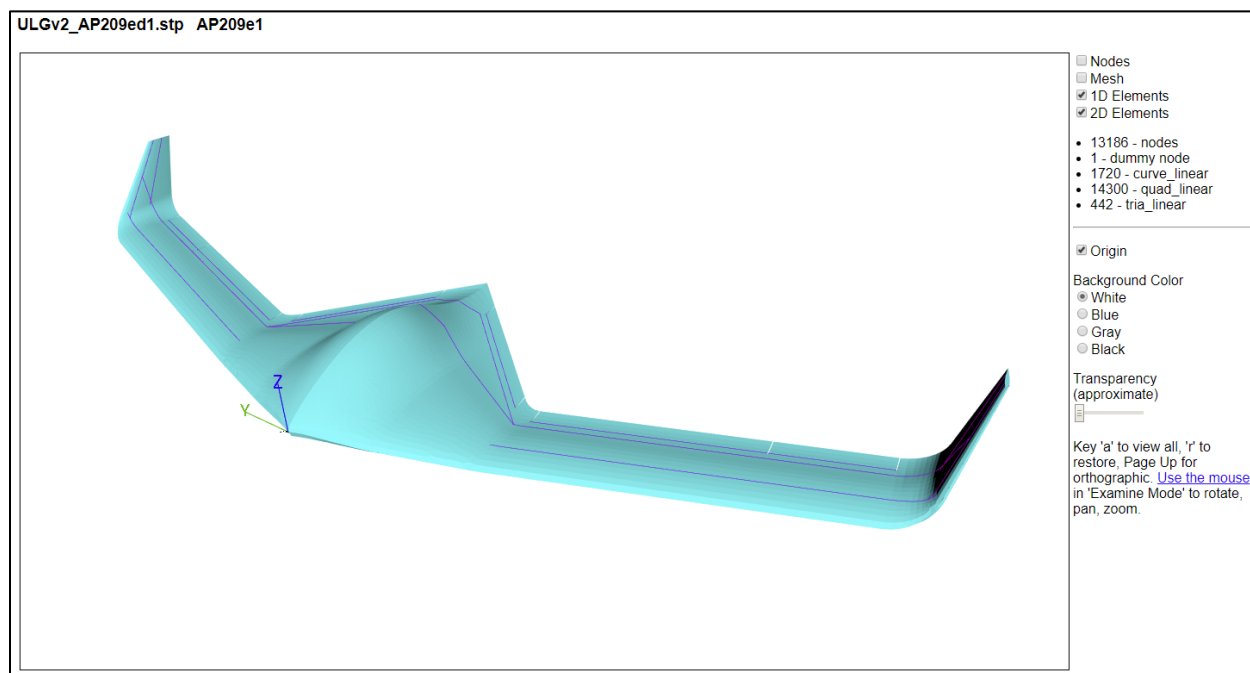


Figure 30: AP209 FEM, no mesh

Figure 31 shows only the nodes of the same FEM.

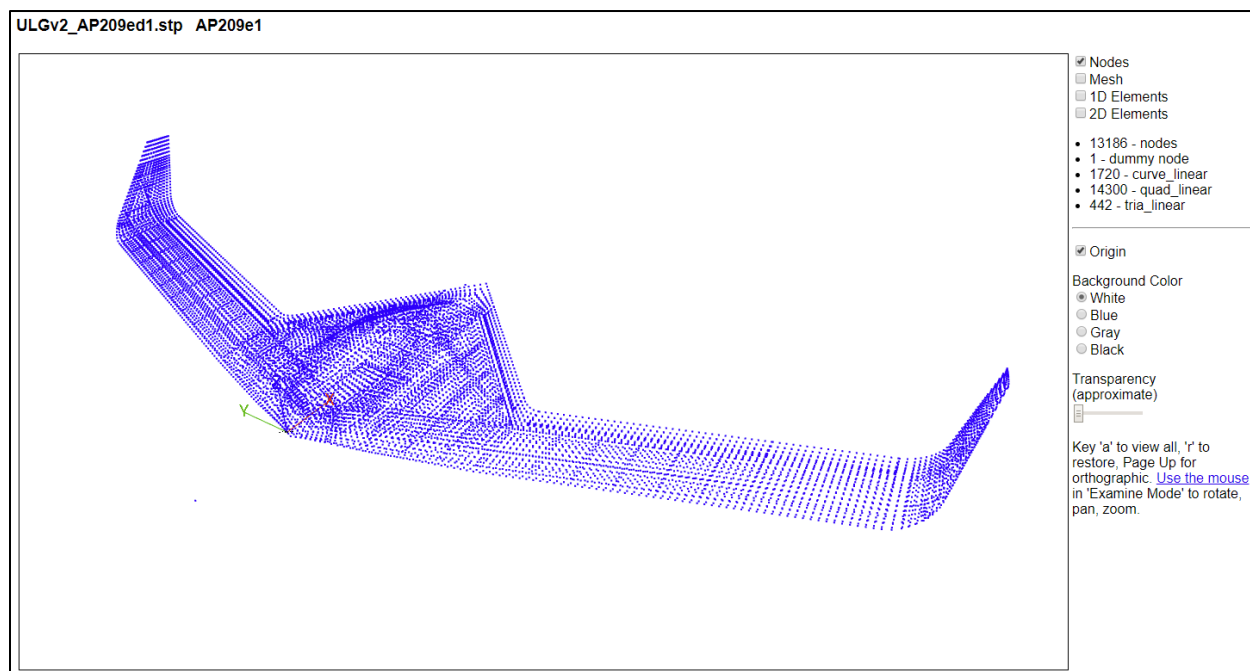


Figure 31: AP209 FEM, nodes only

4.4.2 Boundary Conditions, Loads, and Displacements

Figure 32 shows the AP209 FEM that is used to show boundary conditions, loads, and displacements. Options to control how they are viewed are on the Options tab.

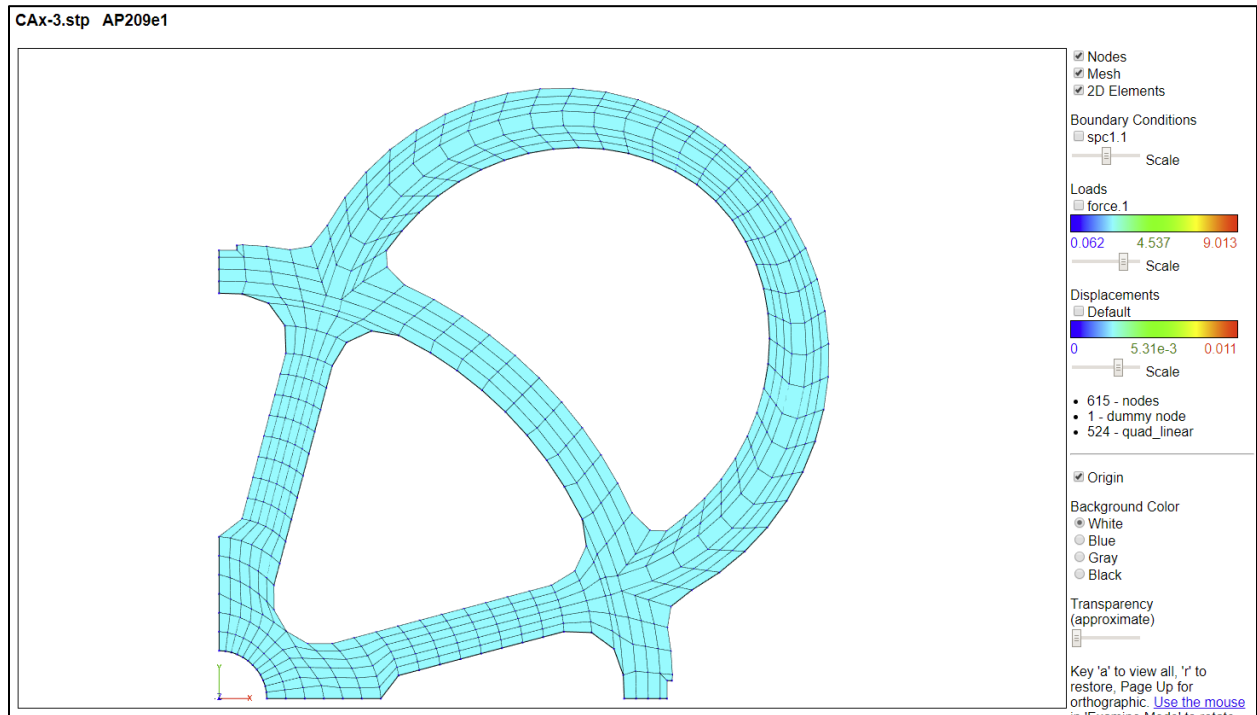


Figure 32: AP209 FEM

Table 1 shows the icons used for constrained degrees-of-freedom (DOF). Different types of icons can be combined for the appropriate DOF.

Table 1: Icons for constrained DOF

Degree-of-freedom	Icon
All six DOF	Gray box
All three translation DOF	Gray pyramid
All three rotation DOF	Gray sphere
Single translation DOF	Red (x), green (y), or blue (z) line along the constrained translation DOF axis
Single rotation DOF	Red (x), green (y), or blue (z) circle around the constrained rotation DOF axis

Figure 33 shows some of the nodal boundary conditions for the FEM in Figure 32. All rotation (gray spheres) and Z translation (blue vertical lines) DOF are constrained for all nodes. Nodes along the X and Y axis are constrained in Y (green lines) and X (red lines) DOF, respectively.

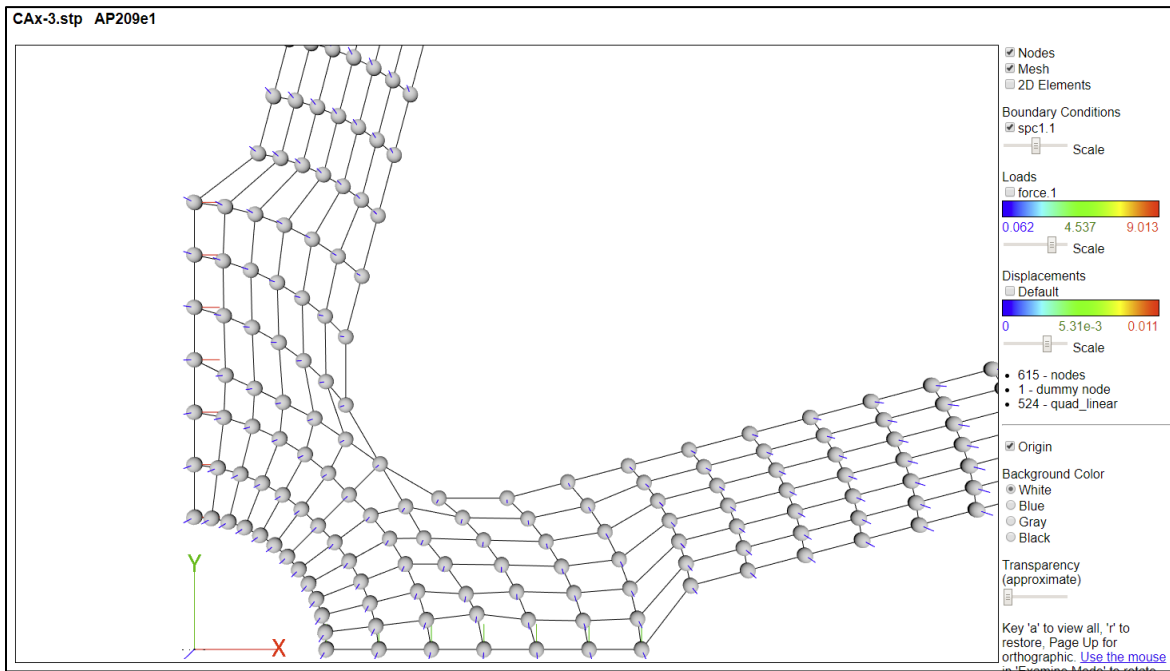


Figure 33: AP209 nodal boundary conditions

Figure 34 shows nodal load vectors that are colored and scaled by the magnitude of the load. The vectors can also be shown with constant length. In this example there is only one load case. The color scale shows the value of the loads.

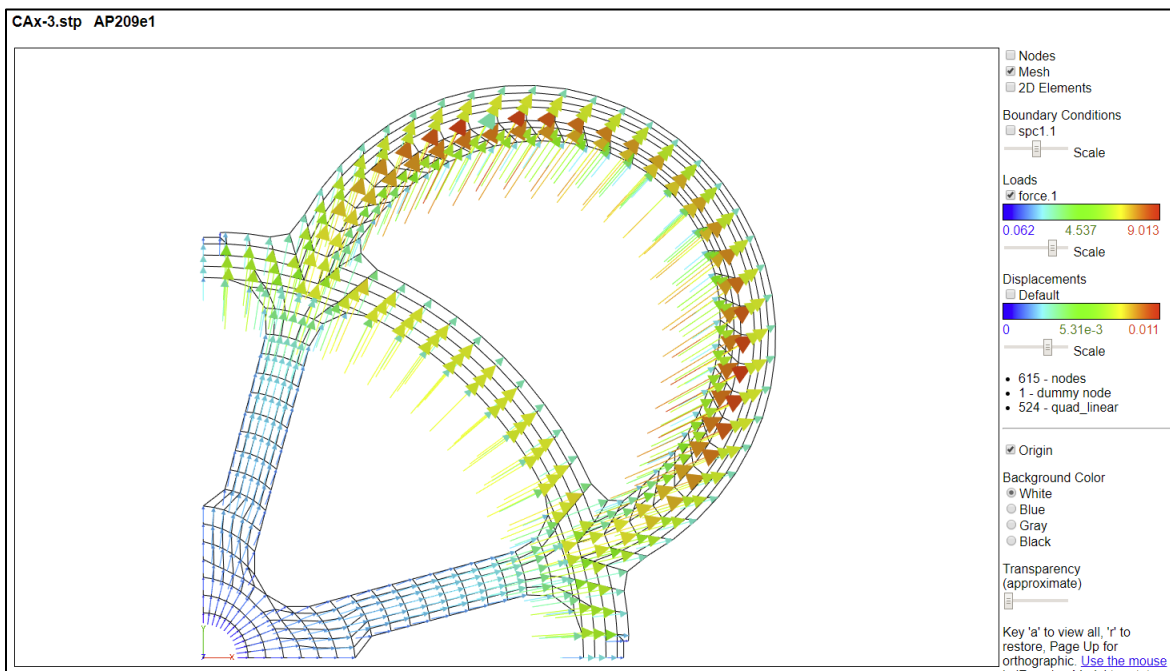


Figure 34: AP209 nodal load vectors

Figure 35 shows nodal displacement vectors that are colored and scaled by the magnitude of the displacement. The color scale shows the value of the displacements. The finite element mesh is not displaced.

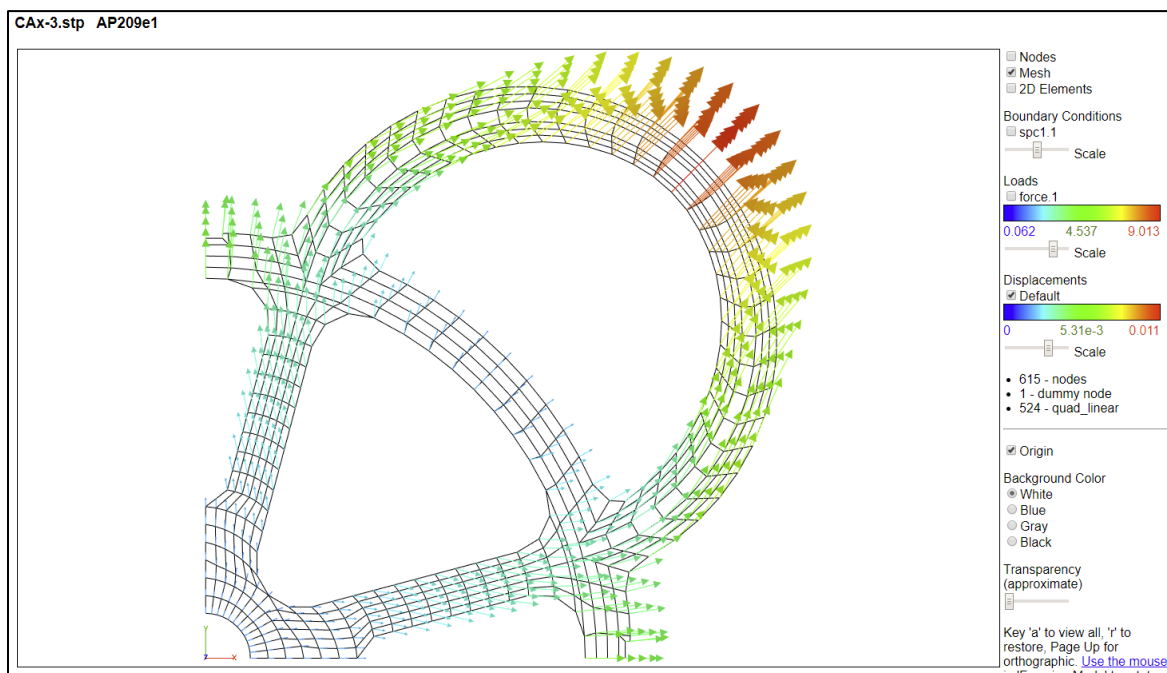


Figure 35: AP209 displacement vectors

Figure 36 shows the displacements for one of ten mode shapes of a connecting rod.

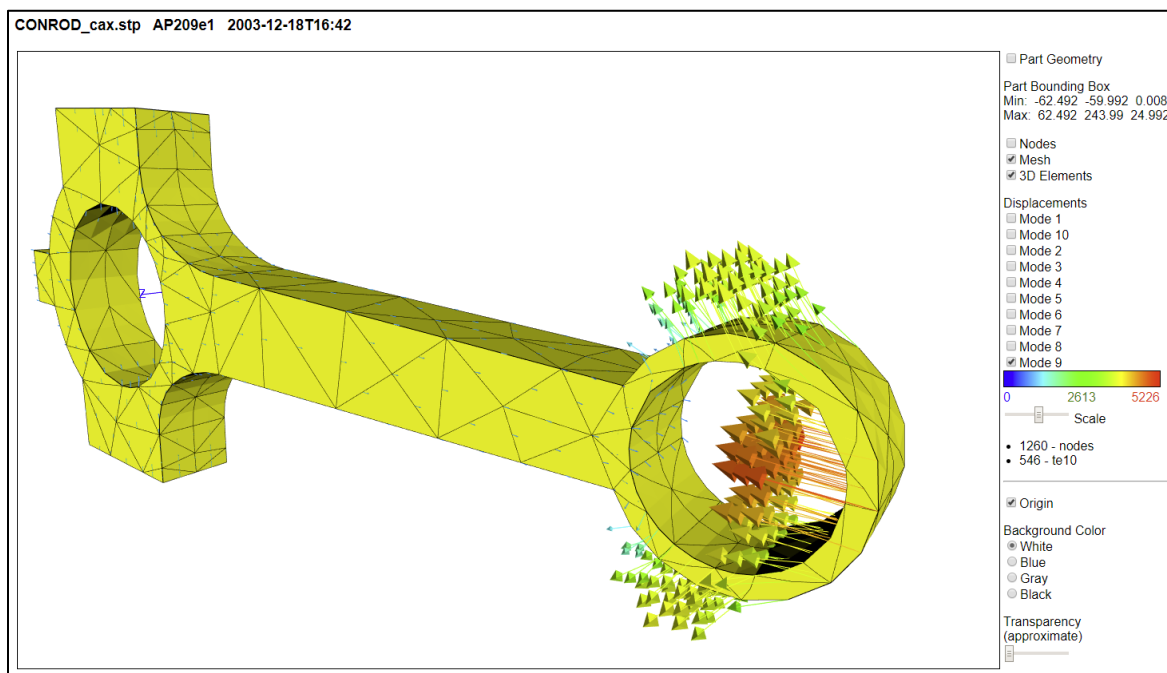


Figure 36: AP209 mode shape displacements

4.5 Augmented Reality

The viewer can save an X3D file [33] with the option on the Spreadsheet tab. Figure 37 shows an augmented reality application⁵ to visualize model-based product definitions that uses the saved X3D file [31].

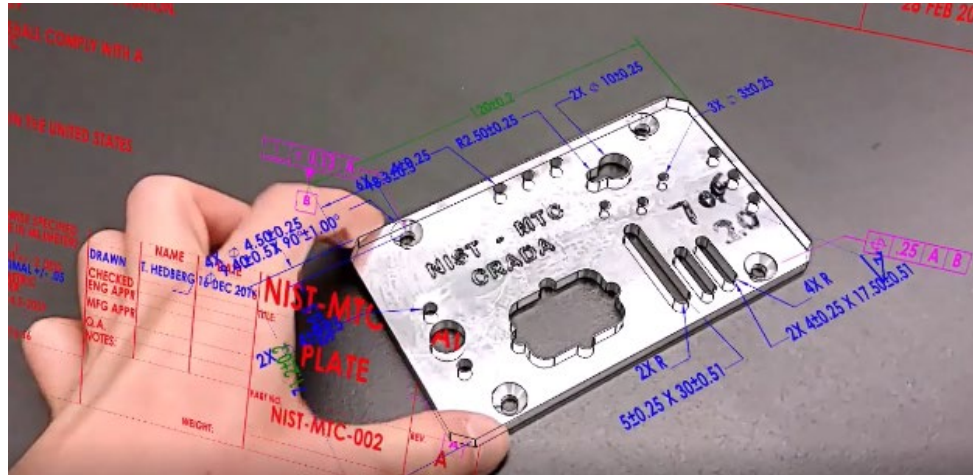


Figure 37: Augmented reality application of SFA output

⁵ <https://pages.nist.gov/CAD-PMI-Testing/NIST-AR-video.html>

5 Spreadsheets

Typical STEP file viewers show a 3D view of the part or model represented by the STEP file. The viewers usually have a high-level hierarchical display of the assembly structure in the STEP file where you can drill down to individual attributes of parts. However, there is no way to view all of the actual STEP entities and their attributes at once.

SFA provides this capability by creating a spreadsheet from the STEP file. The spreadsheet generated by SFA contains several worksheets. There are Summary and Header worksheets, along with a worksheet for each entity type that was processed from the STEP file. Links to sample worksheets are in the Examples menu.

5.1 Summary Worksheet

A Summary worksheet is shown in Figure 38. Rows 1-7 contain basic information about the STEP file including a link to documentation for the schema used in the file. Starting with row 10, each row in column A is the name of an entity processed from the STEP file. The entity names are linked to their corresponding worksheet. Column B is the number of each entity type.

	A	B	C	D
1	STEP Directory	C:\Users\lipman\Documents\A		
2	STEP File	Vertical-Plate.stp		
3	Excel File	Vertical-Plate-sfa.xlsx		
4	Application	Autodesk Inventor 2011		
5	Timestamp	2011-10-07T13:05:48		
6	Total Entities	1848		
7	Schema	AP214		
8				
9	Entity	Count		
10	draughting_pre_defined_colour	1		
11	fill_area_style	1		
12	fill_area_style_colour	1		
13	presentation_style_assignment	1		
14	styled_item	1		
15	surface_side_style	1		
16	surface_style_fill_area	1		
17	surface_style_usage	1		
18	advanced_brep_shape_representation	1		
	(geometric representation context)			
	(global uncertainty assigned context)	2		
19	(global unit assigned context)			
20	mechanical_design_geometric_presentation_representation	1		
21	shape_definition_representation	1		
22	shape_representation	1		
23	shape_representation_relationship	1		
24	application_context	1		
25	application_protocol_definition	1		
26	product	1		
27	product_context	1		
28	product_definition	1		
29	product_definition_context	1		
30	product_definition_formation	1		
31	product_definition_shape	1		
32	product_related_product_category	1		
33	advanced_face	58		
34	axis2_placement_3d	99		
	Summary	Header	draughting_pre_defined_colour	fill_area_style
			fill_a	

Figure 38: Summary worksheet

At the bottom of the spreadsheet are tabs for the Summary, Header, and many entity worksheets. Entities in column A and in the worksheet, tabs are grouped, ordered, and colored according to the categories of entities in the Process section of the Options tab. Selecting a tab, using the links in column A, or using the Control-PageUp and Control-PageDown keys will switch to a different worksheet.

5.2 Header Worksheet

A Header worksheet is shown in Figure 39. Rows 3-11 contain the information in a STEP file header section. Rows 1 and 2 are the STEP file name and directory.

	A	B
1	Name	Vertical Plate
2	FileDirectory	C:\Users\lipman\Documents\CAX-IF\STEP Files\
3	FileDescription	
4	FileImplementationLevel	2;1
5	FileTimeStamp	2011-10-07T13:05:48
6	FileAuthor	lipman
7	FileOrganization	
8	FilePreprocessorVersion	Autodesk Inventor 2011
9	FileOriginatingSystem	Autodesk Inventor 2011
10	FileAuthorisation	
11	SchemaName	AUTOMOTIVE_DESIGN { 1 0 10303 214 1 1 1 1 }
<div> Summary Header draughting_pre_defined_colour fill_a </div>		

Figure 39: Header worksheet

5.3 Entity Worksheets

An entity worksheet is generated for each entity type shown on the Summary worksheet above. The following example relates entities in a STEP file to the resulting worksheet generated by SFA. Six datum_system entities from a STEP file are shown in Figure 40. The entity ID is the number before the equal sign. Values between the outermost parentheses are attribute values that are separated by commas. There are several different types of attributes including strings delimited by quote marks, references to other entity IDs (numbers preceded by #), boolean values (.T.), and null values (\$).

```
#37106=DATUM_SYSTEM('Perpendicularity.1',$,#56,.T.,(#37101));
#42046=DATUM_SYSTEM('Position.1',$,#56,.T.,(#42036,#42041));
#51481=DATUM_SYSTEM('Position.3',$,#56,.T.,(#51466,#51471,#51476));
#53696=DATUM_SYSTEM('Position.4',$,#56,.T.,(#53681,#53686,#53691));
#70801=DATUM_SYSTEM('Position Surfacic Profile.2',$,#56,.T.,(#70786,#70791,#70796));
#84091=DATUM_SYSTEM('Perpendicularity.2',$,#56,.T.,(#84086));
```

Figure 40: datum_system entities

The resulting datum_system entity worksheet is shown in Figure 41. Row 1 contains the name of the entity and the number of entities. It is also a link back to the Summary worksheet. Row 3 is the names of the entity attributes. Column A is the entity ID.

Starting with row 4, each row contains the attribute values for an entity. Column B is the text string for the name attribute. Column C is the description attribute which is blank as indicated by the dollar sign above. Column D is the of_shape attribute where, in this example, all of the values for the entities are product_definition_shape 56. This means that the of_shape attribute is a reference to the product_definition_shape entity with an ID of 56 as shown above. In column F, the constituents attribute refers to either single or multiple datum_reference_compartment entities. The number in parentheses is the number of entity references and the numbers after the entity name are the entity IDs that are referenced.

	A	B	C	D	E	F
1	datum_system (6)					
2						
3	ID	name	description	of_shape	product_definitional	constituents
4	37106	Perpendicularity.1		product_definition_shape 56	TRUE	(1) datum_reference_compartment 37101
5	42046	Position.1		product_definition_shape 56	TRUE	(2) datum_reference_compartment 42036 42041
6	51481	Position.3		product_definition_shape 56	TRUE	(3) datum_reference_compartment 51466 51471 51476
7	53696	Position.4		product_definition_shape 56	TRUE	(3) datum_reference_compartment 53681 53686 53691
8	70801	Position Surfacic Profile.2		product_definition_shape 56	TRUE	(3) datum_reference_compartment 70786 70791 70796
9	84091	Perpendicularity.2		product_definition_shape 56	TRUE	(1) datum_reference_compartment 84086

Figure 41: Entity worksheet (datum_system)

In the draughting_model entity worksheet, shown in Figure 42, cells C4 and C6 refer to multiple entity types. Cell C5 refers to multiple styled_item entities, however, the entity IDs are not shown because there are too many entity IDs to fit in one worksheet cell.

	A	B	C
1	draughting_model (3)		
2			
3	ID	name	items
4	31471		(2) annotation_plane 29651 31466 (1) axis2_placement_3d 36
5	31941		(93) styled_item
6	32031	detail view	(1) axis2_placement_3d 36 (1) camera_model_d3_multi_clipping 32026

Figure 42: Entity worksheet (draughting_model)

5.4 Skipped Attributes

Sometimes SFA skips some specific types of entity attributes due to limitations of the IFCsvr toolkit. A message about skipping an entity attribute will be shown in the Status tab and question marks are shown in the worksheet. Figure 43 shows question marks (???) in column E where the control_points_list attributes were skipped.

	A	B	C	D	E
1	b_spline surface with knots (730)				
2					
3	ID	name	u_degree	v_degree	control_points_list
4	51332		5	5	???
5	51464		3	1	???

Figure 43: Entity worksheet (b_spline_surface_with_knots)

5.5 Options

There are several options that affect how information is shown in a spreadsheet.

5.5.1 Maximum Rows

The maximum rows option in the Spreadsheet tab limits the maximum numbers of rows in any spreadsheet or CSV file to the selected value. This reduces the size of the spreadsheet and speed processing of the STEP file. Figure 44 shows that only the first 100 of 43681 rows for the cartesian_point entities are written to the worksheet. Syntax errors (Sec.6.5) related to reports might be missed if some entities are not processed due smaller values for maximum rows.

	A	B	C		
1	cartesian_point (100 of 43681)				
2					
3	ID	name	coordinates		
4	18 #18	-0.9881	1.634176638	18.017717023	
5	20 #20	-0.9881	1.547763978	17.548888756	
6	22 #22	-0.892674976425	1.568442637	17.469469568	
7	24 #24	-0.247174976425	1.828113272	17.582158424	
8	26 #26	-0.1846	1.864882875	17.656001817	
9	28 #28	-0.1846	1.961858223	18.18213751	
10	30 #30	0.3089	2.140780414	18.161940186	

Figure 44: Maximum rows example

5.5.2 Text Strings and Numbers

Text strings in STEP files might use non-English characters or symbols. Some examples are accented characters in European languages (for example é), and Asian languages that use different characters sets such as Cyrillic or Chinese. Text strings with non-English characters or symbols are usually found on descriptive measure or product related STEP entities with name, description, or id attributes.

According to ISO 10303 Part 21 section 6.4.3 [5], Unicode can be used for non-English characters and symbols with the control directives \X\ and \X2\. For example, \X\E9 or \X2\00E9\X0\ is used for the accented character é. Unicode characters, such as E9, are defined by the Unicode standard⁶. Some CAD software does not support these control directives when exporting or importing a STEP file.

For a spreadsheet, the \X\ and \S\ control directives are supported by default. Use the option on the Spreadsheets tab to support non-English characters using the \X2\ control directive. In some cases, the option will be automatically selected based on the file schema or size. There is a warning message if \X2\ is detected in the STEP file and the option is not selected. In this case the \X2\ characters are ignored and will be missing in the spreadsheet. Figure 45 shows an example of how Unicode text strings appear in the spreadsheet.

	A	B	C
1	string with language (140)		
2			
3	ID	contents	language_specification
46	583	CoroPlex™ MT мултифункционален инструмент за фрезоване и струговане	language 606
47	584	Multifunkční nástroj CoroPlex™ MT pro frézování a soustružení	language 607
48	585	CoroPlex™ MT multifunktionsværktøj til fræsning og drejning	language 608
49	586	CoroPlex™ MT Multifunktionales Dreh- und Fräswerkzeug	language 609
50	587	CoroPlex™ MT multifunctional tool for milling and turning	language 610
51	588	CoroPlex™ MT -monitoimityökalu jysintään ja sorvaukseen	language 611
52	589	Outil multifonctions CoroPlex™ MT pour le fraisage et le tournage	language 612
53	590	CoroPlex™ MT többfunkciós maró- és esztergaszerszám	language 613
54	591	Utensile multifunzionale CoroPlex™ MT per tornitura e fresatura	language 614
55	592	コロプレックスMT フライス加工・旋削加工用多機能工具	language 615
56	593	밀링 및 선삭 가공용 CoroPlex™ MT 다기능 공구	language 616
57	594	CoroPlex™ MT multifunctioneel gereedschap voor frezen en draaien	language 617
58	595	CoroPlex™ MT, wielofunkcyjne narzędzie frezarskie i tokarskie	language 618
59	596	Ferramenta multifuncional CoroPlex™ MT para torneamento e fresamento	language 619
60	597	Sculă multifuncțională CoroPlex™ MT pentru frezare și strunjire	language 620
61	598	Многофункциональный инструмент для фрезерования и точения CoroPlex™ MT	language 621
62	599	CoroPlex™ MT, herramienta multifuncional para fresado y torneado	language 622
63	600	CoroPlex™ MT flerfunktionsverktyg för fräsning och svarvning	language 623
64	601	เครื่องมือกลึงฟังก์ชัน CoroPlex™ MT สำหรับการกัดและการกลึง	language 624
65	602	CoroPlex™ MT çok fonksiyonlu frezeleme ve tornalama takımı	language 625
66	603	Багатофункціональний інструмент для фрезерування та точіння CoroPlex™ MT	language 626
67	604	CoroPlex™ MT多功能铣削和车削刀具	language 627

Figure 45: Entity worksheet with Unicode characters

For the viewer, all control directives are supported for part and assembly names.

Non-English characters that do not use the Unicode control directives are supported depending the STEP file encoding, e.g., UTF-8 or ANSI. Use the Notepad++ text editor to convert the file to UTF-8 encoding. Some non-English characters might cause the software to crash or prevent a view from being generated. The Syntax Checker (Sec. 7) identifies non-English characters as 'illegal characters'.

Numbers in a STEP file use a period '.' as the decimal separator. Some non-English language versions of Excel use a comma ',' as a decimal separator. This might cause some real numbers to be formatted as a date in a spreadsheet. For example, the number 1.5 might appear as 1-Mai.

⁶ <https://www.unicode.org/charts>

To change the formatting in Excel, go to the Excel File menu > Options > Advanced. Uncheck 'Use system separators' and change 'Decimal separator' to a period . and 'Thousands separator' to a comma ,. Note that this change applies to all Excel spreadsheets on your computer. Change the separators back to their original values when finished. You can always check the STEP file to see the actual value of the number.

5.5.3 Tables

Figure 46 shows the shape_aspect worksheet with the option for generating tables selected. With this option, pull-down menus (selector on the right of each cell in row 3) are shown with the column headers in row 3 that access functions to sort and filter the rows. The table is sorted by the name attribute in column B. This is evident by the non-numerical ordering of the entity IDs in column A. The worksheet containing validation properties (Sec. 6.3) is always sorted.

	A	B	C	D	E
1	shape_aspect (69)				
2					
3	ID	name	descriptio	of_shape	product_definition
4	73686	Angularity.1		product_definition_shape 56	TRUE
5	73091	Flatness.1		product_definition_shape 56	TRUE
6	35771	Linear Size.1		product_definition_shape 56	TRUE
7	35786	Linear Size.1		product_definition_shape 56	TRUE
8	66951	Linear Size.10		product_definition_shape 56	TRUE
9	66966	Linear Size.10		product_definition_shape 56	TRUE
10	69381	Linear Size.11		product_definition_shape 56	TRUE
11	69396	Linear Size.11		product_definition_shape 56	TRUE
12	40141	Linear Size.2		product_definition_shape 56	TRUE

Figure 46: Entity worksheet (shape_aspect) with tables for sorting

5.5.4 Number Format

By default, when a single real number is written to a worksheet cell, Excel might round the number. Figure 47, on the left, shows values of radius in column D that are rounded. Using the Number Format option in the Spreadsheet tab to not round real numbers, results in the radius column is shown with full precision in the worksheet on the right. The non-rounded real numbers are the actual values that appear in a STEP file. The non-rounded real numbers are indicated by the small green triangle in the upper left corner of a cell. The non-rounded real numbers are also left justified as opposed to the rounded real numbers that are right justified. Real numbers that appear in pairs or triplets, such as cartesian points, are never rounded.

	A	B	C	D
1	circle (146)			
2				
3	ID	name	position	radius
4	86	axis2_placement_3d 85		3
5	103	axis2_placement_3d 102		3
6	128	axis2_placement_3d 127		3
7	145	axis2_placement_3d 144		3
8	170	axis2_placement_3d 169		3
9	187	axis2_placement_3d 186		3
10	212	axis2_placement_3d 211		3
11	229	axis2_placement_3d 228		3
12	358	axis2_placement_3d 357		3.375
13	388	axis2_placement_3d 387		3.375

	A	B	C	D
1	circle (146)			
2				
3	ID	name	position	radius
4	86	axis2_placement_3d 85		2.9999999999999695
5	103	axis2_placement_3d 102		2.9999999999999695
6	128	axis2_placement_3d 127		2.9999999999999792
7	145	axis2_placement_3d 144		2.9999999999999792
8	170	axis2_placement_3d 169		2.9999999999999695
9	187	axis2_placement_3d 186		2.9999999999999695
10	212	axis2_placement_3d 211		2.9999999999999803
11	229	axis2_placement_3d 228		2.9999999999999803
12	358	axis2_placement_3d 357		3.375
13	388	axis2_placement_3d 387		3.375

Figure 47: Rounding numbers example

5.6 Anchor Section

ISO 10303 Part 21 Edition 3 [27] is a new version of Part 21 that supports anchor, reference, and signature sections in a STEP file. The anchor section can be used to assign a globally unique ID (GUID) to a specific entity. Figure 48 shows the ANCHOR section in a STEP file which appears after the HEADER section and before the DATA section.

```
ANCHOR;
<6db46031-4fab-4838-824b-91cea43922e4>=#10; /* product_definition */
<3c9773de-5015-4c05-86b4-0e35a5bfd96f>=#17076; /* dimensional_size */
<305dc4d8-d6cd-4e44-89c7-9ad5476774cb>=#17090; /* cylindricity_tolerance */
<09c07753-38cf-4928-928f-4acd0e636247>=#17095; /* datum */
<f1ab2591-7e18-4898-90c4-a60ff7916774>=#17099; /* datum */
<9416b6d8-e4ef-4f0e-8b50-44d24aa5d06e>=#17103; /* perpendicularity_tolerance */
<2871d0c8-9f87-4349-aab0-7832e53fa25a>=#17105; /* datum */
ENDSEC;
```

Figure 48: ANCHOR section in a STEP file

Figure 49 shows the ANCHOR section worksheet corresponding to the STEP file above.

	A	B
1	ANCHOR	Entity
2	<6db46031-4fab-4838-824b-91cea43922e4>=#10; /* product_definition */	product_definition
3	<3c9773de-5015-4c05-86b4-0e35a5bfd96f>=#17076; /* dimensional_size */	dimensional_size
4	<305dc4d8-d6cd-4e44-89c7-9ad5476774cb>=#17090; /* cylindricity_tolerance */	cylindricity_tolerance
5	<09c07753-38cf-4928-928f-4acd0e636247>=#17095; /* datum */	datum
6	<f1ab2591-7e18-4898-90c4-a60ff7916774>=#17099; /* datum */	datum
7	<9416b6d8-e4ef-4f0e-8b50-44d24aa5d06e>=#17103; /* perpendicularity_tolerance */	perpendicularity_tolerance
8	<2871d0c8-9f87-4349-aab0-7832e53fa25a>=#17105; /* datum */	datum
<div> <div>Summary</div> <div>Header</div> <div>ANCHOR</div> <div>application_context</div> <div>id_attribute</div> <div>product</div> <div>product_context</div> </div>		

Figure 49: ANCHOR section worksheet

Figure 50 shows the ANCHOR IDs associated with the three datum entities. ANCHOR IDs are also reported on the PMI Representation Summary worksheet (Sec. 6.1.6). GUIDs can also be assigned to entities with the id_attribute entity.

	A	B	C	D	E	F	G
1	datum (3)						
2							
3	ID	name	description	of_shape	product_definitional	identification	ANCHOR ID
4	17095	Simple Datum.1		product_definition_shape 11	FALSE	A	09c07753-38cf-4928-928f-4acd0e636247
5	17099	Simple Datum.2		product_definition_shape 11	FALSE	B	f1ab2591-7e18-4898-90c4-a60ff7916774
6	17105	Simple Datum.3		product_definition_shape 11	FALSE	C	2871d0c8-9f87-4349-aab0-7832e53fa25a

Figure 50: ANCHOR ID reported on datum worksheet

6 Analysis Reports

The analysis reports check the STEP file against recommended practices are defined by the CAX Interoperability Forum (CAX-IF) [26, 28]. The objective of the CAX-IF is to advance CAX (mainly Computer-Aided Design, Engineering, and Manufacturing) software system translator development and to ensure that user requirements for interoperability are satisfied. Three different reports can be created.

1. PMI Representation (Semantic PMI) described in Sec. 6.1
2. PMI Presentation (Graphical PMI) described in Sec. 6.2
3. Validation Properties described in Sec. 6.3

Product and manufacturing information (PMI) are annotations and attributes that define product geometry and product specifications [34]. PMI includes 3D annotations to specify Geometric Dimensioning and Tolerancing (GD&T), as well as non-geometric data such as surface texture specifications, finish requirements, process notes, material specifications, and welding symbols. GD&T is a symbolic language used to communicate tolerances on manufactured parts. The industry standards for presentation of GD&T in axonometric views in 3D space are ASME Y14.41-2003 [35] and ISO 16792:2006 [36]. Some common tolerances include dimensional tolerances on length and diameter, and geometric tolerances on flatness, position, surface profile, and circular runout.

Figure 51 shows NIST test case CTC 3⁷ with typical feature control frames (FCF) with PMI annotations including dimensions, geometric and dimensional tolerances, and datum features. Most of these types of annotations are processed by SFA.

⁷ https://s3.amazonaws.com/nist-el/mfg_digitalthread/nist_ctc_03_asme1_rc.pdf

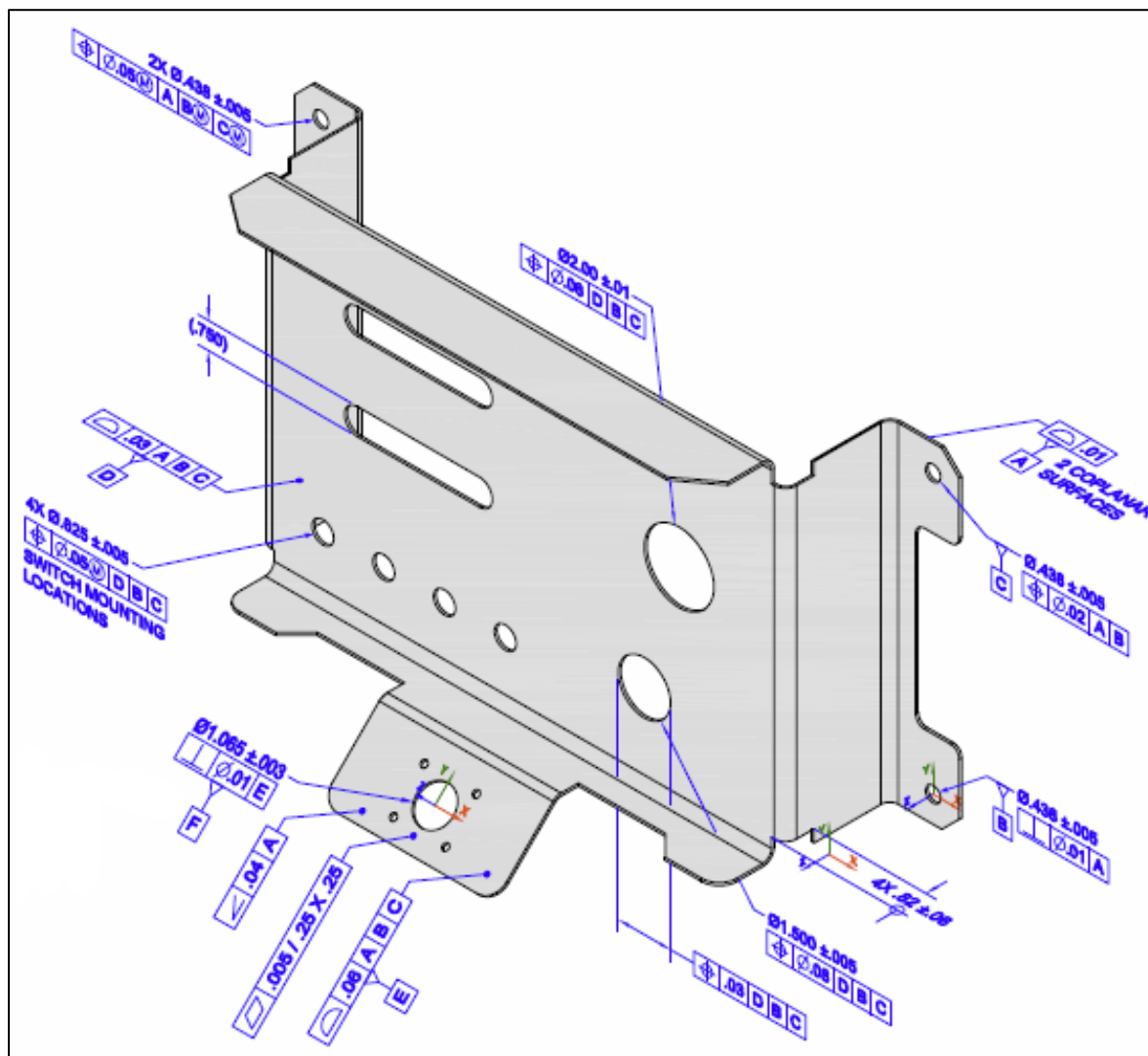


Figure 51: NIST test case CTC 3

Figure 52 shows the summary worksheet, similar to Figure 38, with entities highlighted that have information related to PMI Representation and PMI Presentation. Rows 11-14 are entities related to the datum reference frame. Row 15 is the `dimensional_characteristic_representation` entity which is associated with all dimensional tolerances. Rows 10 and 19-29 are entities related to geometric tolerances. Row 30 is the `annotation_curve_occurrence` entity which is associated with PMI presentation. The entity name in parentheses in cell A19 is for a complex entity (`flatness_tolerance`)(`geometric_tolerance_with_defined_unit_area`). The cells colored gray indicate that there are errors or warnings associated with at least one entity instance of the entity type. All of the worksheets for the highlighted entities will have additional columns with PMI information related to that type of entity.

	A	B	C	D	E	F
1	STEP Directory	C:\Users\lipman\Documents\Analyzer\User Gui				
2	STEP File	nist_ctc_03_asme1_ap242.stp				
3	Excel File	nist_ctc_03_asme1_ap242-sfa.xlsx				
4	Timestamp	2014-12-19T16:21:44+01:00				
5	Total Entities	17312				
6	Schema	AP242e1				
7	Dimension Units	INCH				
8						
9	Entity	Count				
10	angularity tolerance [PMI Representation]	1				
11	datum	6				
12	datum feature [PMI Representation]	6				
13	datum reference compartment [PMI Representation]	26				
14	datum system [PMI Representation]	6				
15	dimensional characteristic representation [PMI Representation]	10				
16	dimensional location	1				
17	dimensional size	8				
18	directed dimensional location	1				
19	(flatness tolerance)					
	(geometric tolerance with defined area unit) [PMI Representation]	1				
	(geometric tolerance with datum reference)					
	(geometric tolerance with modifiers)	2				
20	(position tolerance) [PMI Representation]					
	(geometric tolerance with datum reference)	4				
21	(position tolerance) [PMI Representation]					
	(geometric tolerance with datum reference)	2				
22	(surface profile tolerance) [PMI Representation]					
23	perpendicularity tolerance [PMI Representation]	2				
24	plus minus tolerance	8				
25	shape dimension representation	10				
26	surface profile tolerance [PMI Representation]	1				
27	tolerance value	8				
28	tolerance zone	7				
29	tolerance zone form	7				
30	annotation curve occurrence [PMI Presentation]	30				
	Summary	Header	PMI Representation Summary	PMI Representation Coverage	angularity_to	

Figure 52: Summary worksheet with entities highlighted for PMI

6.1 PMI Representation (Semantic PMI)

PMI representation (also known as semantic PMI) includes all information necessary to represent GD&T without any graphical presentation elements. PMI representation is associated with CAD model geometry and is computer-interpretable to facilitate automated consumption by downstream applications for manufacturing, measurement, inspection, and others. PMI representation does not contain any information regarding its visual appearance although an importing CAD system can attempt to recreate the visual presentation of the annotation. The CAX-IF defines recommended practices for PMI representation [37]. Syntax errors related to nonconformance to the recommended practices are highlighted in red in the Status tab and in the relevant entity worksheets (Sec. 6.5).

6.1.1 Visual Presentation of PMI Representation

Sections 6.1.2 through 6.1.4 show three examples of how PMI representation is reported. The report includes a visual presentation of the semantic PMI information that can be used for visual verification of that information. The visual presentation is based only on the semantic PMI and not on the graphical PMI. The visual presentation should correspond to the expected PMI annotations similar to those on Figure 51. If the visual presentation does not look right, then the semantic PMI information might be wrong. The visual presentation is limited by the characters and symbols available in the spreadsheet. Section 6.6.1 has examples of problems with the visual presentation of the PMI representation.

6.1.2 Datum Reference Frame

The following figures show how a datum reference frame is modeled in a STEP file. Figure 53 shows the datum worksheet that defines the datum labels in column F.

	A	B	C	D	E	F
1	datum (6)					
2						
3	ID	name	description	of_shape	product_definitional	identification
4	36203	Simple Datum.2	Simple Datum.2	product_definition_shape 56	TRUE	B
5	40518	Simple Datum.3	Simple Datum.3	product_definition_shape 56	TRUE	C
6	70983	Simple Datum.5	Simple Datum.5	product_definition_shape 56	TRUE	E
7	37096	Simple Datum.1	Simple Datum.1	product_definition_shape 56	TRUE	A
8	53676	Simple Datum.4	Simple Datum.4	product_definition_shape 56	TRUE	D
9	84273	Simple Datum.6	Simple Datum.6	product_definition_shape 56	TRUE	F

Figure 53: Entity worksheet (datum)

Figure 54 shows the datum_reference_compartment worksheet with information for the compartments of a datum reference frame. The compartments are constructed from the base attribute that refers to the datum entity above and the modifiers attribute. The visual presentation of the compartments is shown in column H. The parenthetic notation in cell H3 specifies the section number in the CAX-IF recommended practice for PMI representation related to that information [37].

	A	B	C	D	E	F	G	H
1	datum_reference_compartment (26)							
2								PMI Representation
3	ID	name	description	of_shape	product_definitional	base	modifiers	compartment (Sec. 6.9.7, 6.9.8)
4	37101	Perpendicularity.1		product_definition_shape 56	TRUE	datum 37096		A
5	42036	Position.1		product_definition_shape 56	TRUE	datum 37096		A
6	42041	Position.1		product_definition_shape 56	TRUE	datum 36203		B
7	51466	Position.3		product_definition_shape 56	TRUE	datum 37096		A
8	51471	Position.3		product_definition_shape 56	TRUE	datum 36203	maximum_material_requirement	B (M)
9	51476	Position.3		product_definition_shape 56	TRUE	datum 40518	maximum_material_requirement	C (M)
10	53681	Position.4		product_definition_shape 56	TRUE	datum 53676		D

Figure 54: Entity worksheet (datum_reference_compartment)

Figure 55 shows the datum_system worksheet with information to combine the datum reference compartments, defined by the constituents attribute, to create a datum reference frame. The visual presentation of the datum reference frames is shown in column G.

	A	B	C	D	E	F	G
1	datum_system (6)						
2							PMI Representation
3	ID	name	description	of_shape	product_definitional	constituents	Datum Reference Frame (Sec. 6.9.7, 6.9.8)
4	37106	Perpendicularity.1		product_definition_shape 56	TRUE	(1) datum_reference_compartment 37101	A
5	42046	Position.1		product_definition_shape 56	TRUE	(2) datum_reference_compartment 42036 42041	A B
6	51481	Position.3		product_definition_shape 56	TRUE	(3) datum_reference_compartment 51466 51471 51476	A B C D
7	53696	Position.4		product_definition_shape 56	TRUE	(3) datum_reference_compartment 53681 53686 53691	D B C
8	70801	Position Surface Profile.2		product_definition_shape 56	TRUE	(3) datum_reference_compartment 70786 70791 70796	A B C
9	84091	Perpendicularity.2		product_definition_shape 56	TRUE	(1) datum_reference_compartment 84086	E

Figure 55: Datum reference frame example

6.1.3 Dimensional Tolerance

The following example shows how a dimensional tolerance is modeled in a STEP file. Figure 56 and Figure 57 show the dimensional_characteristic_representation worksheet where information related to dimensional tolerances is reported.

- Column B is the type of dimension, either dimensional_size or dimensional_location.
- Column C is a reference to shape_dimension_representation which refers to information for the dimension name and value.
- Column D shows the visual presentation of the dimensional tolerances that correspond to the PMI annotations in Figure 51.
- Column E shows the name attribute of the entity type shown in column B.
- Column F shows the dimension (length value) associated with the shape_dimension_representation entity in column C.
- Column G shows the name of the length value in column F.
- Column H shows the plus-minus bounds associated with the dimensional tolerance. The bounds are defined by plus_minus_tolerance entities.
- Column I shows the geometric entities associated with the dimensional tolerances. In this case, the association is through shape_aspect entities which refer to advanced_face entities. The geometry entities cylindrical_surface and plane are referred to by the advanced_face attribute face_geometry.
- Section 6.1.5 explains how associated geometry is important to relate dimensional tolerances with geometric tolerances and datum features.
- More columns may show other attributes of dimensional tolerances.

The parenthetic notation in row 3 specifies the section number in the CAX-IF recommended practice for PMI representation related to that piece of information. For example, recommended practice sections 5.1.1 (column E) and 5.2.1 (column G) specify allowable attribute values shown in those columns.

	A	B	C
1	dimensional characteristic representation (10)		
2			
3	ID	dimension	representation
4	35831	dimensional_size 35801	shape_dimension_representation 35826
5	40201	dimensional_size 40171	shape_dimension_representation 40196
6	45336	dimensional_size 45306	shape_dimension_representation 45331
7	48741	dimensional_size 48711	shape_dimension_representation 48736
8	60541	dimensional_size 60511	shape_dimension_representation 60536
9	64886	dimensional_size 64856	shape_dimension_representation 64881
10	67011	dimensional_size 66981	shape_dimension_representation 67006
11	69441	dimensional_location 69411	shape_dimension_representation 69436
12	80071	dimensional_location 80041	shape_dimension_representation 80066
13	83181	dimensional_size 83151	shape_dimension_representation 83176

Figure 56: Dimensional tolerance example (columns A-C)

The visual presentation in Figure 57 can be used to do a semantic analysis of the PMI representation information. The dimension ‘0.75’ in cell D11 appears as a reference dimension ‘(.750)’ in Figure 51. In this case, the STEP file is missing the dimension modifier for a reference dimension. The visual presentation of the dimension shows that parentheses for a reference dimension are missing.

The feature count for a repetitive dimension, e.g., ‘4X’ and ‘2X’, in cells D6 and D7, respectively, are derived from the number of geometric surfaces in the associated geometry in column I. In this example, the feature count is half the number of cylindrical_surface entities in cells I6 and I7. This assumes that a cylindrical hole is modeled with two half cylindrical surfaces.

	A	D	E	F	G	H	I
1	dimen						
2		PMI Representation					
3	ID	Dimensional Tolerance	dimension name (Sec. 5.1.1, 5.1.5)	length/angle (Sec. 5.2.1)	length/angle name	plus minus bounds (Sec. 5.2.3)	Associated Geometry (Sec. 5.1.1, 5.1.5)
4	35831	0.438 ± .005	diameter	0.438	nominal value	-0.005 0.005	(2) cylindrical_surface 23661 23771 (2) advanced_face 23746 23806 (2) shape_aspect 35771 35786 (1) composite_group_shape_aspect 35766
5	40201	0.438 ± .005	diameter	0.438	nominal value	-0.005 0.005	(2) cylindrical_surface 23831 23941 (2) advanced_face 23916 23976 (2) shape_aspect 40141 40156 (1) composite_group_shape_aspect 40136
6	45336	4X 0.625 ± .005	diameter	0.625	nominal value	-0.005 0.005	(8) cylindrical_surface 10716 10826 10886 10996 11056 11166 11226 11336 (8) advanced_face 10801 10861 10971 11031 11141 11201 11311 11371 (8) shape_aspect 45186 45201 45216 45231 45246 45261 45276 45291 (1) composite_group_shape_aspect 45181
7	48741	2X 0.438 ± .005	diameter	0.438	nominal value	-0.005 0.005	(4) cylindrical_surface 24571 24681 24741 24851 (4) advanced_face 24656 24716 24826 24886 (4) shape_aspect 48651 48666 48681 48696 (1) composite_group_shape_aspect 48646
8	60541	0.200 ± .01	diameter	2.0	nominal value	-0.01 0.01	(2) cylindrical_surface 9696 9806 (2) advanced_face 9781 9841 (2) shape_aspect 60481 60496 (1) composite_group_shape_aspect 60476
9	64886	0.1500 ± .005	diameter	1.5	nominal value	-0.005 0.005	(2) cylindrical_surface 10546 10656 (2) advanced_face 10631 10691 (2) shape_aspect 64826 64841 (1) composite_group_shape_aspect 64821
10	67011	0.15	diameter	1.5	nominal value		(2) cylindrical_surface 10546 10656 (2) advanced_face 10631 10691 (2) shape_aspect 66951 66966 (1) composite_group_shape_aspect 66946
11	69441	.750	linear distance	0.75	nominal value		(2) plane 9866 10061 (2) advanced_face 9951 10121 (2) shape_aspect 69381 69396
12	80071	.82 ± .06	linear distance	0.82	nominal value	-0.06 0.06	(2) plane 11621 13991 (2) advanced_face 11711 14051 (2) shape_aspect 79966 79981
13	83181	0.1065 ± .003	diameter	1.065	nominal value	-0.003 0.003	(2) cylindrical_surface 2556 2666 (2) advanced_face 2641 2701 (2) shape_aspect 83121 83136 (1) composite_group_shape_aspect 83116

Figure 57: Dimensional tolerance example (columns A, D-I)

6.1.3.1 Rounding

The number of decimal places for dimension and geometric tolerance values can be specified in the STEP file. If specified, the value is always truncated. However, using the ‘Round dimensions and geometric tolerances’ option the values can be rounded instead. For example, the value 0.5625 could be truncated to 0.562, however, rounding will show 0.563. Rounding values might result in a better match to graphical PMI shown by the viewer or expected PMI in the NIST models (Sec. 6.6). This option is different than the Number Format option (Sec. 5.5.4).

6.1.4 Geometric Tolerances

The following examples show how geometric tolerances are modeled in a STEP file. Figure 58 and Figure 59 show the flatness_tolerance worksheet with the reconstructed visual presentation for the flatness tolerance.

- Column D is the magnitude of the flatness tolerance zone which is a reference to a length_measure_with_unit. As a convenience, the value of the length measure “0.005” is also shown.
- Column E is a reference to the toleranced shape_aspect.
- Columns F and G define the unit-basis size and type for the flatness tolerance. Another unit-basis parameter in column H is not shown.
- Column I shows the visual presentation of the FCF for the flatness tolerance with the corresponding unit-basis and datum feature. It corresponds to the PMI annotations in Figure 51.
- Column J is the datum feature associated with the flatness tolerance.
- Column K shows the toleranced geometry associated with the flatness tolerance derived from the toleranced_shape_aspect attribute in column E. The advanced_face entity references the plane entity.
- Section 6.1.5 explains how toleranced geometry is important to relate geometric tolerances with dimensional tolerances and datum features.

The reconstructed visual presentation of the PMI representation is limited by the character set available in the spreadsheet. The flatness tolerance symbol (parallelogram) appears somewhat small and misshapen. The lines for the compartments of the feature control frame are not shown. The combination of the inverted triangle, vertical line, and ‘E’ in brackets represents the reference to datum feature ‘E’.

	A	B	C	D	E	F	G
1	(flatness_tolerance)(geometric_tolerance_with_defined_area_unit) (1)						
2							
3	ID	name	description	magnitude	toleranced_shape_aspect	unit_size	area_type
	73111	Flatness.1	_Geometric tolerance for feature_	0.005 (length_measure_with_unit 73101)	shape_aspect 73091	0.25 (length_measure_with_unit 73106)	square
4							

Figure 58: Flatness tolerance example (columns A-H)


	I	J	K
1			
2	PMI Representation		
3	GD&T Annotation	Datum Feature (Sec. 6.5)	Toleranced Geometry (column E)
4	 .005 / 0.25 X 0.25 datum_feature 70982 (1) plane 1081 (1) advanced_face 1696		

Figure 59: Flatness tolerance example (columns I-K)

Figure 60 and Figure 61 show the position_tolerance worksheet with the reconstructed visual presentations of two position tolerances.

- Column D is the magnitude of the position tolerance zone. As a convenience, the value of the length measure “0.005” is also shown.
- Column E is a reference to the toleranced shape_aspect.
- Column F is a reference to the associated datum reference frame.
- Column G is the modifier applied to the tolerance zone.
- Column H shows the visual presentation of the position tolerances with their associated dimensions. An association between a geometric tolerance and dimension (or datum) is shown if each has the identical cylindrical_surface entities in the geometric tolerance Toleranced Geometry (Figure 61, Column J) and dimension Associated Geometry (Figure 57, cells I6 and I7).
- Column I shows the FCF of the dimensional tolerance, defined in Figure 57, associated with the position tolerance. The dimensional_size entities are referred to in column B of Figure 56.
- Column J shows the geometry, defined by the toleranced_shape_aspect attribute in column E, associated with the position tolerance.
- Section 6.1.5 explains how toleranced geometry is important to relate geometric tolerances with dimensional tolerances and datum features.

	A	B	C	D	E	F	G
1	[geometric tolerance with datum reference][geometric tolerance with modifiers](position tolerance) [2]						
2							
3	ID	name	description	magnitude	toleranced_shape_aspect	datum_system	modifiers
4	51491	Position.3	Geometric tolerance for feature	0.05 (length_measure_with_unit 51486)	composite_group_shape_aspect 51401	(1) datum_system 51481	maximum_material_requirement
5	53706	Position.4	Geometric tolerance for feature	0.05 (length_measure_with_unit 53701)	composite_group_shape_aspect 53551	(1) datum_system 53696	maximum_material_requirement

Figure 60: Position tolerance example (columns A-G)

	H	I	J
1			
2	PMI Representation		
3	GD&T Annotation	Dimensional Tolerance (Sec. 6.2)	Toleranced Geometry (column E)
4	2X Ø.438 ± .005 ⊕ Ø.05 Ⓜ A B Ⓜ C Ⓜ	dimensional_size 48711	(4) cylindrical_surface 24571 24681 24741 24851 (4) advanced_face 24656 24716 24826 24886 (4) shape_aspect 51406 51421 51436 51451 (1) composite_group_shape_aspect 51401
5	4X Ø.625 ± .005 ⊕ Ø.05 Ⓜ D B C	dimensional_size 45306	(8) cylindrical_surface 10716 10826 10886 10996 11056 11166 11226 11336 (8) advanced_face 10801 10861 10971 11031 11141 11201 11311 11371 (8) shape_aspect 53556 53571 53586 53601 53616 53631 53646 53661 (1) composite_group_shape_aspect 53551

Figure 61: Position tolerance example (columns H-J)

6.1.5 Associated and Toleranced Geometry

The previous examples for dimensional and geometric tolerances show columns for associated and toleranced geometry. The relationship between the geometries is important to understand how the visual presentation of the feature controls frames (FCF) in Figure 59 and Figure 61 are constructed. Figure 62 shows one of the position tolerances from Figure 51 where the FCF contains a position tolerance, hole dimension, and datum feature.

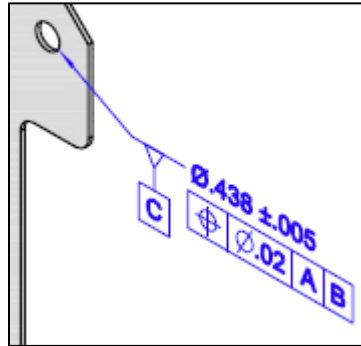


Figure 62: Position tolerance feature control frame

Cell G4 in Figure 63 shows the visual presentation of the FCF based on the position tolerance, dimension tolerance, and datum feature. The key to the visual presentation is that all three components of the FCF refer to the same geometric entities. The toleranced geometry for the position tolerance in cell J4 should be read from bottom to top. The composite_group_shape_aspect (CGSA) entity is from the toleranced_shape_aspect attribute on the position_tolerance entity. CGSA refers to two shape_aspect entities. Those two entities each refer to a single advanced_face entity which each refer to a cylindrical_surface entity. The two cylindrical_surface entities (#23831, #23941), highlighted in red, are the two half cylinders for the surfaces of the hole. Sometimes there is only one cylindrical_surface for a hole as described in Sec. 6.1.5.

	A	G	H	I	J
1	[geometric tolerance with datum reference](positi				
2	See CA PMI Representation				
3	ID	GD&T Annotation	Dimensional Tolerance (Sec. 6.2)	Datum Feature (Sec. 6.5)	Toleranced Geometry (column E)
4	42056	$\varnothing.438 \pm .005$ $\oplus \varnothing.020 A B$ ∇ $ $ $[C]$	dimensional_size 40171	datum_feature 40517	(2) cylindrical_surface 23831 23941 (2) advanced_face 23916 23976 (2) shape_aspect 42006 42021 (1) composite_group_shape_aspect 42001

Figure 63: Toleranced geometry for position tolerance

Cell K5 in Figure 64 shows the associated geometry for the dimension tolerance in cell D5. Although the CGSA and shape_aspect entities are different than those in cell J4 of Figure 63, the advanced_face and cylindrical_surface (#23831, #23941) entities are identical. Therefore, the position and dimension tolerance are both associated with the same hole geometry. The associated geometry for dimensions is found through the applies_to attribute on dimensional_size and the relating_shape_aspect and related_shape_aspect attributes on dimensional_location.

	A	D	E	F	G	H	I	J	K
1	dimensional characteristic representation (10)								
2	See CA PMI Representation								
3	ID	Dimensional Tolerance	dimension name (Sec. 5.1.1, 5.1.5)	length/angle (Sec. 5.2.1)	length/angle name	plus minus bounds (Sec. 5.2.3)	modifier type 1 (Sec. 5.3)	modifier type 2 (Sec. 5.3)	Associated Geometry (Sec. 5.1.1, 5.1.5)
5	40201	0.438 ± .005	diameter	0.438	nominal value	-0.005 0.005			(2) cylindrical_surface 23831 23941 (2) advanced_face 23916 23976 (2) shape_aspect 40141 40156 (1) composite_group_shape_aspect 40136

Figure 64: Associated geometry for dimensional tolerance

Cell G5 in Figure 65 shows the associated geometry for datum feature 'C'. In this case, the datum_feature entity refers directly to the advanced_face entities. Therefore, the datum feature is also associated with the same hole as the position and dimension tolerance. The datum feature is also directly associated with the position tolerance because the position_tolerance entity is a complex entity with geometric_tolerance_with_datum_reference that refers directly to the datum feature.

	A	F	G
1	datum feature (6)		
2	See CA PMI Representation		
3	ID	Datum (Sec. 6.5)	Associated Geometry (Sec. 6.5)
5	40517	C	(2) cylindrical_surface 23831 23941 (2) advanced_face 23916 23976 (1) datum_feature 40517

Figure 65: Associated geometry for datum feature

If an expected association between a geometric tolerance and a dimension or datum is not reported, then the associated geometry and toleranced geometry for each tolerance, dimension, and datum should be checked. A common problem is a position tolerance for a hole being associated with the surfaces of the hole cylinder and the corresponding hole diameter dimension only being associated with the circular edge of the hole and the hole surfaces.

In Figure 51 datum feature 'E' is associated with a surface profile tolerance. Datum feature 'E' is the surface of the tab. However, in Figure 69, datum feature 'E' is associated with two geometric tolerances shown in cells C21 and C28. Semantically both are correct since both tolerances refer to the same surface. There is no semantic information in the STEP file to specify which tolerance the datum feature is presented with.

6.1.5.1 Multiple Dimensions

In some cases, multiple dimensions might be associated with the same geometric entities. Figure 66 shows the warning message when multiple dimensions are detected. Cells D9 and D10 in Figure 67 show the multiple dimensions. In this example, there are two diameter dimensions with and without a tolerance value. Cells K9 and K10 in Figure 68 show the associated geometry for each dimension where they are both associated with the same cylindrical_surface entities (#10546, #10656). Multiple dimensions might also be reported for holes that have a counterbore, countersink, and depth.

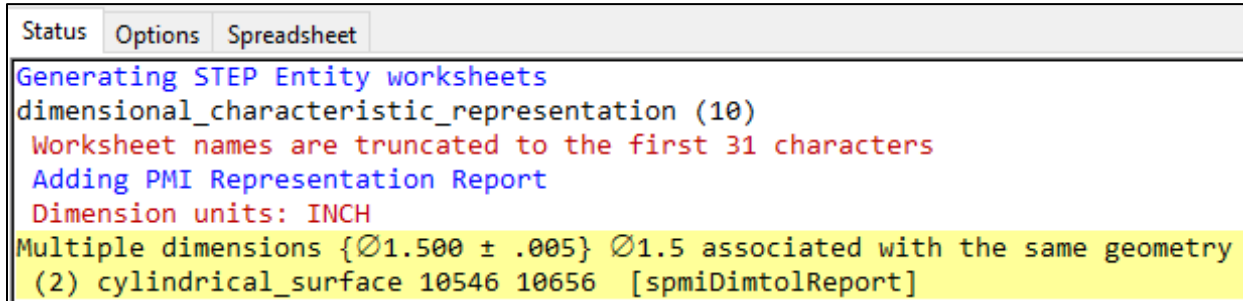


Figure 66: Warning message for multiple dimensions

	A	D	E	F	G	H
1	dimensional characteristic representation (10)					
2	See CA					
3	ID	Dimensional Tolerance	dimension name (Sec. 5.1.1, 5.1.5)	length/angle (Sec. 5.2.1)	length/angle name	plus minus bounds (Sec. 5.2.3)
9	64886	Ø1.500 ± .005	diameter	1.5	nominal value	-0.005 0.005
10	67011	Ø1.5	diameter	1.5	nominal value	

Figure 67: Multiple dimensions example (columns D-H)

	A	K	L	M	N	O
1	dimen					
2	See CA	PMI Representation				
3	ID	Associated Geometry (Sec. 5.1.1, 5.1.5)				
9	64886	(2) cylindrical_surface 10546 10656 (2) advanced_face 10631 10691 (2) shape_aspect 64826 64841 (1) composite_group_shape_aspect 64821				
10	67011	(2) cylindrical_surface 10546 10656 (2) advanced_face 10631 10691 (2) shape_aspect 66951 66966 (1) composite_group_shape_aspect 66946				

Multiple dimensions are associated with the same geometry. The identical information in this cell should appear in another Associated Geometry cell above.

Figure 68: Multiple dimensions example (column K)

6.1.6 PMI Representation Summary

As a convenience, all of the visual presentations of the datum reference frames, dimensional tolerances, and geometric tolerances are collected on the PMI Representation Summary worksheet shown in Figure 69. The annotations in column C are collected from column G in Figure 55, column D in Figure 57, column I in Figure 59, and column H in Figure 61. The annotations in column C correspond to the annotations shown in Figure 51.

	A	B	C
1		nist_ctc_03_asme1_ap242.stp (2014-12-19T16:21:44+01:00)	See CAX-IF Recommended Practice
2			
3	ID	Entity	PMI Representation
4	73706	angularity tolerance	$\angle 0.04 A$ ∇ [E]
5	37106	datum system	A
6	42046	datum system	A B
7	51481	datum system	A B (M) C (M)
8	53696	datum system	D B C
9	70801	datum system	A B C
10	84091	datum system	E
11	35831	dimensional characteristic representation	$0.438 \pm .005$
12	40201	dimensional characteristic representation	$0.438 \pm .005$
13	45336	dimensional characteristic representation	$4X 0.625 \pm .005$
14	48741	dimensional characteristic representation	$2X 0.438 \pm .005$
15	60541	dimensional characteristic representation	$02.00 \pm .01$
16	64886	dimensional characteristic representation	$01.500 \pm .005$
17	67011	dimensional characteristic representation	01.5
18	69441	dimensional characteristic representation	(.75)
19	80071	dimensional characteristic representation	$.82 \pm .06$ (directed)
20	83181	dimensional characteristic representation	$01.065 \pm .003$
21	73111	(flatness tolerance) (geometric tolerance with defined area unit)	$\square 0.005 / 0.25x0.25$ ∇ [E]
22	51491	(geometric tolerance with datum reference) (geometric tolerance with modifiers) (position tolerance)	$2X 0.438 \pm .005$ $\oplus 00.050 (M) A B (M) C (M)$
23	53706	(geometric tolerance with datum reference) (geometric tolerance with modifiers) (position tolerance)	$4X 0.625 \pm .005$ $\oplus 00.050 (M) D B C$
24	42056	(geometric tolerance with datum reference) (position tolerance)	$0.438 \pm .005$ $\oplus 00.020 A B$ ∇ [C]
25	62431	(geometric tolerance with datum reference) (position tolerance)	$02.00 \pm .01$ $\oplus 00.06 D B C$
26	66861	(geometric tolerance with datum reference) (position tolerance)	$01.500 \pm .005$ $\oplus 00.080 D B C$
27	68596	(geometric tolerance with datum reference) (position tolerance)	$01.500 \pm .005$ $\oplus 0.030 D B C$
28	70811	(geometric tolerance with datum reference) (surface profile tolerance)	$\triangle 0.06 A B C$ ∇ [E]

Figure 69: PMI Representation Summary worksheet

If a STEP file that was generated from a NIST CAD model from the MBE PMI Validation and Conformance Testing Project [38] is processed and the file can be recognized as having been generated from one of the CAD models, then the PMI Representation Summary worksheet is color-coded by the expected PMI annotations (Sec. 6.6.1).

6.1.7 PMI Representation Coverage Analysis

Coverage analysis counts the number of occurrences of a PMI element in a STEP file. Figure 70 shows the worksheet that is generated for coverage analysis of PMI Representation. Column A in rows 4 through 26 contain different types of PMI elements related to geometric and dimensional tolerances. Tolerances and modifiers show their associated symbol. The numbers in parentheses refer to the sections in the CAX-IF recommended practice for the representation of PMI [37] where there is implementation guidance for that type of PMI element.

Column B contains the number of occurrences of that type of PMI element in the file. Comparing the count to the number of expected PMI elements is a way to verify the PMI in the STEP file and resolve and modeling issues. If a STEP file that was generated from a NIST CAD model is processed, then the PMI Representation Coverage worksheet is color-coded by the expected number of PMI elements (Sec. 6.6.2).

	A	B	C
1	sp3_1101_3de.stp		
2	(2014-08-13T12:42:32+02:00)		
3	PMI Element	Count	
4	(See Help > Analyze > PMI Coverage Analysis)		
5	flatness_tolerance □	1	
6	perpendicularity_tolerance ⊥	1	
7	position_tolerance ⊕	5	
8	surface_profile_tolerance ⤿	2	
9	tolerance zone diameter (6.9.2)	5	
10	projected ⊗ (6.9.2.2)	1	
11	unequally_disposed ⊕ or UZ (6.9.4)	1	
12	dimensional location (5.1.1)	1	
13	dimensional size (5.1.5)	5	
14	angular location (5.1.2)	1	
15	dimension association to geometric tolerance (5.1)	6	
16	bilateral tolerance (5.2.3)	4	
17	diameter ∅ (5.1.5)	5	
18	linear distance (5.1.1)	1	
19	datum (6.5)	6	
20	datum system (6.9.7)	8	
21	multiple datum features (6.9.8)	3	
22	datum feature association to geometric tolerance (6.1)	5	
23	circle datum target (6.6.1)	2	
24	free_state ⊕ (6.9.3 or 6.9.7)	1	
25	least_material_requirement ⊖ (6.9.3 or 6.9.7)	3	
26	maximum_material_requirement ⊕ (6.9.3 or 6.9.7)	5	
27	document identification (3, see Header worksheet)	5	
<div> ◀ ▶ Summary Header PMI Representation Coverage </div>			

Figure 70: PMI Representation Coverage worksheet

Table 2 shows the complete list of PMI Elements that can appear in column A above. Tolerances and modifiers show their associated symbol. The numbers in parentheses refer to the sections in the CAX-IF recommended practice for the representation of PMI.

Table 2: All PMI Elements for PMI Representation Coverage

angularity_tolerance ∠	linear distance inner/outer (5.1.1)	depth ⏊
circular_runout_tolerance ↗	curve length (5.1.5)	derived_feature Ⓐ (6.9.3)
coaxiality_tolerance ◎	thickness (5.1.5)	distance_variable DV (6.9.7)
concentricity_tolerance ◎	toroidal radius/diameter (5.1.5)	each_radial_element ERE (6.9.3)
cylindricity_tolerance Ⓢ	controlled radius CR (5.3)	envelope_requirement Ⓢ (5.2.1)
flatness_tolerance □	dimension basic (5.3)	free_state Ⓢ (6.9.3 or 6.9.7)
line_profile_tolerance ⏏	reference dimension (5.3)	free_state_condition Ⓢ (5.3)
parallelism_tolerance //	square □ (5.3)	independency Ⓢ (5.2.1)
perpendicularity_tolerance ⊥	dimension qualifier (5.4)	least_material_condition Ⓢ
position_tolerance ⊕	measure qualifier	least_material_requirement Ⓢ (6.9.3 or 6.9.7)
roundness_tolerance ○	datum (6.5)	least_square_association_criteria (GG) (5.3)
straightness_tolerance -	datum system (6.9.7)	line SL (6.9.7)
surface_profile_tolerance ⏏	datum with axis system (6.9.7)	line_element LE (6.9.3)
symmetry_tolerance ⤵	datum with modifiers (6.9.7)	local_size_defined_by_a_sphere (LS) (5.3)
total_runout_tolerance ⏏	multiple datum features (6.9.8)	major_diameter MD (6.9.3)
tolerance zone diameter (6.9.2)	datum feature association to geometric tolerance (6.1)	maximum_inscribed_association_criteria (GX) (5.3)
tolerance zone within a cylinder (6.9.2)	all datum targets	maximum_material_condition Ⓢ
tolerance zone spherical diameter (6.9.2)	point datum target (6.6.1)	maximum_material_requirement Ⓢ (6.9.3 or 6.9.7)
tolerance zone other (6.9.2)	line datum target (6.6.1)	maximum_rank_order_size (SX) (5.3)
all_over ✓Ⓢ (6.3)	rectangle datum target (6.6.1)	median_rank_order_size (SM) (5.3)
all_around ⤵ (6.4.2)	circle datum target (6.6.1)	mid_range_rank_order_size (SD) (5.3)
between ↔ (6.4.3)	circular curve datum target (6.6.1)	minimum_circumscribed_association_criteria (GN) (5.3)
affected plane tolerance zone (6.9.2.1)	curve datum target (6.6.2)	minimum_rank_order_size (SN) (5.3)
projected Ⓢ (6.9.2.2)	area datum target (6.6.2)	minor_diameter LD (6.9.3)
non-uniform tolerance zone (6.9.2.3)	placed datum target geometry (6.6.3)	not_convex NC (6.9.3)
unequally_disposed Ⓢ or UZ (6.9.4)	movable datum target (6.6.4)	orientation >< (6.9.7)
tolerance with max value (6.9.5)	any_cross_section ACS (5.3)	pitch_diameter PD (6.9.7)
unit-basis tolerance (6.9.6)	any_longitudinal_section ALS (6.9.7)	plane PL (6.9.7)
composite tolerance (6.9.9)	any_part_of_the_feature /Length (5.3)	point PT (6.9.7)
intersection/orientation plane indicator	arc_length —	range_rank_order_size (SR) (5.3)
dimensions (location+size)	area_diameter_calculated_size (CA) (5.3)	reciprocity_requirement Ⓢ (6.9.3)
dimensional location (5.1.1)	associated_least_square_feature Ⓢ (6.9.3)	regardless_of_feature_size Ⓢ
dimensional size (5.1.5)	associated_maximum_inscribed_feature Ⓢ (6.9.3)	separate_requirement SEP REQ (6.9.3)
angular location (5.1.2)	associated_minimum_inscribed_feature Ⓢ (6.9.3)	simultaneous_requirement SIM REQ
angular size (5.1.6)	associated_minmax_feature Ⓢ (6.9.3)	slope -
directed dimension * (5.1.1)	associated_tangent_feature Ⓢ (6.9.3)	specific_fixed_cross_section SCS (5.3)
oriented dimensional location (5.1.3)	average_rank_order_size (SA) (5.3)	spotface SF
derived shapes dimensional location (5.1.4)	basic [BSC] (6.9.7)	statistical_dimension <ST> (5.3)
location with path (5.1.7)	circumference_diameter_calculated_size (CC) (5.3)	statistical_tolerance <ST> (6.9.3)
repetitive dimensions 'nX' (5.1, User Guide 5.1.3)	common_tolerance CT (5.3)	tangent_plane Ⓢ (6.9.3)
dimension association to geometric tolerance (5.1)	common_zone CZ (6.9.3)	translation ⤵ (6.9.7)
bilateral tolerance (5.2.3)	conical_taper -	two_point_size (LP) (5.3)
non-bilateral tolerance (5.2.3)	contacting_feature CF (6.9.7)	united_feature UF (6.9.3)
type qualifier (5.2.2)	continuous_feature <CF> (5.3)	volume_diameter_calculated_size (CV) (5.3)
value range (5.2.4)	counterbore ⏏	saved views (9.4)
limits and fits (5.2.5)	countersink ∨	editable text (7.4)
diameter Ø (5.1.5)	degree_of_freedom_constraint_u u (6.9.7)	document identification (3, see Header worksheet)
radius R (5.1.5)	degree_of_freedom_constraint_v v (6.9.7)	ASME dimensioning standard (4, Fig. 1)
spherical diameter SØ (5.1.5)	degree_of_freedom_constraint_w w (6.9.7)	ASME modeling standard (4, Fig. 2)
spherical radius SR (5.1.5)	degree_of_freedom_constraint_x x (6.9.7)	ISO dimensioning standard (4, Fig. 1)
curved distance (5.1.1)	degree_of_freedom_constraint_y y (6.9.7)	ISO modeling standard (4, Fig. 2)
linear distance (5.1.1)	degree_of_freedom_constraint_z z (6.9.7)	default tolerance decimal places (4.1)

6.2 PMI Presentation (Graphical PMI)

PMI presentation (also known as graphical PMI) presents GD&T annotations as a visual representation of geometric elements such as lines and arcs as part of the CAD model, i.e., how the annotation is drawn on the model. PMI presentation is not intended to be computer-interpretable and does not carry any semantic representation information although it can be linked to its corresponding semantic representation. The CAX-IF defines recommended practices for PMI presentation [37]. Syntax errors related to nonconformance to the recommended practices are highlighted in red in the Status tab and in the relevant entity worksheets (Sec. 6.5).

Figure 71 through Figure 73 show how PMI presentation is reported in the spreadsheet. The report for PMI presentation only contains information about the graphical elements (points, lines, colors) needed to draw PMI annotations. PMI presentation information is always reported on the `annotation_curve_occurrence` (as in this example), `tessellated_annotation_occurrence`, or `annotation_occurrence` worksheets.

- Columns B, C, and D show the entity attributes.
- Column E shows the name attribute of the `geometric_curve_set` in column D.
- Column F shows the element attributes of the `geometric_curve_set`. In this case, the elements refer to polyline entities.
- Column G shows the `curve_style` associated with the `presentation_style_assignment` in column C.
- Column H shows the color associated with the `curve_style` in column G.
- Column I shows the annotation plane associated with the annotation.
- Column J shows the geometry that the annotation is attached to. If associated geometry is missing, then there is no cross-highlighting between the annotation and geometry.
- Column K shows the associated PMI representation entities.
- Not shown are columns for PMI presentation validation properties and Saved Views.

	A	B	C	D
1	annotation curve occurrence (30)			
2				
3	ID	name	styles	item
4	35736	Linear Size.1	(1) presentation_style_assignment 35731	geometric_curve_set 35726
5	36196	Simple Datum.2	(1) presentation_style_assignment 36191	geometric_curve_set 36186
6	37056	Perpendicularity.1	(1) presentation_style_assignment 37051	geometric_curve_set 37046
7	40131	Linear Size.2	(1) presentation_style_assignment 40126	geometric_curve_set 40121
8	40511	Simple Datum.3	(1) presentation_style_assignment 40506	geometric_curve_set 40501

Figure 71: PMI presentation example (columns A-D)

	E	F	G	H
1				
2	PMI Presentation			
3	name (Sec. 8.4)	elements (Sec. 8.1.1)	presentation style (Sec. 8.5)	color (Sec. 8.5)
4	diameter dimension	(35) polyline 32921 32996 33061 33151 33241 33271 33296 33361 33636 33726 33896 33986 34016 34106 34196 34226 34316 34406 34496 34586 34786 34856 34946 35036 35066 35156 35246 35336 35426 35626 35651 35676 35691 35706 35721	curve_style 35732	draughting_pre_defined_colour 35734
5	datum	(6) polyline 35941 36006 36111 36141 36156 36181	curve_style 36192	draughting_pre_defined_colour 36194
6	perpendicularity	(13) polyline 36281 36311 36491 36566 36631 36661 36751 36841 36906 36936 36961 37011 37041	curve_style 37052	draughting_pre_defined_colour 37054
7	diameter dimension	(35) polyline 37316 37391 37456 37546 37636 37666 37691 37756 38031 38121 38291 38381 38411 38501 38591 38621 38711 38801 38891 38981 39181 39251 39341 39431 39461 39551 39641 39731 39821 40021 40046 40071 40086 40101 40116	curve_style 40127	draughting_pre_defined_colour 40129
8	datum	(4) polyline 40426 40456 40471 40496	curve_style 40507	draughting_pre_defined_colour 40509

Figure 72: PMI presentation example (columns E-H)

	I	J	K
1			
2			
3	plane (Sec. 9.1)	Associated Geometry (Sec. 9.3.1)	Associated Representation (Sec. 7.3)
4	annotation_plane 69461 (ProjView.1)	(2) cylindrical_surface 23661 23771 (2) advanced_face 23746 23806 (2) shape_aspect 35771 35786 (1) composite_group_shape_aspect 35766	dimensional_size 35801
5	annotation_plane 69461 (ProjView.1)	(2) cylindrical_surface 23661 23771 (2) advanced_face 23746 23806 (1) datum_feature 36202	datum_feature 36202
6	annotation_plane 69461 (ProjView.1)	(2) cylindrical_surface 23661 23771 (2) advanced_face 23746 23806 (2) shape_aspect 37066 37081 (1) composite_group_shape_aspect 37061	perpendicularity_tolerance 37116
7	annotation_plane 69461 (ProjView.1)	(2) cylindrical_surface 23831 23941 (2) advanced_face 23916 23976 (2) shape_aspect 40141 40156 (1) composite_group_shape_aspect 40136	dimensional_size 40171
8	annotation_plane 69461 (ProjView.1)	(2) cylindrical_surface 23831 23941 (2) advanced_face 23916 23976 (1) datum_feature 40517	datum_feature 40517

Figure 73: PMI presentation example (columns I-K)

6.2.1 PMI Presentation Coverage Analysis

Coverage analysis counts the number of occurrences of a PMI element in a STEP file. Figure 74 shows the worksheet that is generated for coverage analysis of PMI presentation. Rows 4 through 35 of column A contain the recommended names [37] that can be associated with a PMI annotation. The names correspond to the values in column E in Figure 72. There is no semantic meaning associated with the names. PMI presentation assumes a semantic meaning through its association with PMI representation as shown in column K of Figure 73.

	A	B	C
1	nist_ctc_03_asme1_ap242.stp		
2			
3	PMI Presentation Names	Count	
4	angularity	1	
5	circular runout		
6	circularity		
7	coaxiality		
8	concentricity		
9	cylindricity		
10	flatness	1	
11	parallelism		
12	perpendicularity	2	
13	position	6	
14	profile of line		
15	profile of surface	3	
16	roundness		
17	straightness		
18	symmetry		
19	total runout		
20	general tolerance		
21	linear dimension	2	
22	radial dimension		
23	diameter dimension	8	
24	angular dimension		
25	ordinate dimension		
26	curve dimension		
27	general dimension		
28	datum	6	
29	datum target		
30	note	1	
31	label		
32	surface roughness		
33	weld symbol		
34	general note		
35	over riding style set		
36			
37			
38	See Help > PMI Coverage Analysis		
	PMI Presentation Coverage		

Figure 74: PMI Presentation Coverage worksheet

6.3 Validation Properties

Validation properties are an important tool to verify the information in a STEP file. The properties include geometric, PMI, assembly, annotation, attribute, and tessellated validation properties. For example, geometric validation properties are characteristics of solid and surface models, such as area, volume, and centroid. Geometric validation properties could be written to a STEP file when it is exported from a CAD system. When the STEP file is imported to a receiving CAD system, that system can compute the same validation properties and compare them to the values from the originating system in the STEP file. If the computed validation properties are within an agreed tolerance to the original validation properties, then the exchange of geometric information has been validated. The CAX-IF defines recommended practices for validation properties [39]. Syntax errors related to nonconformance to the recommended practices are highlighted in red in the Status tab and in the relevant entity worksheets (Sec. 6.5).

Figure 75 and Figure 76 shows a validation properties report. The report always appears on the property_definition worksheet. The rows can be sorted by any of the column attributes. The validation properties are shown in the yellow and green columns E, G, I, K, and M. Row 3 contains the names of the type of value in those columns. Properties not colored yellow and green are not validation properties as defined by the recommended practice. The values in cells I7, I10, and I16 are cartesian coordinates. Empty cells E13 and E14 show that values for those attributes were not specified in the STEP file. If no values for units and exponent appear in rows K and M, then none are required based on the type of value in row I.

The hidden columns F, H, J, L, and N can be shown by clicking on the plus (+) signs above the columns or the “2” in the upper left corner. Those columns contain the entity attribute name and ID for the corresponding validation property value in the column to the left. Opening the hidden columns shows where the validation property values come from in the STEP file. The hidden columns F, H, and J are shown in Figure 77. Columns L, M, and N are not shown. For example, the value in cell G4 “surface area measure” comes from the measure_representation_item name attribute of entity ID 393. The expanded columns can be hidden again by clicking on the minus (-) signs above the columns or the “1” in the upper left corner.

	A	B	C	D
1	property_definition (35)			
2				
3	ID	name	description	definition
4	385		shape for solid data with which properties are associated	shape_aspect 384
5	394	geometric validation property	area of C1_SOLID	shape_aspect 384
6	403	geometric validation property	volume of C1_SOLID	shape_aspect 384
7	407	geometric validation property	centroid of C1_SOLID	shape_aspect 384
8	416	geometric validation property	area of C1_SOLID	product_definition_shape 383
9	425	geometric validation property	volume of C1_SOLID	product_definition_shape 383
10	429	geometric validation property	centroid of C1_SOLID	product_definition_shape 383
11	482	pmi validation property	number of views of C1_SOLID	product_definition_shape 383
12	486	pmi validation property	number of annotations of Default	(characterized_object) (draughting_model) 434
13	489	DESCRIPTION	user defined attribute	product_definition 382
14	495	MODELED_BY	user defined attribute	product_definition 382
15	502	attribute validation property	part user attributes of C1_SOLID	product_definition_shape 383
16	513	geometric validation property	centroid of C1_SOLID	product_definition_shape 511

Figure 75: Validation properties example (columns A-D)

1					
2					
	E	G	I	K	M
1					
2	Validation Properties				
3	representation name	value name	value	units	exponent
4	(1) shape_definition_representation.definition 387				
5	surface area	surface area measure	60000	INCH	2
6	volume	volume measure	1000000	INCH	3
7	centroid	centre point	0.0 50.0 0.0		
8	surface area	surface area measure	60000	INCH	2
9	volume	volume measure	1000000	INCH	3
10	centroid	centre point	0.0 50.0 0.0		
11	number of views	number of views	1		
12	number of annotations	number of annotations	0		
13	DESCRIPTION				
14	MODELED_BY				
15	part user attributes	part user attributes	2		
16	centroid	centre point	50.0 50.0 -50.0		

Figure 76: Validation properties example (columns E-O)

1					
2					
	E	F	G	H	I
1					
2	Validation Properties				
3	representation name	attribute	value name	attribute2	attribute3
4	(1) shape_definition_representation.definition 387				
5	surface area	#395 representation.name	surface area measure	#393 measure_representation_item.name	60000 #393 measure_representation_item.value_component
6	volume	#404 representation.name	volume measure	#402 measure_representation_item.name	1000000 #402 measure_representation_item.value_component
7	centroid	#408 representation.name	centre point	#406 cartesian_point.name	0.0 50.0 0.0 #406 cartesian_point.coordinates
8	surface area	#417 representation.name	surface area measure	#415 measure_representation_item.name	60000 #415 measure_representation_item.value_component
9	volume	#426 representation.name	volume measure	#424 measure_representation_item.name	1000000 #424 measure_representation_item.value_component
10	centroid	#430 representation.name	centre point	#428 cartesian_point.name	0.0 50.0 0.0 #428 cartesian_point.coordinates
11	number of views	#483 representation.name	number of views	#481 value_representation_item.name	1 #481 value_representation_item.value_component
12	number of annotations	#487 representation.name	number of annotations	#485 value_representation_item.name	0 #485 value_representation_item.value_component
13		#493 representation.name	DESCRIPTION	#492 descriptive_representation_item.name	#492 descriptive_representation_item.description
14		#499 representation.name	MODELED_BY	#498 descriptive_representation_item.name	#498 descriptive_representation_item.description
15	part user attributes	#503 representation.name	part user attributes	#501 value_representation_item.name	2 #501 value_representation_item.value_component
16	centroid	#514 representation.name	centre point	#512 cartesian_point.name	50.0 50.0 -50.0 #512 cartesian_point.coordinates

Figure 77: Validation properties example with expanded columns (columns E-J)

Validation properties are also reported on their associated annotation, dimension, geometric tolerance, and shape aspect entities. The report includes the validation property name and names of the properties. Some properties are reported only if the analysis for semantic PMI is selected. Other properties and user defined attributes are also reported.

6.3.1 Semantic Text

Another type of validation property is known as semantic text where explicit text strings in the STEP file can be associated with part surfaces similar to semantic PMI. Figure 51 shows text strings SWITCH MOUNTING LOCATIONS and 2 COPLANAR SURFACES as graphical PMI. The semantic text will appear in the spreadsheet on shape_aspect and other related entities. A message in the Status tab will indicate when semantic text is added to entities.

6.4 Inverse Relationships

In a STEP schema, an entity attribute whose value consists of entity references, in which the referenced entity has attributes referring to the referencing attribute's entity is called an inverse attribute. This establishes an inverse relationship [40] that is explicitly defined in a STEP schema.

Figure 78 is an entity worksheet for shape_aspect_relationship that shows the entity relationships established between the attribute values for relating_shape_aspect and related_shape_aspect in columns D and E.

	A	B	C	D	E
1	shape_aspect_relationship (71)				
2					
3	ID	name	description	relating_shape_aspect	related_shape_aspect
4	35781	Linear Size.1		composite_group_shape_aspect 35766	shape_aspect 35771
5	35796	Linear Size.1		composite_group_shape_aspect 35766	shape_aspect 35786
6	36201	Simple Datum.2		datum_feature 36202	datum 36203
7	37076	Perpendicularity.1		composite_group_shape_aspect 37061	shape_aspect 37066
8	37091	Perpendicularity.1		composite_group_shape_aspect 37061	shape_aspect 37081
9	40151	Linear Size.2		composite_group_shape_aspect 40136	shape_aspect 40141
10	40166	Linear Size.2		composite_group_shape_aspect 40136	shape_aspect 40156
11	40516	Simple Datum.3		datum_feature 40517	datum 40518
12	42016	Position.1		composite_group_shape_aspect 42001	shape_aspect 42006
13	42031	Position.1		composite_group_shape_aspect 42001	shape_aspect 42021

Figure 78: Entity worksheet (shape_aspect_relationship)

Figure 79 and Figure 80 show how inverse relationships are shown on the datum entity based on shape_aspect_relationship shown above. Column G shows the relationship between datum and other entities. Column H, with the 'Used In' header, shows where datum is referred to from other entity attributes although not by an inverse relationship established by a STEP schema. The tooltip in the Options tab for the Inverse Relationships selection shows the list of entities for which some attributes with Inverse and Used In relationships that are reported.

	A	B	C	D	E	F
1	datum (6)					
2						
3	ID	name	description	of_shape	product_definitional	identification
4	36203	Simple Datum.2	Simple Datum.2	product_definition_shape 56	TRUE	B
5	40518	Simple Datum.3	Simple Datum.3	product_definition_shape 56	TRUE	C
6	70983	Simple Datum.5	Simple Datum.5	product_definition_shape 56	TRUE	E
7	37096	Simple Datum.1	Simple Datum.1	product_definition_shape 56	TRUE	A
8	53676	Simple Datum.4	Simple Datum.4	product_definition_shape 56	TRUE	D
9	84273	Simple Datum.6	Simple Datum.6	product_definition_shape 56	TRUE	F

Figure 79: Inverse Relationships and Used In example (columns A-F)

	G	H
1		
2		
3	INV-relating_shape_aspect	Used In
4	(1) datum_feature 36202	(8) datum_reference_compartment.base 42041 51471 53686 62416 66846 68581 70791 77256
5	(1) datum_feature 40517	(7) datum_reference_compartment.base 51476 53691 62421 66851 68586 70796 77261
6	(1) datum_feature 70982	(1) datum_reference_compartment.base 84086
7	(1) datum_feature 75912	(6) datum_reference_compartment.base 37101 42036 51466 70786 73696 77251
8	(1) datum_feature 77502	(4) datum_reference_compartment.base 53681 62411 66841 68576
9	(1) datum_feature 84272	

Figure 80: Inverse Relationships and Used In example (columns G-H)

6.5 Syntax Errors

Syntax errors, related to nonconformance to a CAX-IF recommended practice, are highlighted in red in the Status tab and on the relevant entity worksheets. Figure 81 shows a syntax error displayed in the Status tab associated with an `annotation_curve_occurrence` entity while generating the PMI Presentation report. The second line of the syntax error refers to specific sections, figures, or tables in the relevant recommended practice that provides the guidance for the correct implementation of that information. Figure 82 shows a warning message highlighted in yellow related to `dimensional_characteristic_representation`.

Status	Options	Spreadsheet
type_qualifier (6)		
value_format_type_qualifier (6)		
annotation_curve_occurrence (22)		
Adding PMI Presentation Report		
Syntax Error: For Saved Views, missing required reference to 'mapped_item' on (characterized_representation)(d		
(Representation and Presentation of PMI (AP242), Sec. 9.4.2.1, Fig. 86)		
annotation_plane (7)		

Figure 81: Syntax error related to `annotation_curve_occurrence`

Status	Options	Spreadsheet
Generating STEP Entity worksheets		
dimensional_characteristic_representation (6)		
Worksheet names are truncated to the first 31 characters		
Adding PMI Representation Report		
Dimension units: INCH		
Associated Geometry for a 'diameter' dimension is only a 'edge_curve'. Check that t		
datum (4)		

Figure 82: Warning message related to `dimensional_characteristic_representation`

Entity types that have any syntax or warning messages are highlighted in gray on the Summary worksheet as shown in Figure 83. The red triangle in the upper left corner of a cell indicates that there is a comment shown in the yellow box. Entities with errors are also highlighted in red in the Status tab with the messages about Formatting Worksheets.

	A	B	C	D	E	F	G
1	STEP Directory	C:\Users\lipman\Documents\Analyzer\User Guide					
2	STEP File	nist_ctc_05_asme1_ap242.stp					
3	Excel File	nist_ctc_05_asme1_ap242-sfa.xlsx					
4	Timestamp	2014-12-19T16:03:21+01:00					
5	Total Entities	13400					
6	Schema	AP242e1					
7	Standards	ISO 16792					
8	Dimension Units	INCH					
9							
10	Entity	Count					
11	circular runout tolerance [PMI Representation]	3					
12	coaxiality tolerance [PMI Representation]	1					
13	datum	4					
14	datum feature [PMI Representation]	2					
15	datum reference compartment [PMI Representation]	8					
16	datum reference element [PMI Representation]	6					
17	datum system [PMI Representation]	6					
18	dimensional characteristic representation [PMI Representation]	5					
19	dimensional location	1					
20	dimensional size	2					
21	perpendicularity tolerance [PMI Representation]	2					
22	placed datum target feature [PMI Representation]	2					
23	plus minus tolerance	2					
24	roundness tolerance [PMI Representation]	1					
25	shape dimension representation	6					
26	straightness tolerance [PMI Representation]	1					
27	tolerance value	2					
28	tolerance zone	1					
29	tolerance zone form	1					
30	total runout tolerance [PMI Representation]	2					
31	annotation curve occurrence	22					
32	annotation plane	7					
33	camera model d3	2					
34	(characterized representation)	2					
	(draughting model) [Properties]						
	Summary	Header	PMI Representation Summary	PMI Representation Coverage	circular_runout_toler		

There are Errors or Warnings for at least one entity of this type. See Help > Analyze > Syntax Errors

Figure 83: Entities with errors or warnings highlighted on Summary worksheet

Figure 84 shows the (characterized_representation)(draughting_model) worksheet where the syntax errors from Figure 81 are highlighted in cells C4 and C5. The comment is same text displayed in the Status tab in Figure 81. Although the syntax error was detected when processing annotation_curve_occurrence entities, the actual error is related to the items attribute on the (characterized_representation)(draughting_model) entity.

	A	B	C	D
1			(characterized_representation)(draughting_model) (2)	
2				
3	ID	name	items	context_of_items
4	45	MBD_A	(1) camera_model_d3 47 (13) draughting_callout 267 269 273 274 275 276 277 278 279 280 281 282 285	(geometric_representation_context) (global_uncertainty_assigned
5	46	MBD_B	(1) camera_model_d3 48 (10) draughting_callout 268 269 270 271 272 283 284 286 287 288	(g (g For Saved Views, missing required reference to 'mapped_item' (g on (characterized_representation)(draughting_model).items (g (Representation and Presentation of PMI (AP242), Sec. 9.4.2.1, Fig. 86) See Websites > Recommended Practices or the link in row 2.
6				
7				
8				
9				

Figure 84: Syntax error on (characterized_representation)(draughting_model)

Figure 85 shows the dimensional_characteristic_representation worksheet where the warning message from Figure 82 is shown with a comment for the cell in column L. The comment means that the associated geometry for this hole diameter is an edge curve when a hole diameter would usually be associated with cylindrical surfaces.

L	M	N	O	P	Q
Associated Geometry (Sec. 5.1.1, 5.1.5)					
(2) edge_curve 2685 2691					
(2) shape_aspect 1004 1005					
(2) trimmed_curve 3892 3893					
(2) shape_aspect 1006 1007					
(2) trimmed_curve 3898 3899					
(2) shape_aspect 1008 1009					
(1) edge_curve 2839					
(1) shape_aspect 1010					
(2) trimmed_curve 3893 3895					
(2) shape_aspect 1012 1013					
(1) trimmed_curve 3898					
(2) shape_aspect 1014 1015					

Diameter dimension (column E) is not associated with curved surfaces. Check that this is the intended association.

Figure 85: Warning message on dimensional_characteristic_representation

There are also some other explanatory comments for the headings in row 3 on several types of worksheets as shown in Figure 86.

D	E	F	G	H	I
<p>See Help > User's Guide (section 5.1.3) for an explanation of how the dimensions below are constructed. ***** Dimension units: INCH ***** Repetitive dimensions (e.g., 4X) might be shown for diameters and radii. They are computed based on the number of cylindrical, spherical, and toroidal surfaces associated with a dimension (see Associated Geometry column to the right) and, depending on the CAD system, might be off by a factor of two, have the wrong value, or be missing. ***** See the PMI Representation Summary worksheet to see how the Dimensional Tolerance below compares to the expected PMI.</p>					
Dimensional Tolerance	di				
5.000 ± .008 <ST>	lin				
[1.250]	lin				
[1.250]	linear distance	1.25	nominal value		NR2 1.3
Ø10.000 ± .001	diameter	10.0	nominal value	-0.001 0.001	NR2 2.3
[2.000]	linear distance	2.0	nominal value		NR2 1.3
[2.000]	linear distance	2.0	nominal value		NR2 1.3

Figure 86: Cell comment for dimensional tolerances

6.6 Color-coding Results for NIST CAD Models

If a STEP file is processed that was generated from a NIST CAD model from the MBE PMI Validation and Conformance Testing Project [38] and the file can be recognized as having been generated from one of the CAD models, then the PMI Representation Summary and PMI Representation Coverage worksheets are color-coded by the expected PMI annotations.

6.6.1 Representation Summary

The PMI Representation Summary worksheet is color-coded by the expected PMI annotations in a NIST test case drawing. Figure 87 is a color-coded worksheet for a STEP AP242 file generated from CAD model based on NIST test case CTC 5⁸. A similar worksheet based on NIST test case CTC 3, without color-coding, is shown in Figure 69.

The color-coding is determined by comparing the expected PMI annotations for a NIST test case, that are stored in SFA, with the PMI Representation generated by SFA in column C. The comparison has nothing to do with the graphic PMI in the STEP AP242 file, only the semantic PMI.

The legend at the bottom of column C describes the color-coding.

- Green is an exact match to an expected PMI annotation in the NIST test case drawing.
- Cyan is a partial match.
- Yellow is a possible match.
- Red is no match.

For partial and possible matches, the best match to expected Similar PMI is shown in column D. At the bottom of column C are the expected Missing PMI annotations not found in the STEP file. The red triangles in the upper right corners of cells C3 and D3 indicate that there is a cell comment that explains the meaning of the cells in columns C and D.

In this example, cell C14 is missing the diameter symbol for a hole dimension. This means that the `dimensional_characteristic_representation` entity (#906) refers to a `dimensional_location` entity instead of a `dimensional_size` entity. `Dimensional_size` should almost always be used for hole diameters. Cell D14 shows the expected Similar PMI, from the NIST test case drawing for the hole diameter, that includes the diameter symbol.

Cell C15 is colored red because the reference dimension value '(2.500)' found in the STEP file does not appear in the NIST test case drawing. Conversely, the missing PMI in cells C33 and C34 show that those two basic dimensions are found in the NIST test case drawing but not in the STEP file.

The shape of the placed datum targets in cells C18 and C19 are incorrect. This means that the description attributes on the `placed_datum_target_feature` entities (#1103, #1104) are 'point' instead of 'rectangle'.

⁸ https://s3.amazonaws.com/nist-el/mfg_digitalthread/nist_ctc_05_asme1_rd.pdf

	A	B	C	D
1		nist_ctc_05_asme1_ap242.stp	See CAX-IF Recommended Practice for Repre	
2				
3	ID	Entity	PMI Representation	Similar PMI
4	946	circular runout tolerance	$\nearrow .035 A-B$	
5	947	circular runout tolerance	$\nearrow .025 A-B$	
6	948	circular runout tolerance	$\nearrow .025 A-B$	
7	960	coaxiality tolerance	$\odot \varnothing .03 A$	
8	964	datum system	A	
9	965	datum system	B	
10	967	datum system	C	
11	968	datum system	D	
12	969	datum system	A-B	
13	903	dimensional characteristic representation	$5.000 \pm .008 <ST>$	
14	906	dimensional characteristic representation	$10.000 \pm .001$	$\varnothing 10.000 \pm .001$
15	908	dimensional characteristic representation	(2.500)	
16	955	perpendicularity tolerance	$\perp .01 C$	
17	956	perpendicularity tolerance	$\perp .01 D$	
18	1103	roundness tolerance	C1 (point)	C1 (rectangle)
19	1104	roundness tolerance	D1 (point)	D1 (rectangle)
	961	roundness tolerance	$\bigcirc .002$ ∇ [A]	
20				
21	957	straightness tolerance	$- .005$	
	962	total runout tolerance	$\text{U} .001 A$	$\varnothing 10.000 \pm .001$ $\text{U} .002 A$ ∇ [B]
22				
23	963	total runout tolerance	$\text{U} .015 B$	
24				
25			Expected PMI	
26			See Help > NIST CAD Models	
27			Exact match	
28			Partial match	
29			Possible match	
30			No match	
31				
32		Entity Type	Missing PMI	
33		dimensional_characteristic_representation	[1.250]	
34		dimensional_characteristic_representation	[2.000]	

Figure 87: Color-coded PMI Representation Summary worksheet for CTC 5

There are several problems with the total_runout_tolerance in cell C22. Because there are more problems it is colored yellow as a possible match. The magnitude of the tolerance zone is '.001' instead of '.002'.

The feature control frame (FCF) for the similar PMI in cell D22 shows that there is a dimension tolerance and datum feature associated with the geometric tolerance. Figure 88, from NIST test case drawing for CTC 5, shows a large inner diameter surface with the total runout tolerance. That surface also has a diameter dimension that is defined as datum feature 'B'. Semantically, those three PMI elements all refer to the same large inner diameter surface in the test case drawing. Therefore, the similar PMI in cell D22 is also a correct visual presentation of the FCF for the PMI annotation. Cell C22 is missing the diameter dimension and datum feature because the geometric tolerance is not associated with the same geometric surfaces as the diameter dimension and datum feature. This can be confirmed by checking the toleranced or associated geometry for the total_runout_tolerance, the dimensional_characteristic_representation, and datum_feature. The geometric tolerance must have the exact same toleranced or associated geometry to be able to show the FCF in cell C22 as it appears in cell D22. The association of toleranced and associated geometry is described in Sec. 6.1.5.

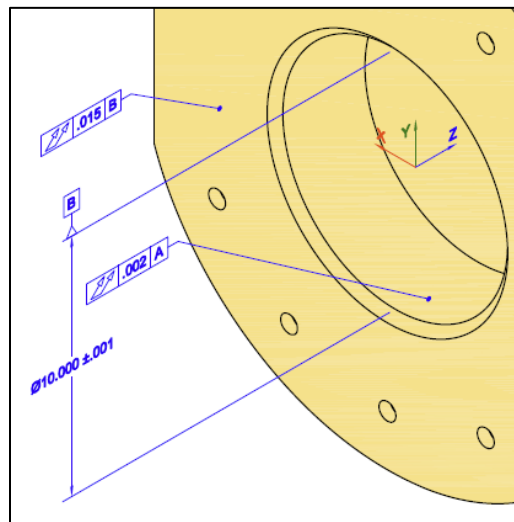


Figure 88: Feature from NIST CTC 5

The roundness_tolerance in cell C20 has the exact same associated geometry as datum feature 'A'. therefore, the FCF appears correct and is colored green.

Trailing and leading zeros are ignored when matching a PMI annotation to the expected PMI. Matches also only consider the current capabilities of PMI in STEP AP242 and CAX-IF Recommended Practices. For example, PMI annotation symbols for counterbore, countersink, and depth are ignored although they might appear in the corresponding CAD model.

Some causes of partial and possible matches are:

- missing associations of a geometric tolerance with a datum feature or dimension
- missing diameter and radius symbols
- wrong feature counts for repetitive dimensions
- wrong dimension or tolerance zone values
- missing or wrong values for dimension tolerances
- missing or wrong datum reference frames
- missing datum features
- missing or incorrect modifiers for dimensions, tolerance zones, and datum reference frames
- missing composite tolerances

6.6.2 Representation Coverage Analysis

The PMI Representation Coverage worksheet is color-coded by the expected number of PMI elements for a NIST test case. The expected number of PMI elements was determined by manually counting them in each test case drawing, similar to Figure 51, for the NIST test cases. The color-coded worksheet is shown in Figure 89. A similar worksheet without color-coding is shown in Figure 70.

If more or less than the expected number of PMI elements was found, then the first value of two is the number found and the second is the expected number. For example, ‘2/3’ means that two PMI elements were found when three were expected. Counting of some modifiers, e.g., maximum material condition in row 24, does not differentiate whether the modifier appears in the tolerance zone definition or datum reference frame.

A legend describing the colors is in column D of Figure 89.

- A green cell is a match to the expected number of PMI elements.
- Cyan means that more were found than expected, e.g., ‘4/3’.
- Yellow, yellow-green, and orange mean that less were found than expected, e.g., ‘2/3’.
- Red means that no instances of an expected PMI element were found, e.g., ‘0/3’
- Magenta means that PMI elements were found when none were expected, e.g., ‘1/0’

In this example, there is one extra dimensional location (cell B13). This is also apparent from cell B11 which counts that total number of dimensions in cells B12 and B13. Cell B24 shows that the saved view is missing.

A cell color other than green might mean that a CAD system or translator

- did not or cannot correctly create in the CAD model, a PMI element defined in a NIST test case,
- did not follow CAX-IF Recommended Practices for PMI [37],
- has not implemented exporting a PMI element to a STEP file, or
- mapped an internal PMI element to the wrong STEP PMI element.

Some of the NIST test cases have complex PMI annotations that are not commonly used. There might be ambiguities in counting the number of PMI elements.

6.6.2.1 Color-coding Expected PMI

From the PMI Representation Summary results in Figure 87, color-coded percentages of exact, partial, and possible matches to Expected PMI and missing PMI is shown in a table below the PMI Representation Coverage Analysis in Figure 89 in rows 29 through 35. The Total PMI on which the percentages are based on is also shown. Coverage Analysis is only based on individual PMI elements. The PMI Representation Summary is based on the entire PMI feature control frame and provides a better understanding of the PMI. The Coverage Analysis might show that there is an exact match for all of the PMI elements, however, the Representation Summary might show less than exact matches.

For example, if a STEP file has the correct number of dimensions, the dimension PMI elements will be colored green. This does not mean that the dimension values are correct. Those incorrect dimension values are not reflected in the PMI Coverage Analysis. Incorrect values would show up as partial or possible matches in Figure 87. Those partial or possible matches would show up in the second table in Figure 89.

	A	B	C	D
1	nist_ctc_03_asme1_ap242.stp (2014-12-19T16:21:44+01:00)			
2				
3	PMI Element (See Help > Analyze > PMI Coverage Analysis)	Count		Values as Compared to NIST Test Case Drawing
4	angularity_tolerance ∠	1		See Help > Analyze > NIST CAD Models
5	flatness_tolerance □	1		More than expected
6	perpendicularity_tolerance ⊥	2		Exact match
7	position_tolerance ⊕	6		Less than expected (upper third)
8	surface_profile_tolerance ⤴	3		Less than expected (middle third)
9	tolerance zone diameter (6.9.2)	7		Less than expected (lower third)
10	unit-basis tolerance (6.9.6)	1		None (0/n)
11	dimensions (location+size)	10/9		Unexpected (n/0)
12	dimensional location (5.1.1)	2		Not checked
13	dimensional size (5.1.5)	8/7		
14	directed dimension ⤵ (5.1.1)	1		
15	repetitive dimensions 'nX' (5.1, User Guide 6.1.3)	2		
16	dimension association to geometric tolerance (5.1)	8/7		
17	bilateral tolerance (5.2.3)	8		
18	diameter Ø (5.1.5)	8/7		
19	linear distance (5.1.1)	2		
20	reference dimension (5.3)	1		
21	datum (6.5)	6		
22	datum system (6.9.7)	11		
23	datum feature association to geometric tolerance (6.1)	8		
24	maximum_material_requirement (M) (6.9.3 or 6.9.7)	4		
25	saved views (9.4)	0/1		
26				
27	Section numbers above refer to the CAX-IF Recommended Practice for Representation and Presentation of PMI (AP242)			
28				
29	Expected PMI (See PMI Representation Summary worksheet)	%		
30	Exact match	96		
31	Partial match	4		
32	Possible match	0		
33	Missing match	0		
34	No match	4		
35	Total PMI	28		

Figure 89: Color-coded PMI Representation Coverage worksheet

7 Syntax Checker

The Syntax Checker checks for basic syntax errors and warnings in the STEP file related to missing or extra attributes, incompatible and unresolved entity references, select value types, illegal and unexpected characters, and other problems with entity attributes. Some errors might prevent SFA and other software from processing a STEP file.

There should not be any of these types of syntax errors in a STEP file. Errors should be fixed to ensure that the STEP file conforms to the STEP schema and can interoperate with other software. There are other validation rules defined by STEP schemas (where, uniqueness, and global rules, inverses, derived attributes, and aggregates) that are not checked. Conforming to the validation rules is also important for interoperability with STEP files.

The Syntax Checker can be run with function key F8 or when a Spreadsheet or View is generated. The Status tab might be grayed out when the Syntax Checker is running. The Syntax Checker works with any supported STEP schema.

Syntax checker results appear in the Status tab. If the Log File option is selected, the results are also written to a log file `myfile-sfa-err.log`. The syntax checker errors and warnings are not reported in the spreadsheet.

The Syntax Checker can also be run from the command-line version (Sec. 9) with the command line argument 'syntax'. For example: `sfa-cl.exe myfile.stp syntax`

Syntax Checker errors and warnings are unrelated to those reported when CAX-IF Recommended Practices are checked with one of the Analyze options as described in Sec. 6.5.

Figure 90 is an example of syntax checking results. The number in parentheses is the line number in the STEP file where the error or warning was detected.

```
Syntax Checker results for: C:/Users/test/Documents/syntax-err.stp
Generated by the NIST STEP File Analyzer and Viewer

syntax-err(13497): error: Reference to #4410 is geometric_curve_set, not compatible with representation.
syntax-err(14027): error: Reference to #4451 is geometric_curve_set, not compatible with representation.
syntax-err(20059): warning: Illegal control directive in string.
syntax-err(20060): error: Expecting ',', found _3DV instead.
syntax-err(20060): warning: Illegal character ''' in enum.
syntax-err(20060): warning: Illegal hyphens in keyword BS7752-1.
syntax-err(20060): warning: Unexpected character '{'.
syntax-err(20060): warning: Unexpected character '}'.
syntax-err(22973): error: Reference to #4451 is geometric_curve_set, not compatible with representation.
syntax-err(22976): error: Reference to #4451 is geometric_curve_set, not compatible with representation.
syntax-err(68577): error: Reference to #67531 is axis2_placement_3d, not compatible with representation_map.
syntax-err(68577): error: Reference to #67533 is representation_map, not compatible with representation_item.
syntax-err(68579): error: Reference to #4191 is geometric_curve_set, not compatible with representation.
syntax-err(68580): error: Reference to #67531 is axis2_placement_3d, not compatible with representation_map.
syntax-err(68580): error: Reference to #67536 is representation_map, not compatible with representation_item.
syntax-err: warning: Unresolved reference to instance #19750.
syntax-err: warning: Unresolved reference to instance #19751.
syntax-err: warning: Unresolved reference to instance #19752.
syntax-err: warning: Unresolved reference to instance #19753.
syntax-err: warning: Lowercase letters used in keywords. (8 occurrences)
```

Figure 90: Syntax Checker results

8 Multiple STEP Files

Processing multiple STEP files at once is an easy way to process many STEP files with only a few mouse clicks and to compare entity usage and coverage of PMI representation and presentation across multiple STEP files.

There are two ways you can select multiple STEP files. The first is to use the Open Multiple STEP Files in a Directory option from the File menu as shown in Figure 4. You can select a directory in which all STEP files in that directory will be processed. Subdirectories of the selected directory can also be searched. The other way is to select multiple individual STEP files when using the Open STEP File(s) option from the File menu. Multiple STEP files can be selected in the Open STEP File(s) dialog by holding down the control or shift key when selecting files.

8.1 Summary Worksheet

When processing multiple STEP files, a second spreadsheet is generated in addition to the individual spreadsheets for each STEP file. The second spreadsheet contains a summary worksheet of the entities found in the multiple files and possible coverage worksheets for PMI representation and presentation as shown in Figure 91. In this example five STEP files were processed. Starting after row 9, column A lists all of the entity types in all five files. All of the entities (rows) are not shown. The entities in column A are grouped and colored according to the categories of entities in the Process section of the Options tab. Columns B through F contain the entity counts for each of the five STEP files. Column G is the total entity count for all of the files and column H is the total number of files that an entity appears in.

Row 1 is the top-level directory where all of the STEP files are located. Row 3 contains links to the individual spreadsheets. Row 4 contains the name of the STEP file and a link to it. The file name can also contain the file's subdirectory. Clicking on the STEP file link will show it in whatever program is set to open STEP files (.stp file extension) on your computer. The links in rows 3 and 4 can be turned off in the Spreadsheet tab with the selections for Excel Options. Rows 5 through 9 contain, respectively, the file timestamp, software that generated the STEP file (blank in this example), the STEP AP from the file, the size of the STEP file, and the number of entities in the STEP file.

The gray cell B34 with the comment indicates that there is at least one perpendicularity_tolerance entity that has an error or warning (Sec. 6.5).

	A	B	C	D	E	F	G	H	I
1	STEP Directory	C:\Users\lipman\Documents\Analyzer\User Guide							
2									
3		Link (1)	Link (2)	Link (3)	Link (4)	Link (5)			
		nist ctc 01 asme1_ap242.stp	nist ctc 02 asme1_ap242.stp	nist ctc 03 asme1_ap242.stp	nist ctc 04 asme1_ap242.stp	nist ctc 05 asme1_ap242.stp			
4									
5		15-02-16	15-02-17	14-12-19	15-02-16	14-12-19			
6									
7		AP242e1	AP242e2	AP242e1	AP242e1	AP242e1			
8		390 KB	3381 KB	1261 KB	1073 KB	857 KB			
9	Entity	6139	45646	17312	17926	13400	Total Entities	Total Files	
31	(geometric_tolerance_with_datum_reference) (surface_profile_tolerance)	2	9	2	3		16	4	
	(geometric_tolerance_with_datum_reference) (surface_profile_tolerance)		3				3	1	
32	(unequally_disposed_geometric_tolerance) (geometric_tolerance_with_modifiers)								
33	(perpendicularity_tolerance)		1				1	1	
34	perpendicularity_tolerance	+ 1	2	2		2	7	4	
35	placed_datum_target feature		9			2	11	2	
36	plus_minus_tolerance	6	7	8	7	2	30	5	
37	roundness_tolerance					1	1	1	
38	shape_dimension_representation	8	7	10	9	6	40	5	
39	straightness_tolerance					1	1	1	
40	surface_profile_tolerance		1	1			2	2	
41	tolerance_value	6	7	8	7	2	30	5	
42	tolerance_zone		7	7	3	1	18	4	
43	tolerance_zone_form		7	7	3	1	18	4	
44	total_runout_tolerance					2	2	1	
45	annotation_curve_occurrence		46	30		22	98	3	
46	annotation_plane	22	46	4	25	7	104	5	
47	camera_model_d3 (characterized_representation)	1	11		1	2	15	4	
48	(draughting_model)	2			2	2	6	3	
49	colour		46	4			50	2	
50	colour_rgb	1	3	156	2	7	169	5	
51	curve_style	1	47	30	1	5	84	5	
52	draughting_callout	22			25	22	69	3	
53	draughting_model		12	1		1	14	3	
54	draughting_model_item_association	34	136	59	37	46	312	5	
55	draughting_pre_defined_colour	1	1	30	1	1	34	5	
56	draughting_pre_defined_curve_font	1	47	30	1	5	84	5	
	< >	File Summary	PMI Representation Coverage	+>					

Figure 91: File Summary worksheet, multiple files (rows 31-56)

8.2 Coverage Analysis Worksheets

If PMI representation or presentation is found in the STEP file, then coverage analysis worksheets are generated.

8.2.1 PMI Representation Coverage Analysis

Figure 92 and Figure 93 shows the worksheet that is generated for coverage analysis of PMI representation. The information on the worksheet is the same as described in Sec. 6.1.7. Columns B through F refer to five STEP files and contain the number of occurrences of that PMI element. Column G counts the total number of occurrences for all STEP files that contain that type of PMI element. In this example the cells are color-coded, as described in Sec. 6.6, because all five STEP files were generated from the NIST CAD models.

	A	B	C	D	E	F	G
1		C:\Users\lipman\Documents\Ana					
2							
		nist_dtc_01_asme1_ap242.stp	nist_dtc_02_asme1_ap242.stp	nist_dtc_03_asme1_ap242.stp	nist_dtc_04_asme1_ap242.stp	nist_dtc_05_asme1_ap242.stp	
	PMI Element						
3	(See Help > Analyze > PMI Coverage Analysis)						Total PMI
4	angularity_tolerance ∠			1			1
5	circular_runout_tolerance ↗					3	3
6	coaxiality_tolerance ◎					1/0	1
7	concentricity_tolerance ◎					0/1	0
8	flatness_tolerance □	1	1	1			3
9	line_profile_tolerance ∩		1				1
10	perpendicularity_tolerance ⊥	1	3	2		2	8
11	position_tolerance ⊕	2	4	6	3/4		15
12	roundness_tolerance ○					1	1
13	straightness_tolerance −					1	1
14	surface_profile_tolerance ⚡	2	13	3	3		21
15	total_runout_tolerance ∟					2	2
16	tolerance zone diameter (6.9.2)		7	7	3/4	1	18
17	all_around ∞ (6.4.2)	1					1
18	projected ⊕ (6.9.2.2)					0/1	0
19	unequally_disposed ⊕ or UZ (6.9.4)		3				3
20	unit-basis tolerance (6.9.6)			1			1
21	composite tolerance (6.9.9)				2		2
22	dimensions (location+size)	7	7	10/9	8/9	6	38
23	dimensional location (5.1.1)			2	2/3	5	9
24	dimensional size (5.1.5)	7	7	8/7	6	1	29
25	angular location (5.1.2)	1			1/0		2
26	angular size (5.1.6)				0/1		0
27	directed dimension ∞ (5.1.1)			1			1
28	derived shapes dimensional location (5.1.4)				1		1
29	repetitive dimensions 'nX' (5.1, User Guide 6.1.3)		0/2	2	3/8		5
30	dimension association to geometric tolerance (5.1)		5/7	8/7	2/3	0/1	15
31	dimension precision (5.4)					6	6
32	bilateral tolerance (5.2.3)	2	7	8	7	2	26
33	non-bilateral tolerance (5.2.3)	4					4
34	value range (5.2.4)	2					2

Figure 92: PMI Representation Coverage worksheet, multiple files (rows 1-34)

35	diameter Ø (5.1.5)	7	7	8/7	5/6	1	28
36	linear distance (5.1.1)			2	2	5	9
37	curve length (5.1.5)				1		1
38	dimension basic (5.3)				2	4	6
39	reference dimension (5.3)			1			1
40	datum (6.5)	3	10	6	8	4	31
41	datum system (6.9.7)	5	20	11	6/7	8	50
42	multiple datum features (6.9.8)					3/1	3
43	datum feature association to geometric tolerance (6.1)	1	6	8		1/2	16
44	all datum targets		9			2	11
45	point datum target (6.6.1)		8			2/0	10
46	rectangle datum target (6.6.1)					0/2	0
47	circle datum target (6.6.1)		1				1
48	least_material_requirement Ⓛ (6.9.3 or 6.9.7)		7				7
49	maximum_material_requirement Ⓜ (6.9.3 or 6.9.7)		5	4			9
50	statistical_dimension <ST> (5.3)					1	1
51	saved views (9.4)	1	3	0/1	1	2	7
52	ISO modeling standard (4, Fig. 2)					1	1
53							
54	Section numbers above refer to the CAX-IF Recommended Practice for Representation and						
55							
56	Expected PMI (% from PMI Representation Summary worksheets)						
57	Exact match	94	88	96	73	83	
58	Partial match	0	12	4	18	4	
59	Possible match	6	0	0	0	4	
60	Missing match	0	0	0	9	8	
61	No match	12	12	4	5	17	
62	Total PMI	17	52	28	22	24	
<div> <div> <div>File Summary</div> <div>PMI Representation Coverage</div> <div>+</div> </div> </div>							

Figure 93: PMI Representation Coverage worksheet, multiple files (rows 35-62)

8.2.2 PMI Presentation Coverage Analysis

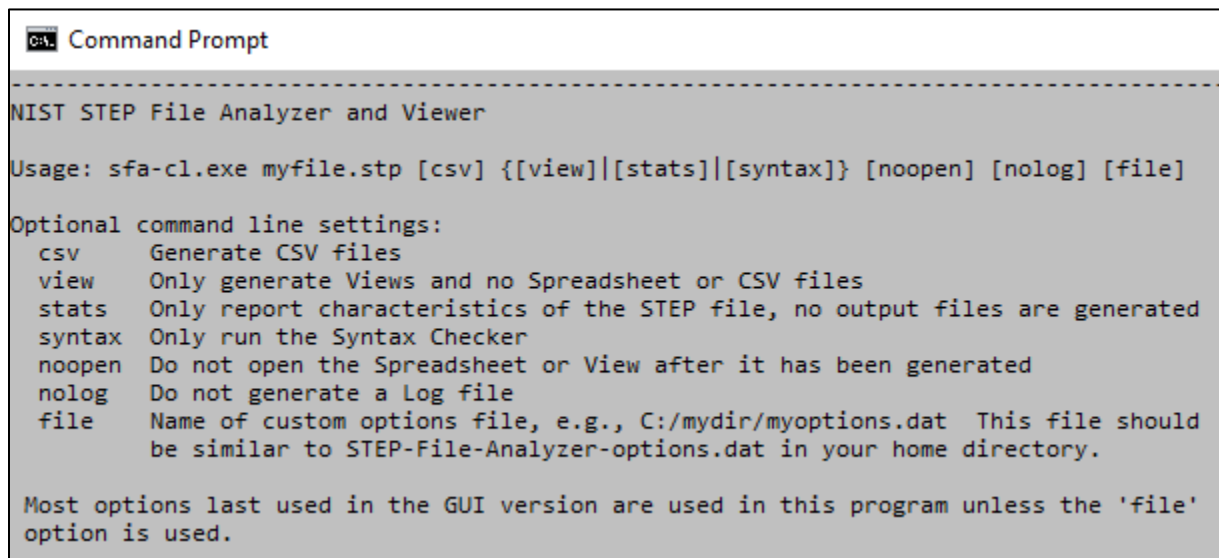
Figure 94 shows the worksheet that is generated for coverage analysis of PMI presentation. The information in the worksheet is the same as described in Sec. 6.2.1. Columns B through F refer to five STEP files and contain the number of occurrences of that PMI presentation name. Column G counts the total number of occurrences for all STEP files that contain that name.

	A	B	C	D	E	F	G	H	I	J	K
1	STEP Directory	C:\Users\lipman\Documents\Analyzer\User-Guide									
2											
		nist_dtc_01_asme1_ap242.stp	nist_dtc_02_asme1_ap242-1.stp	nist_dtc_03_asme1_ap242.stp	nist_dtc_04_asme1_ap242.stp	nist_dtc_05_asme1_ap242-1.stp					
3	PMI Presentation Names						Total PMI				
4	angularity			1			1				
5	circular runout				3		3				
6	circularity				1		1				
7	coaxiality										
8	concentricity				1		1				
9	cylindricity										
10	flatness	1	1	1			3				
11	parallelism										
12	perpendicularity	1	3	2	2		8				
13	position	2	4	6	3		15				
14	profile of line		1				1				
15	profile of surface	2	13	3	2		20				
16	roundness										
17	straightness				1		1				
18	symmetry										
19	total runout				2		2				
20	general tolerance										
21	linear dimension	2		2	4	6	14				
22	radial dimension										
23	diameter dimension	7	7	8	6		28				
24	angular dimension	1			1		2				
25	ordinate dimension										
26	curve dimension										
27	general dimension										
28	datum	3	15	6	8	2	34				
29	datum target				2		2				
30	note			1			1				
31	label	3	1		1		5				
32	surface roughness										
33	weld symbol										
34	general note										
35	over riding style set										
36											
37	Presentation Names defined in Representation and Presentation of PMI (AP242), Sec. 8.4, Table 14										
	< >	File Summary	PMI Representation Coverage	PMI Presentation Coverage							

Figure 94: PMI Presentation Coverage worksheet, multiple files

9 Command-line Version

A command-line (console) version of SFA is available (sfa-cl.exe) that can be run from a Windows command prompt. SFA can also be accessed by or embedded in other programs. The command-line version will use the options that were last used in the GUI version of SFA. Figure 95 shows the options available for the command-line version.



```
Command Prompt

-----
NIST STEP File Analyzer and Viewer

Usage: sfa-cl.exe myfile.stp [csv] {[view] |[stats] |[syntax]} [noopen] [nolog] [file]

Optional command line settings:
  csv      Generate CSV files
  view     Only generate Views and no Spreadsheet or CSV files
  stats    Only report characteristics of the STEP file, no output files are generated
  syntax   Only run the Syntax Checker
  noopen   Do not open the Spreadsheet or View after it has been generated
  nolog    Do not generate a Log file
  file     Name of custom options file, e.g., C:/mydir/myoptions.dat  This file should
           be similar to STEP-File-Analyzer-options.dat in your home directory.

Most options last used in the GUI version are used in this program unless the 'file'
option is used.
```

Figure 95: Command-line version options

To facilitate running the command-line version, the PATH environment variable can be set to include the directory where the command-line executables are located. A batch file can also be created to run the command-line executable. If the STEP file is not located in the same directory as the command-line executable, then the STEP file name should also include the directory pathname for the file. When the command-line version is run, feedback is provided that is similar to what is shown in the Status tab as shown in Figure 96. Error and warning messages are preceded with asterisks (*) and highlighted with a different font and background color.

```

Command Prompt
-----
NIST STEP File Analyzer and Viewer
Reading options file: C:\...\STEP-File-Analyzer-options.dat

*** Begin ST-Developer output
                ST-DEVELOPER
                System Release v10

                Copyright (c) 1991-2003 by
                STEP Tools Inc., Troy, New York
                All Rights Reserved
                -----
*** End ST-Developer output

Opening STEP AP242 file

*** Begin ST-Developer output
** Check for error or warning messages up to 'End ST-Developer output' below
Reading: C:\Users\lipman\Documents\Analyzer\User Guide\nist_ctc_03_asme1_ap242.stp
Reading: C:\PROGRA~2\IFCsvrR300\dll\header_section_schema.rose
Reading: C:\PROGRA~2\IFCsvrR300\dll\ap242_managed_model_based_3d_engineering_mim_lf.rose
Reading: C:\PROGRA~2\IFCsvrR300\dll\keystone_extensions.rose
nist_ctc_03_asme1_ap242(7): "ListOfblend_radius_variation_type": Best-fit class is "RoseEnumList".
nist_ctc_03_asme1_ap242(7): "SetOfgeometric_tolerance_modifier": Best-fit class is "RoseEnumSet".
nist_ctc_03_asme1_ap242(7): "SetOfgeometric_tolerance_modifier": Best-fit class is "RoseEnumSet".
nist_ctc_03_asme1_ap242(7): "ListOfa3m_element_type_name": Best-fit class is "RoseEnumList".
nist_ctc_03_asme1_ap242(7): "ListOfa3m_detected_difference_type_name": Best-fit class is "RoseEnumList".
nist_ctc_03_asme1_ap242(7): "ListOfa3m_accuracy_type_name": Best-fit class is "RoseEnumList".
nist_ctc_03_asme1_ap242(7): "SetOfsummary_report_style_type": Best-fit class is "RoseEnumSet".
*** End ST-Developer output

17312 entities
This file contains: Datums, Dimensions, Geometric tolerances, Graphical PMI (polyline), Part geometry, Supplemental geom
etry

Generating Header worksheet
Name: nist_ctc_03_asme1_ap242
FileDirectory: C:\Users\lipman\Documents\Analyzer\User Guide\
FileDescription: CTC-03 geometry with PMI representation and/or presentation, from the NIST MBE PMI Validation and Conf
ormance Testing Project, https://go.usa.gov/mGVm
FileImplementationLevel: 2;1
FileTimeStamp: 2014-12-19T16:21:44+01:00
FileAuthor:
FileOrganization:
FilePreprocessorVersion:
FileOriginatingSystem:
FileAuthorisation:
SchemaName: AP242_MANAGED_MODEL_BASED_3D_ENGINEERING_MIM_LF {1 0 10303 442 1 1 4 } (Edition 1)

Reading Expected PMI Representation Coverage

Generating STEP Entity worksheets
dimensional_characteristic_representation (10)
Adding PMI Representation Analysis
** Dimension units: INCH
** Multiple (2) dimensions '@1.500 ± .005' and '@1.5' are associated with the same geometry. (IDs 10546 10656) [spmiD
mtolReport]
datum (6)
datum_feature (6)
Adding PMI Representation Analysis
datum_reference_compartment (26)
Adding PMI Representation Analysis
** The datum_reference_compartment 'name' attribute should be blank. [spmiGeotolReport]
*** Syntax Error: The datum_reference_compartment 'product_definitional' attribute should be FALSE.
(Representation and Presentation of PMI (AP242), Sec. 3.4)
datum_system (6)
Adding PMI Representation Analysis
dimensional_location (1)
dimensional_size (8)

```

Figure 96: Command-line version output

10 References

All websites were successfully accessed in October 2021.

- [1] S. Kwon, *STEP to X3D Translator*, National Institute of Standards and Technology, <https://www.nist.gov/services-resources/software/step-x3d-translator>.
- [2] R. Lipman, "STEP File Analyzer Software," *Journal of Research of the National Institute of Standards and Technology*, vol. 122, 2017, doi:<https://doi.org/10.6028/jres.122.016>.
- [3] ISO 10303-1:1994, "Industrial automation systems and integration - Product data representation and exchange - Part 1: Overview and fundamental principles," International Organization for Standardization, Geneva, Switzerland.
- [4] M. J. Pratt, "Introduction to ISO 10303 - the STEP standard for product data exchange," *Journal of Computing and Information Science in Engineering*, vol. 1, pp. 102-103, 2001.
- [5] ISO 10303-21:2016, "Industrial automation systems and integration - Product data representation and exchange - Part 21: Implementation methods: Clear text encoding of the exchange structure," International Organization for Standardization, Geneva, Switzerland.
- [6] *STEP-file, ISO 10303-21*, U. S. Library of Congress, <https://www.loc.gov/preservation/digital/formats/fdd/fdd000448.shtml>.
- [7] ISO 10303-203:2011, "Industrial automation systems and integration - Product data representation and exchange - Part 203: Application protocol: Configuration controlled 3D design of mechanical parts and assemblies," International Organization for Standardization, Geneva, Switzerland.
- [8] ISO 10303-209:2014, "Industrial automation systems and integration - Product data representation and exchange - Part 209: Application protocol: Multidisciplinary analysis and design," International Organization for Standardization, Geneva, Switzerland.
- [9] *ISO 10303-209 Multidisciplinary Analysis and Design*, <http://www.ap209.org>.
- [10] ISO 10303-210:2011, "Industrial automation systems and integration - Product data representation and exchange - Part 210: Application protocol: Electronic assembly, interconnect, and packaging design," International Organization for Standardization, Geneva, Switzerland.
- [11] ISO 10303-214:2010, "Industrial automation systems and integration - Product data representation and exchange - Part 214: Application protocol: Core data for automotive mechanical design processes," International Organization for Standardization, Geneva, Switzerland.
- [12] ISO 10303-238:2007, "Industrial automation systems and integration - Product data representation and exchange - Part 238: Application protocol: Application interpreted model for computerized numerical controllers," International Organization for Standardization, Geneva, Switzerland.
- [13] *ISO 10303-238 STEP-NC Standard*, <http://www.ap238.org>.
- [14] ISO 10303-239:2012, "Industrial automation systems and integration - Product data representation and exchange - Part 239: Application protocol: Product life cycle support," International Organization for Standardization, Geneva, Switzerland.
- [15] *AP239 - Product Life Cycle Support*, <http://www.ap239.org>.
- [16] ISO 10303-242:2020, "Industrial automation systems and integration - Product data representation and exchange - Part 242: Application protocol: Managed Model-based 3D Engineering," International Organization for Standardization, Geneva, Switzerland.
- [17] *Development of a Convergent Modular STEP Application Protocol Based on AP 203 and AP 214: STEP AP 242 – Managed Model Based 3D Engineering*, ASD Strategic Standardization Group, 2009, <http://www.ap242.org>.

- [18] A. B. Feeney, S. P. Frechette, and V. Srinivasan, "A Portrait of an ISO STEP Tolerancing Standard as an Enabler of Smart Manufacturing Systems," *Journal of Computing and Information Science in Engineering*, vol. 15, 2015.
- [19] *ISO 13399 Cutting Tool Data*, https://en.wikipedia.org/wiki/ISO_13399.
- [20] *ISO 13584 Parts Library (PLIB)*, https://en.wikipedia.org/wiki/ISO_13584.
- [21] ISO 16739-1:2018, "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries," International Organization for Standardization, Geneva, Switzerland.
- [22] R. Lipman, "IFC File Analyzer Software," *Journal of Research of the National Institute of Standards and Technology*, vol. 122, 2017, doi:<https://doi.org/10.6028/jres.122.015>.
- [23] *Industry Foundation Classes*, buildingSMART, <https://technical.buildingsmart.org/>.
- [24] C. Eastman, F. Wang, S. J. You, and D. Yang, "Deployment of an AEC industry sector product model," *Computer-Aided Design*, vol. 37, pp. 1214-1228, 2005, doi:<http://dx.doi.org/10.1016/j.cad.2004.11.007>.
- [25] R. Lipman, "SteelVis User's Guide," National Institute of Standards and Technology, NISTIR 7822, 2011.
- [26] *CAX Interoperability Forum*, https://www.cax-if.org/cax/cax_introduction.php.
- [27] *ISO 10303 STEP Standards*, STEP Tools, Inc., <https://www.steptools.com/stds/step/>.
- [28] *CAX-IF Recommended Practices*, CAX Implementor Forum, https://www.cax-if.org/cax/cax_recommPractice.php.
- [29] ISO 10303-11:2004, "Industrial automation systems and integration - Product data representation and exchange - Part 11: Description methods: The EXPRESS language reference manual," International Organization for Standardization, Geneva, Switzerland.
- [30] *EXPRESS data modeling language, ISO 10303-11*, U. S. Library of Congress, <https://www.loc.gov/preservation/digital/formats/fdd/fdd000449.shtml>.
- [31] T. Vernica, R. Lipman, and W. Bernstein, "Visualizing Model-based Product Definitions in Augmented Reality," *Proceedings of the ASME IDETC/CIE 2021*, 2021.
- [32] *X3DOM*, Fraunhofer IGD, <https://www.x3dom.org>.
- [33] *Extensible 3D (X3D) File Format Family*, U. S. Library of Congress, <https://www.loc.gov/preservation/digital/formats/fdd/fdd000490.shtml>.
- [34] S. P. Frechette, A. T. Jones, and B. R. Fischer, "Strategy for Testing Conformance to Geometric Dimensioning & Tolerancing Standards," *Procedia CIRP*, vol. 10, pp. 211-215, 2013, doi:<http://dx.doi.org/10.1016/j.procir.2013.08.033>.
- [35] ASME Y14.41-2012, "Digital Product Definition Data Practices - Engineering Drawing and Related Documentation Practices," American Society of Mechanical Engineers, 2012, New York.
- [36] ISO 16792:2006, "Technical product documentation - Digital product definition data practices," International Organization for Standardization, Geneva, Switzerland.
- [37] J. Boy and P. Rosche, "Recommended Practices for Representation and Presentation of Product Manufacturing Information (PMI) (AP242)," CAX Implementor Forum, 2020.
- [38] R. Lipman, *MBE PMI Validation and Conformance Testing*, National Institute of Standards and Technology, <https://www.nist.gov/el/systems-integration-division-73400/mbe-pmi-validation-and-conformance-testing>.
- [39] J. Boy and P. Rosche, "Recommended Practices for Geometric and Assembly Validation Properties," CAX Implementor Forum, 2019.
- [40] J. Lubell, "From Model to Markup," in *Proceedings of the 2002 XML Conference*, 2002.