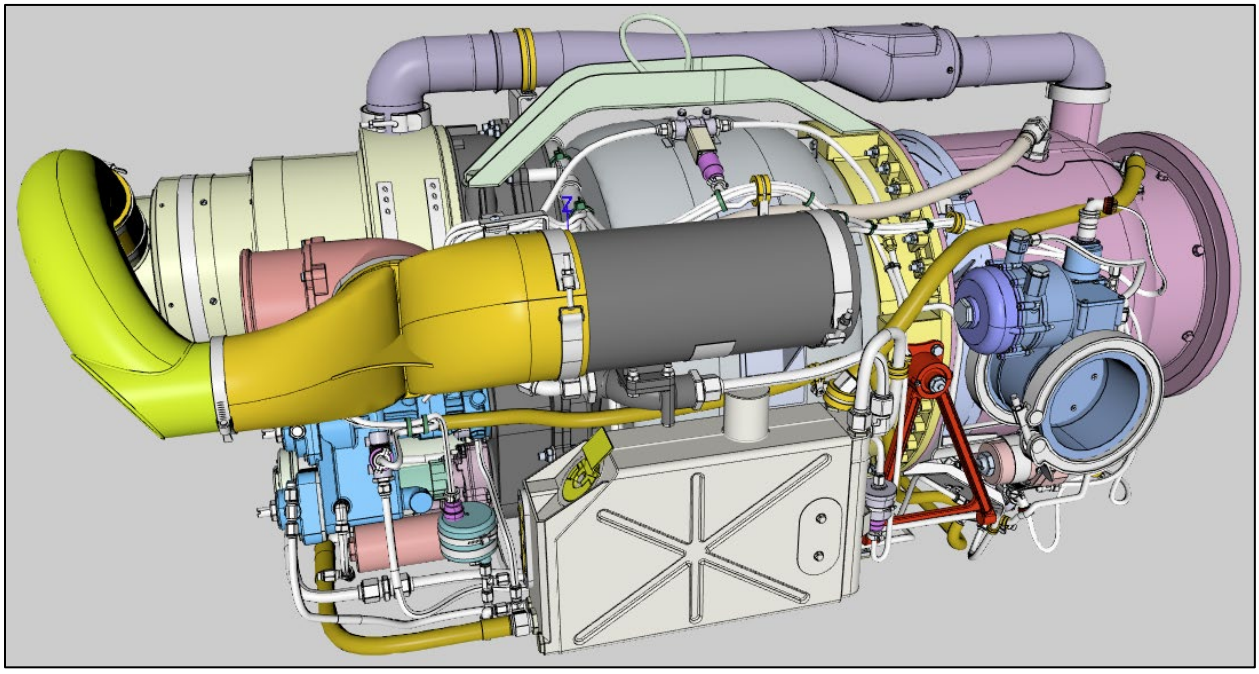
NIST Advanced Manufacturing Series 200-10

STEP File Analyzer and Viewer User Guide (Update 6)

Robert R. Lipman
Soonjo Kwon

This publication is available free of charge from:
https://doi.org/10.6028/NIST.AMS.200-10



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

NIST Advanced Manufacturing Series 200-10

STEP File Analyzer and Viewer User Guide (Update 6)

Robert R. Lipman
Soonjo Kwon
Systems Integration Division
Engineering Laboratory

This publication is available free of charge from:
https://doi.org/10.6028/NIST.AMS.200-10

June 2020

U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Institute of Standards and Technology
Walter Copan, NIST Director and Under Secretary of Commerce for Standards and Technology

National Institute of Standards and Technology Advanced Manufacturing Series 200-10
Natl. Inst. Stand. Technol. Adv. Man. Ser. 200-10, 86 pages (June 2020)

This publication is available free of charge from:
https://doi.org/10.6028/NIST.AMS.200-10

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, 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 **S**TEP **F**ile **A**nalyzer and Viewer.

UPDATES

The first version of this User Guide was published in 2012. For Update 6 of this guide, in addition to updated figures, new content is found on this page and in sections: (1) Introduction, (3.4) Options tab, (4) Viewer, (5) Spreadsheets, (6.1.7, 6.5.2, 8.2.1) PMI Representation Coverage Analysis, and (7) Syntax Checker. Many sections have been reordered from the previous version.

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 guest research at NIST from the Korea Advanced Institute of Science and Technology (KAIST), developed the software that converts STEP to X3D for viewing part geometry as described in section 4.1. That software is based on the Open CASCADE STEP Processor [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

LIST OF TABLES

LIST OF FIGURES

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].

In this report the acronym **SFA** will be used for the **S**TEP **F**ile **A**nalyzer 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.

- AP203 – Configuration Controlled 3D Design of Mechanical Parts and Assemblies [6]
  - The older version of AP203 is known as Config Control Design
- AP209 – Multidisciplinary Analysis and Design [7, 8]
  - The older version of AP209 is known as Structural Analysis Design
- AP210 – Electronic Assembly Interconnect and Packaging Design [9]
- AP214 – Automotive Design [10]
- AP238 – Integrated CNC Schema [11, 12]
  - The newer version of AP238 is known as Model Based Integrated Manufacturing Schema
- AP239 – Product Life Cycle Support (PLCS) [13, 14]
- AP242 – Managed Model Based 3D Engineering [15-17]

IFC (Industry Foundation Classes) [18-20] and CIS/2 (CIMsteel Integration Standards) [21, 22], used in the building and structural steel industries, respectively, are also supported. Parts 25 and 42 from the ISO 13584 Parts Library (PLIB) schema are also supported. A complete list of supported APs can be found in the SFA Help menu under Supported STEP APs.

There are four main features of SFA.

1. SFA is a viewer for part geometry, sketch geometry, graphical PMI annotations, tessellated part geometry, supplemental geometry, 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) [23]. 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 was developed for Windows computers and is a 32-bit application. Microsoft Excel is required to generate a spreadsheet. 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 five files:

1. STEP-File-Analyzer.exe – Graphical user interface (GUI) version of SFA
2. STEP-File-Analyzer-CL.exe – Command-line version (section 9)
3. SFA-User-Guide-v6.pdf – This User Guide
4. SFA-README-FIRST.pdf – A readme file
5. STEP-File-Analyzer-changelog.xlsx – Summary of new and updated features

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. The What's New information is shown in the Status tab.
2. The Disclaimers dialog is opened.
3. This User Guide is opened.
4. You are asked if a shortcut to SFA can be created in the Start Menu and if an icon for SFA can be placed on the Desktop.
5. The Crash Recovery dialog is opened (section 2.4).
6. A file STEP-File-Analyzer-options.dat is created in your home directory that stores the current state of SFA options. Do not edit this file.
7. The installation for the IFCsvr toolkit is automatically started.

2.2.1 Install IFCsvr

The IFCsvr toolkit[1] is used 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 with SFA.

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

Although the IFCsvr toolkit was originally written to process IFC files [18] used in the building and construction industry, it has been adapted to work with STEP files.

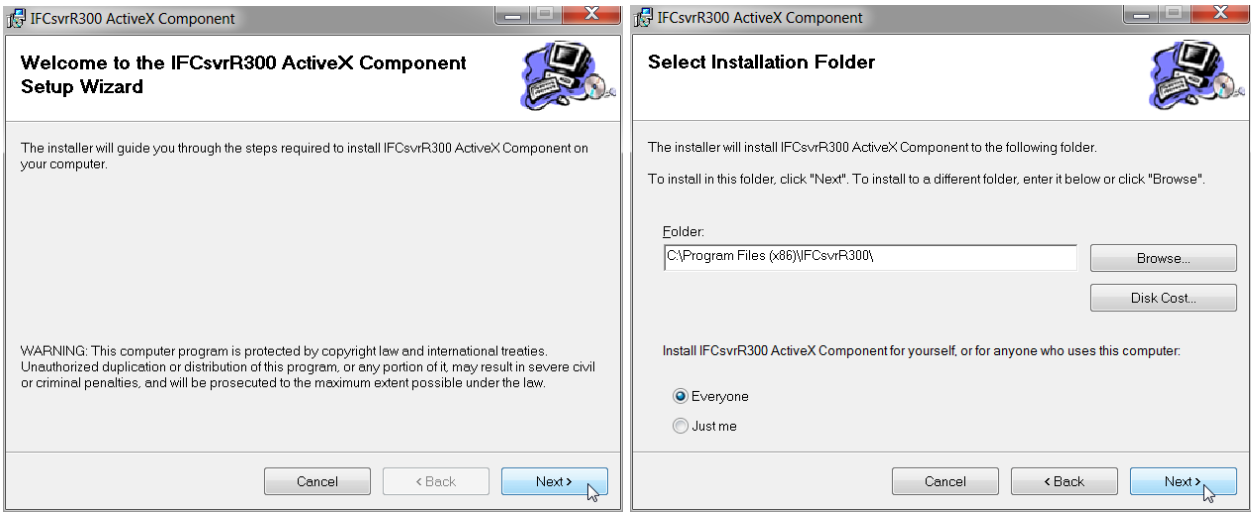


Figure 1: IFCsvr installation dialogs

Sometimes with a new version of SFA, you will be prompted 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 user the Viewer for Part Geometry (section 4.1). Select View Only and Part Only in the Output Format section of the Options tab (section 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 Recover from a Crash

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 might also crash when processing very large STEP files. Figure 2 shows a dialog that is opened the first few times SFA is run. SFA keeps track of which entity type caused the crash for a particular STEP file and will not process that type again. More details about recovering from a crash are explained in section 10.

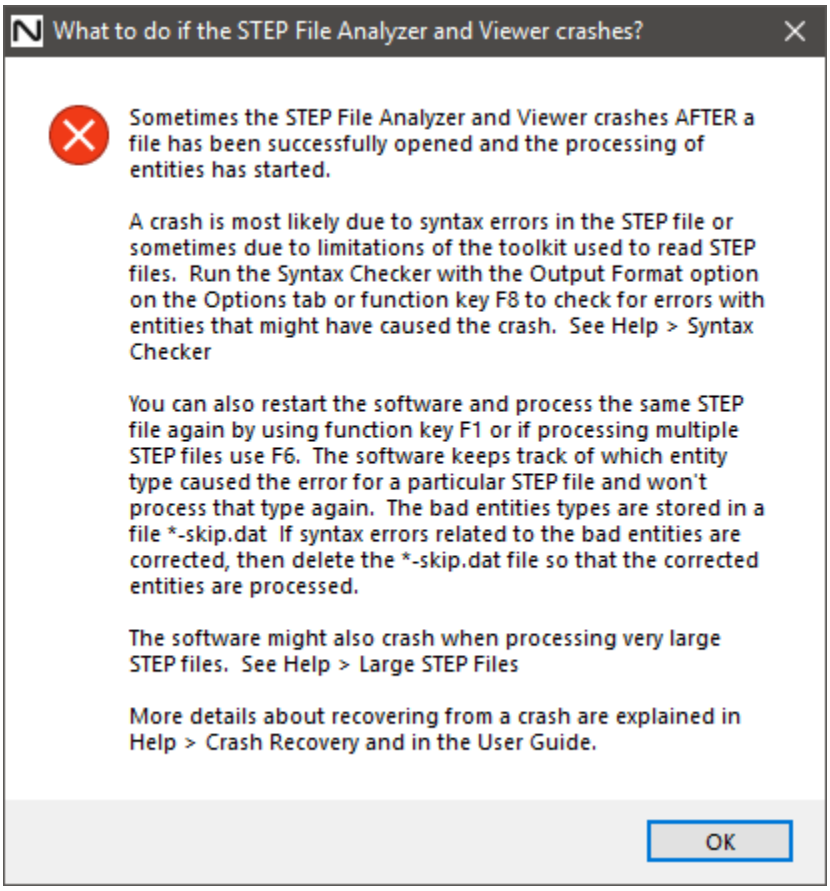


Figure 2: What to do if the STEP File Analyzer and Viewer crashes

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 running on a Windows 10 computer. 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.

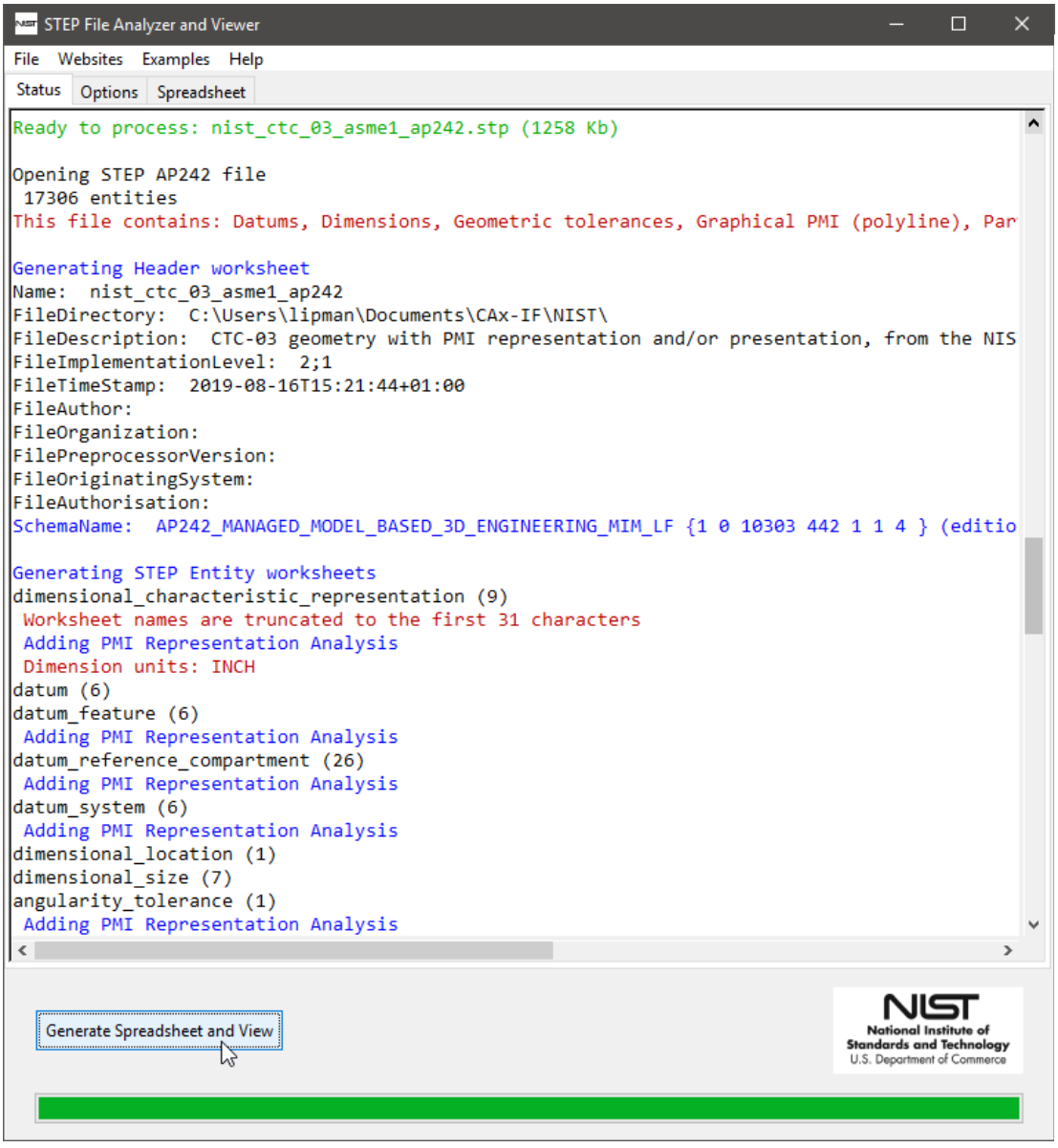


Figure 3: User interface

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, 24] (section 5.7). 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 section 8.1.

Below the first solid line in the File menu is a list of up to 20 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.

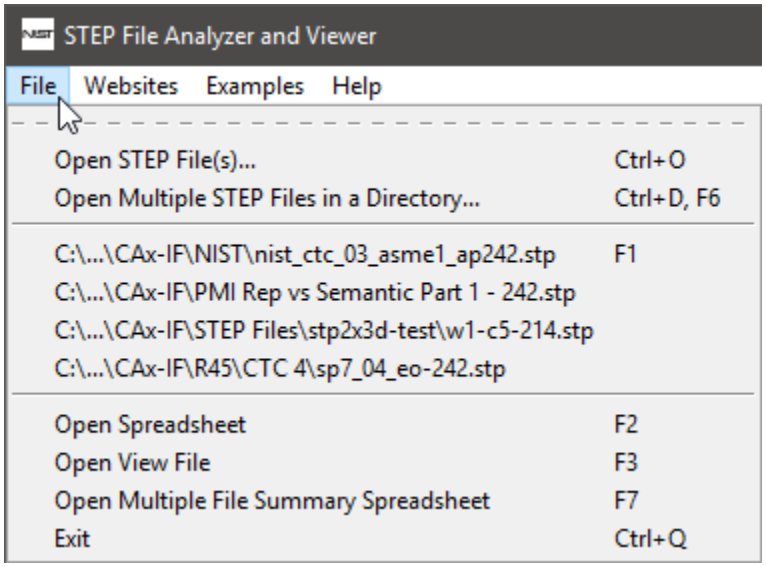


Figure 4: File menu

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, Interoperability Forums (IF), AP242, and the STEP format, schemas, software, and related organizations.

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.

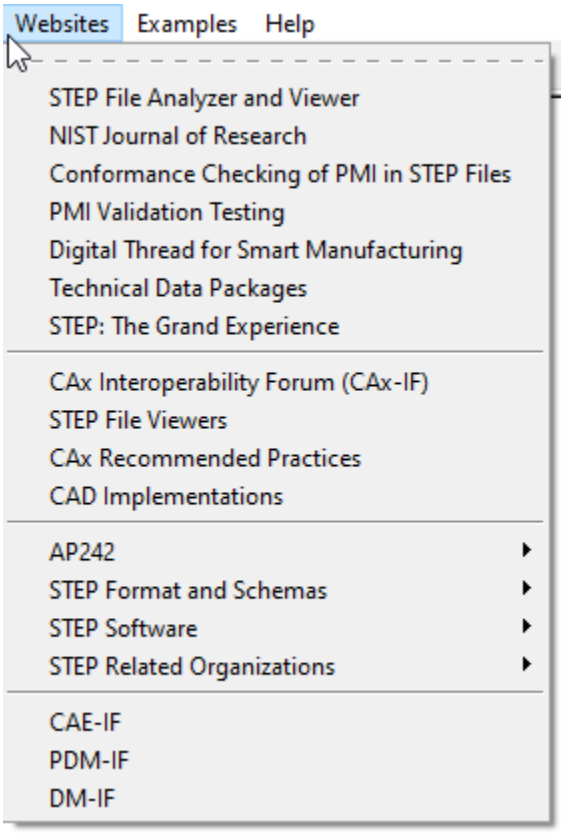


Figure 5: Websites menu

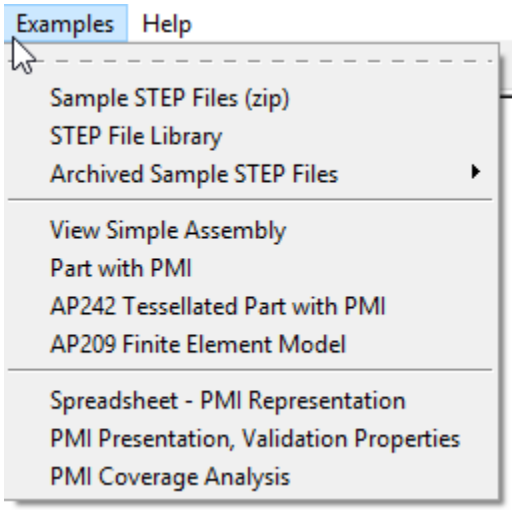


Figure 6: Examples menu

3.1.4 Help Menu

The Help Menu, shown in Figure 7, has six sections. In the first section, User Guide a link to this document. What's New shows information in the Status tab about important new features in SFA. 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 hasn't 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.

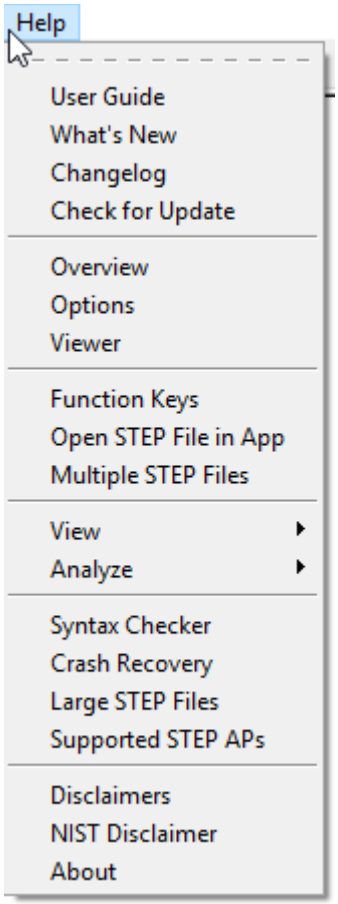


Figure 7: Help menu

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 AP242 tooltip help in the Options tab is shown in Figure 8.

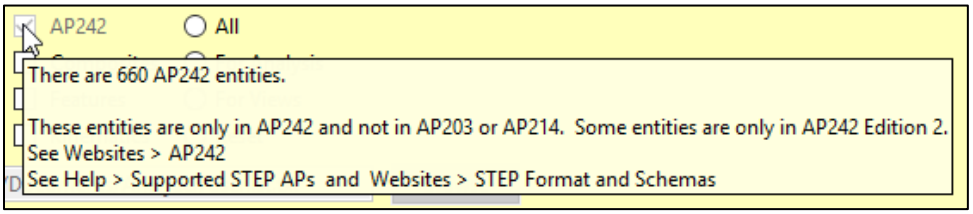


Figure 8: Tooltip help

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 is generated from a STEP file. The options in the Options and Spreadsheet tabs are described in sections 3.4 and 3.5.

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 (section 6.4) highlighted with a red background are for nonconformance of some aspect of the STEP file to a CAx-IF recommended practice [25]. Information in the Status tab is shown in Figure 3 and section 6.4.

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

The following general sequence of status messages appears in the Status tab when a STEP file is processed:

- Messages about Opening STEP file and Number of entities
- Message about Generating Header worksheet and information from the STEP file header section
- STEP entities listed in the order they are processed
    - The number in parentheses is the number of entities of that type in the STEP file
    - The types of entities processed depends on the entities selected in the Process section of the Options tab (section 3.4.2)
- Possible messages about inverse relationships (section 5.6.1), checking recommended practices (section 6), and syntax errors (section 6.4)
- Messages about Generating Summary worksheet, Formatting Worksheets, and Processing time
- Messages about Saving and Opening the spreadsheet and view

3.4 Options Tab

Figure 9 shows the Options tab that enables you to control which entities from the STEP file are written to the spreadsheet, to add supplemental analysis reports to some worksheets, and to generate views. Inverse Relationships are described in section 5.6.1.

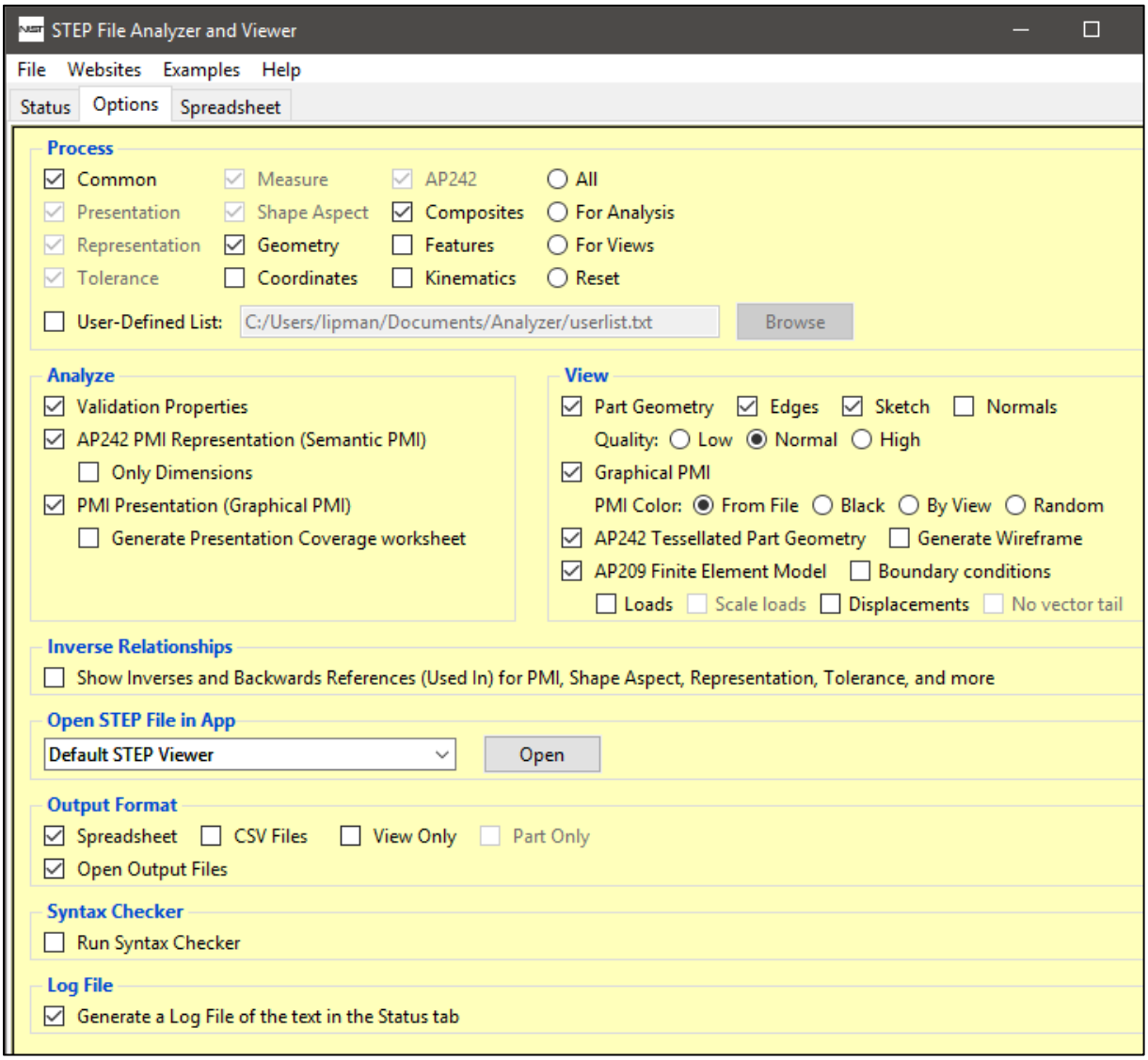


Figure 9: Options tab

3.4.1 Output Format

Information in a STEP file can be output to a spreadsheet or set of CSV files. If Excel is installed, then a spreadsheet and CSV files can be generated. If Excel is not installed, only CSV files can be generated. If Excel is not installed, some features are not available with CSV files such as Reports (section 6) and Inverse Relationship (section 5.6.1). 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.

Use the View Only option to only generate views without generating a spreadsheet or CSV files. Use the Part Only option to view only part geometry.

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 entities on the File Summary worksheet. All entities unique to APs and schemas other than AP203, AP214, and AP242 are always processed, including AP209, AP210, AP238, AP239, IFC, and CIS/2.

As a convenience, several buttons are available to quickly select multiple options.

- All selects all categories except Geometry and Coordinates.
- For Reports selects all Analyze options and associated entity categories.
- For Views selects all View options and associated entity categories.
- Reset deselects all categories, except for Common, and all reports and views.

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

By processing only certain types of entities, the size of and time to generate a spreadsheet can be reduced. The categories of entities are also used to order and color the entity names on the Summary worksheet and tabs for the entity worksheets as shown in Figure 34. Each category of entities is assigned a different color and within each category the entities are listed in alphabetic order.

Holding your mouse over some of 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 specifies that there are 32 entities in the Shape Aspect category. Some of the categories contain hundreds of entities where the associated tooltip might not fit on the screen or be displayed.

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.

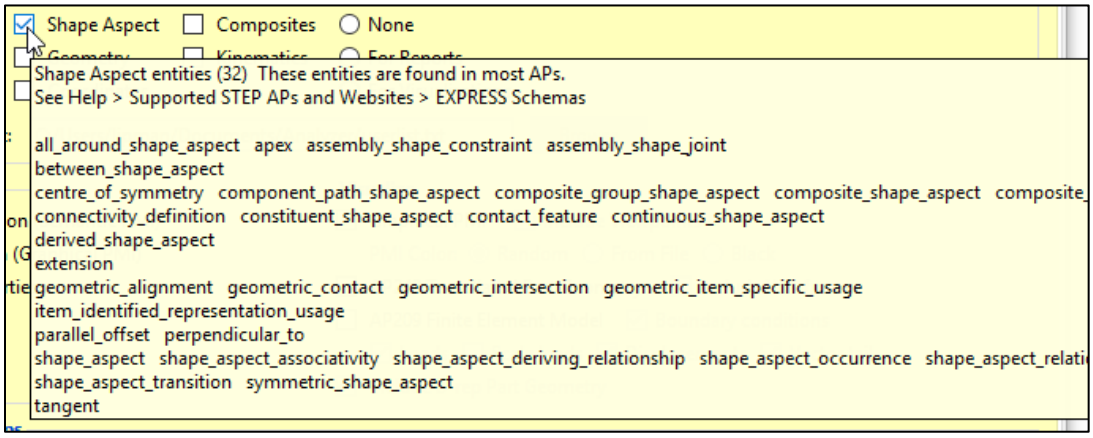


Figure 10: Tooltip help for Shape Aspect entities

3.4.3 Analysis Reports

Recommended practices 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 [25]. Recommended practices are not part of ISO 10303 EXPRESS schema.

SFA checks the STEP file for conformance to those recommended practices. Details about entity attribute values that specify conformance are reported on various worksheets. Non-conformance 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 Apps

The Open STEP File in Apps 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.

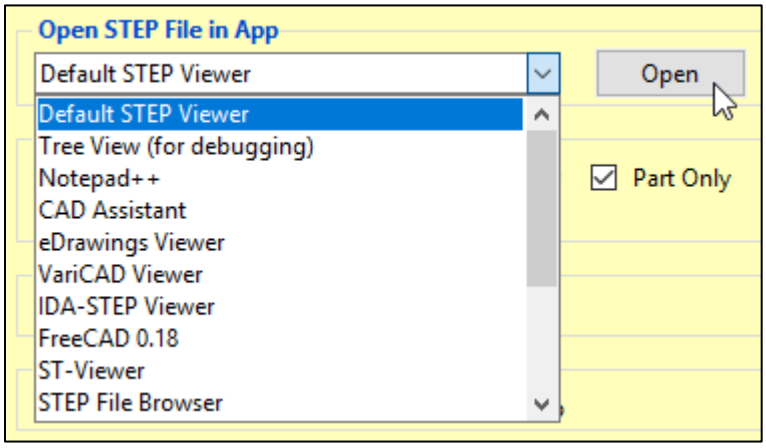


Figure 11: Open STEP File in other applications

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.

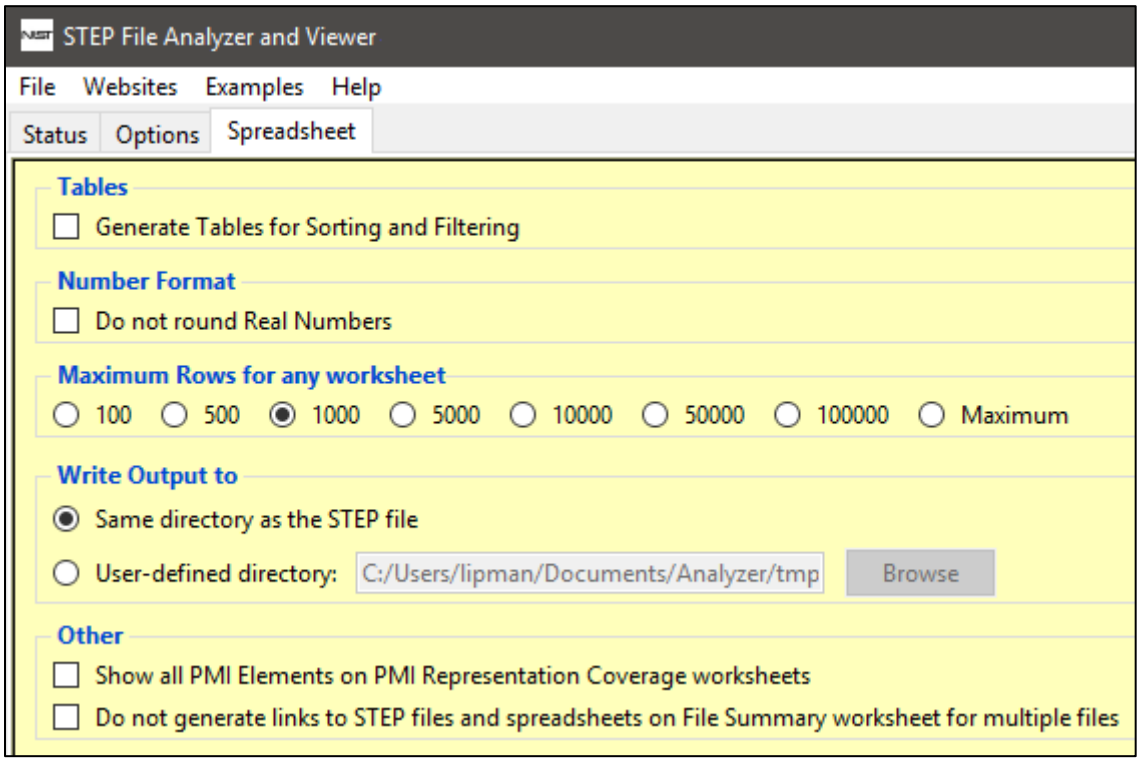


Figure 13: Spreadsheet tab

Section 5.6.2 shows an example of the Tables option. Section 5.6.3 shows an example of the Number Format option. Section 5.6.4 shows an example of the Maximum Rows option.

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 [26]. 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. View examples are available at https://pages.nist.gov/CAD-PMI-Testing/. The viewer does not support measurements.

In the view, the origin of the model at '0 0 0' is shown with a small XYZ coordinate axis that can be switched off. The background color can be changed between white, blue, gray, and black. Depending on your web browser, the appearance of checkboxes and sliders might be different than what is shown in the figures below.

Also 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 Page Up/Down to switch between perspective and orthographic projection modes. Navigation is easier in perspective mode.

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 View Only and Part Only in the Output Format section on the Options tab.

On the right is the dimensions of the part bounding box. 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.

On the right is a list of checkboxes for the parts and/or assemblies in the model. Switching parts and assemblies on and off is a work-in-progress. Most assemblies and parts can be switched on and off depending on the assembly structure. 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 or cause the viewer to crash.

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.

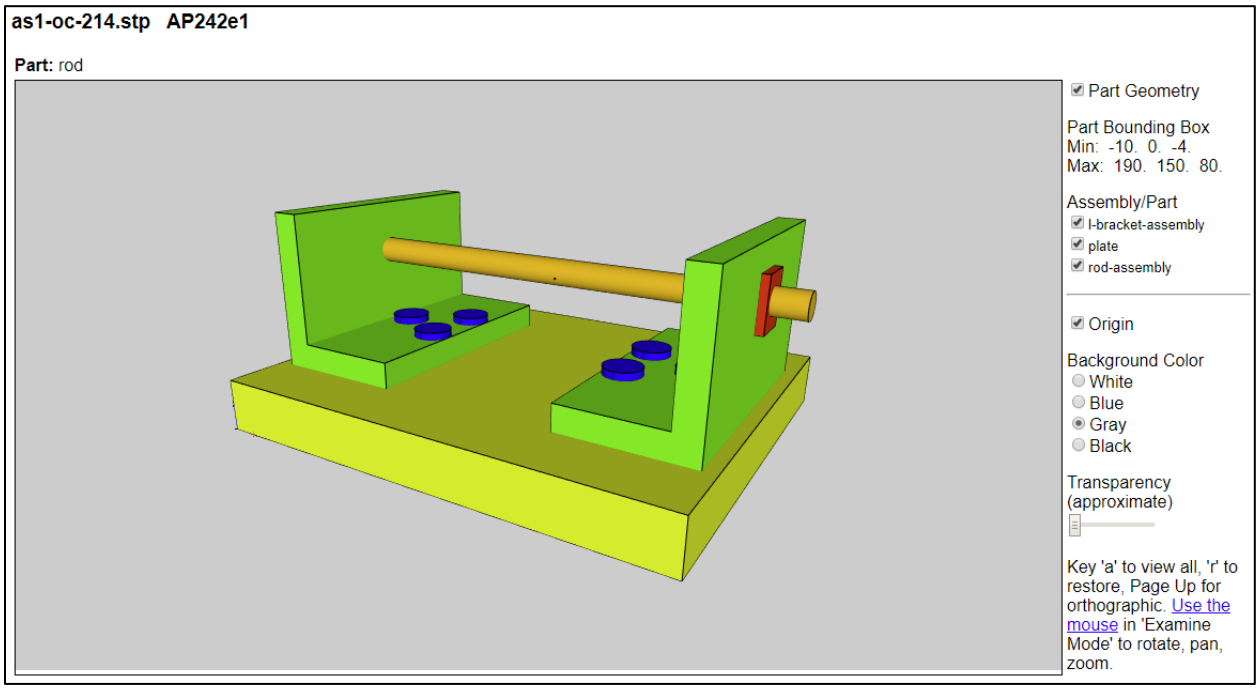


Figure 14: Part geometry view

Figure 15 shows the assembly with the rod-assembly switched off. Figure 20 below shows an example of a longer Assembly/Part list on the right.

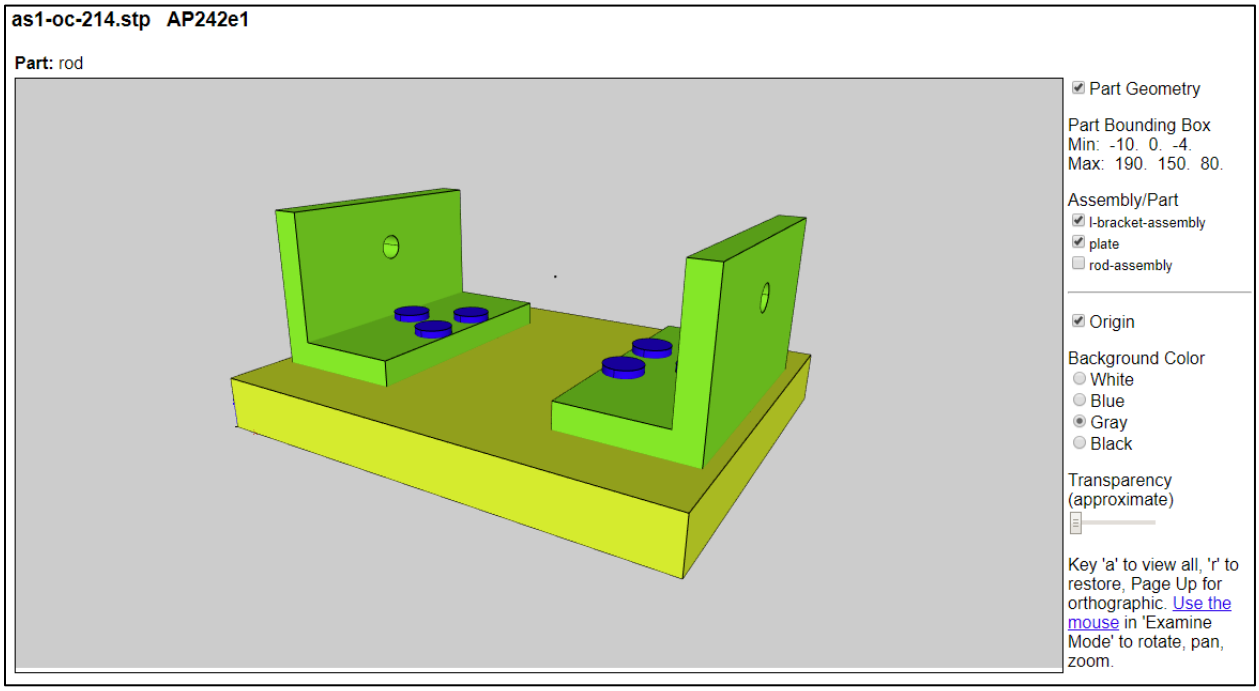


Figure 15: Part geometry view with rod-assembly switched off

Figure 16 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.

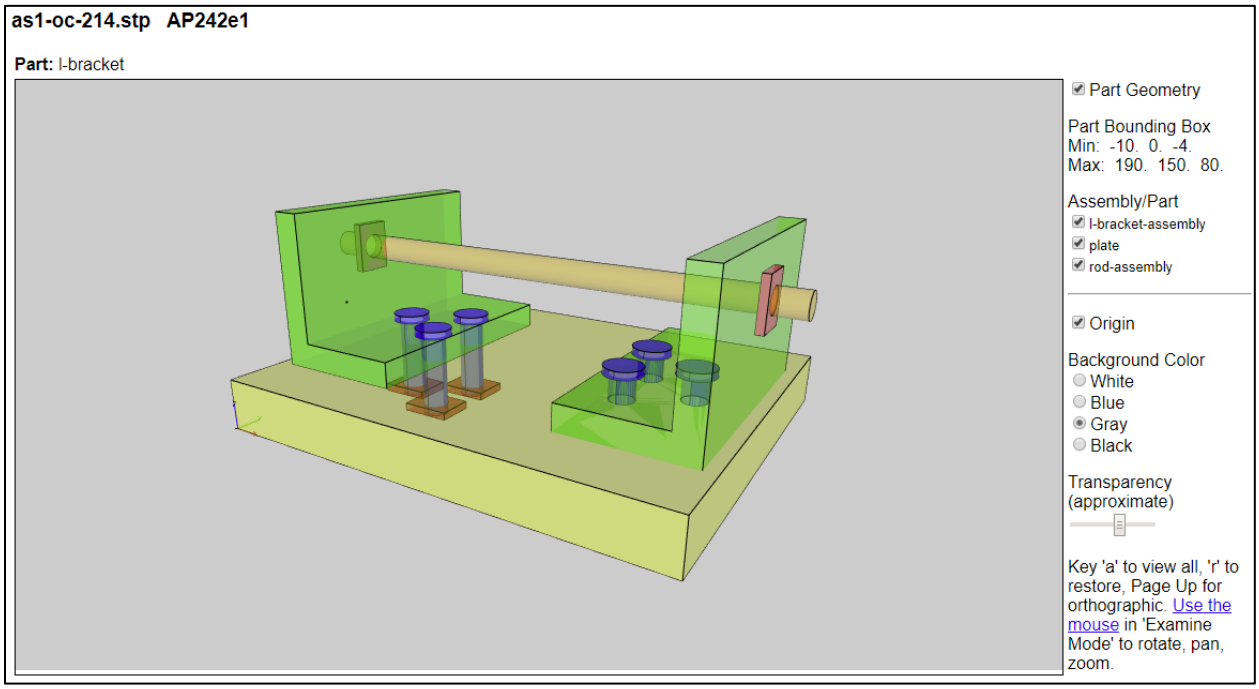


Figure 16: Part geometry view with approximate transparency

Figure 17 shows only the part edges of the completely transparent assembly.

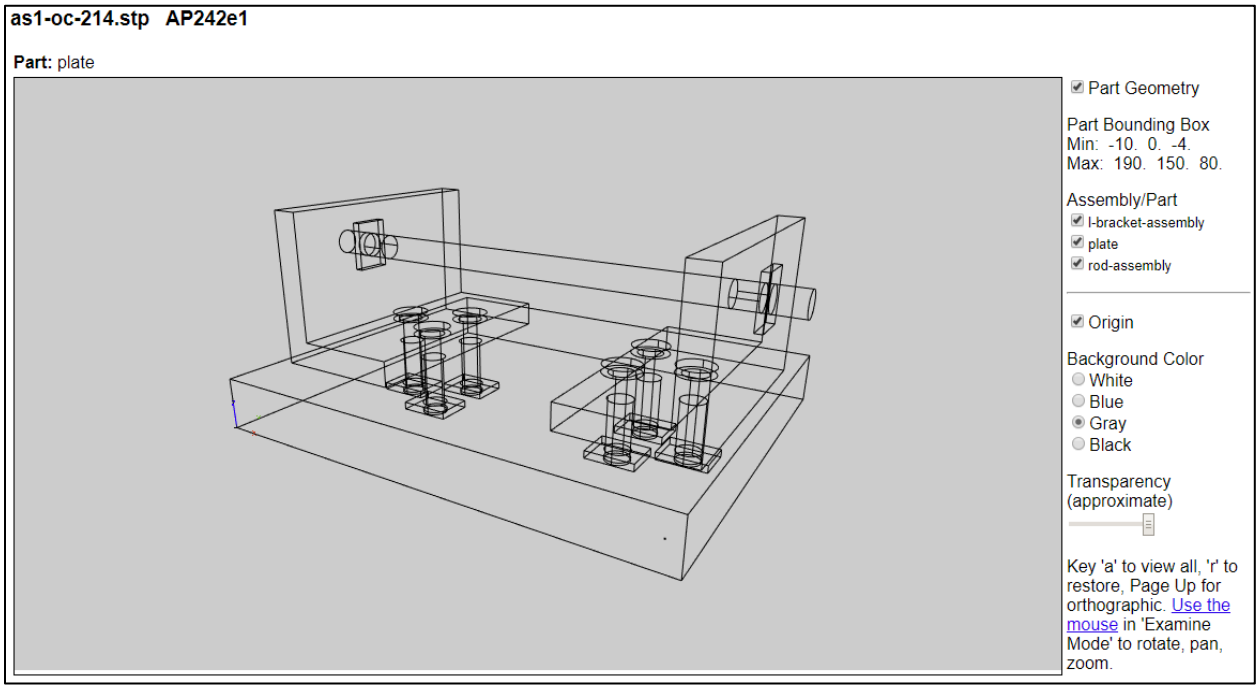


Figure 17: Part geometry view with edges only

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 18. The facets around the cylindrical surfaces are clearly visible. Although the part geometry is always displayed with smooth shading, a discontinuity in the shading is also apparent. Figure 19 shows the same part with quality set to high and normals selected. Normals improve the default smooth shading by explicitly computing surface normals and improves the appearance of curved surfaces.

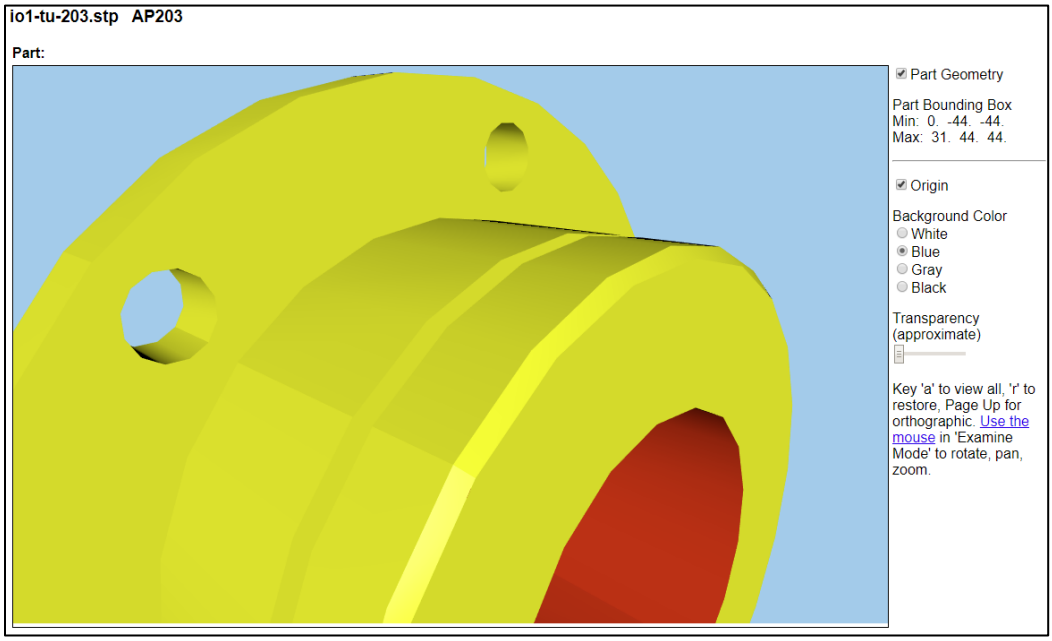


Figure 18: Part geometry view with low quality

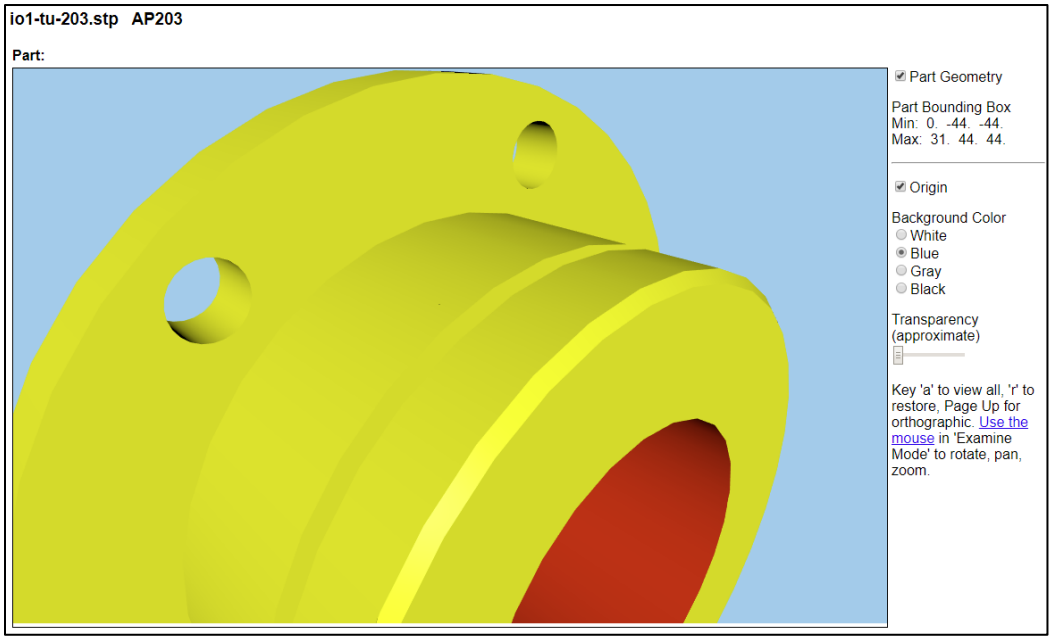


Figure 19: Part geometry view with high quality and normals

4.1.2 Sketch Geometry

The white lines in Figure 20 are an example of sketch geometry that is usually created in a CAD system to aid in geometry modeling. 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 assembly[2] also has eight different types of parts that can be switched on and off. The assembly without sketch geometry can be viewed at https://pages.nist.gov/CAD-PMI-Testing/simple-assembly.html.

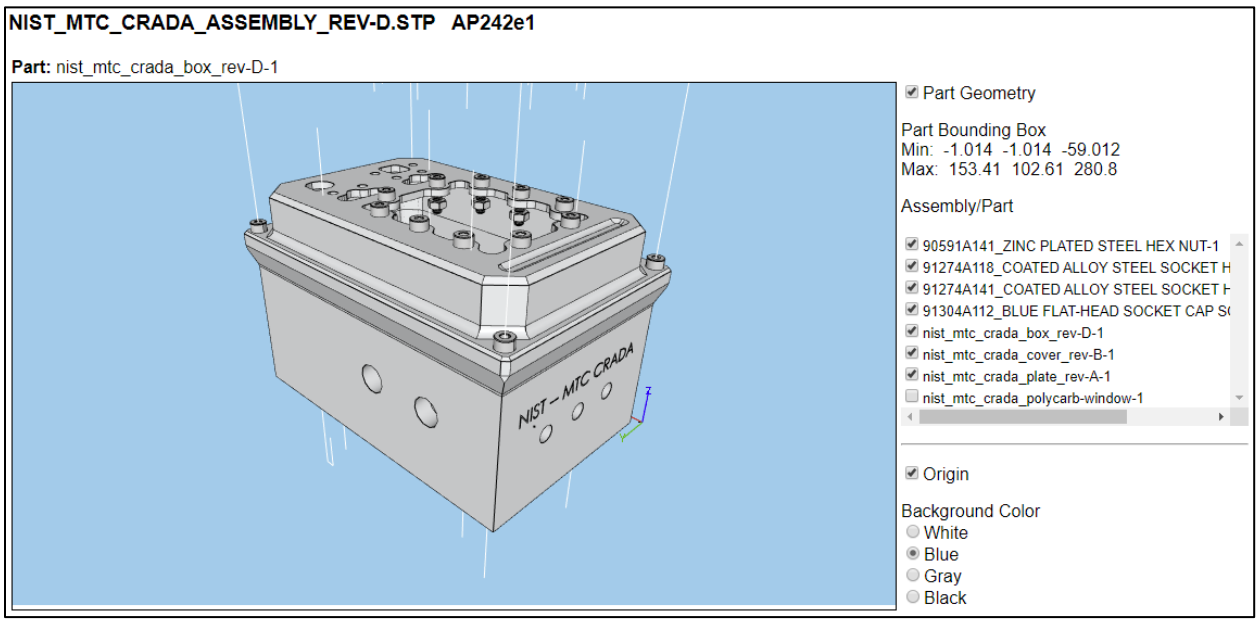


Figure 20: Part geometry view with sketch geometry

[2] https://smstestbed.nist.gov/tdp/mtc/

4.1.3 Supplemental Geometry

Figure 21 shows a part with a lot of 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.

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

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

Bounding edges for planes are ignored. All bounded and unbounded planes are displayed with a fixed size. Supplemental geometry is not the same as sketch geometry described above.

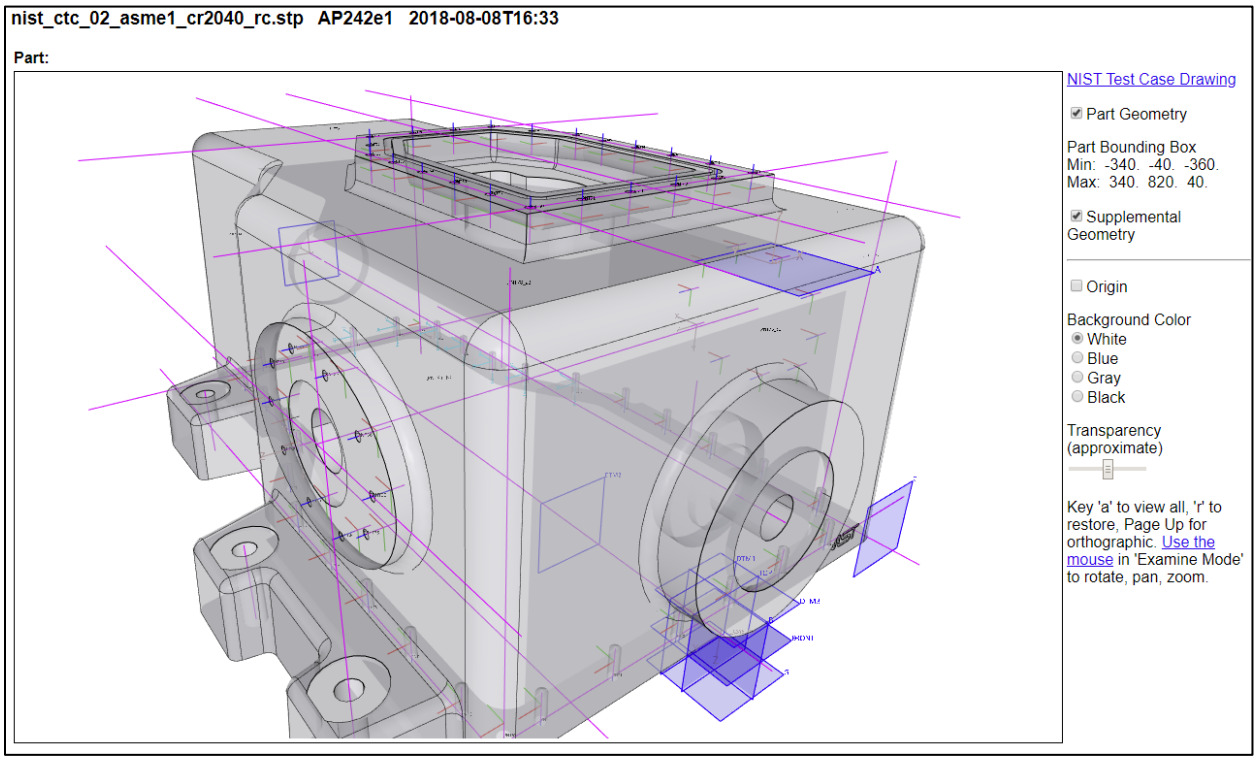


Figure 21: Part with supplemental geometry

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 22 shows the graphical PMI that corresponds to the annotations shown in Figure 49. The view file contains the line segments defined by the polylines in column F of Figure 70. 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. The actual viewpoint for a saved view is not used.

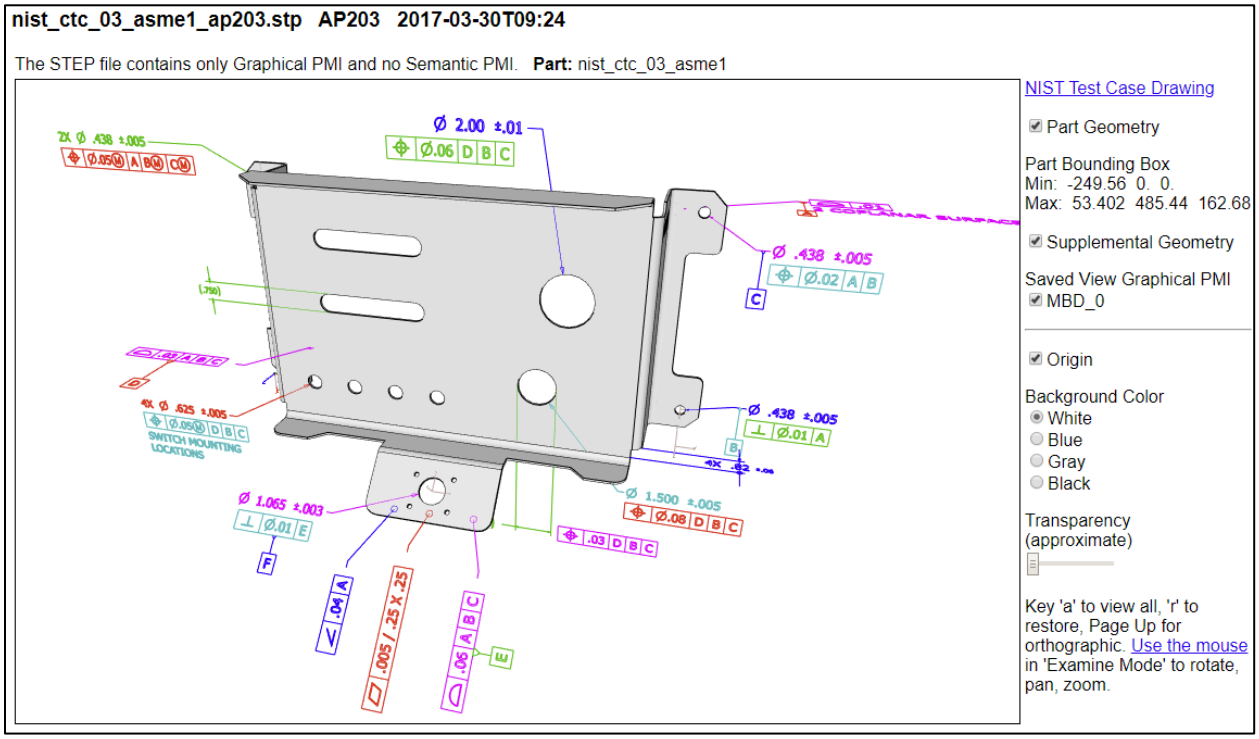


Figure 22: Graphical PMI

Multiple saved view graphical PMI will have multiple checkboxes as shown in Figure 23. In this example the graphical PMI in each saved view is assigned a different color.

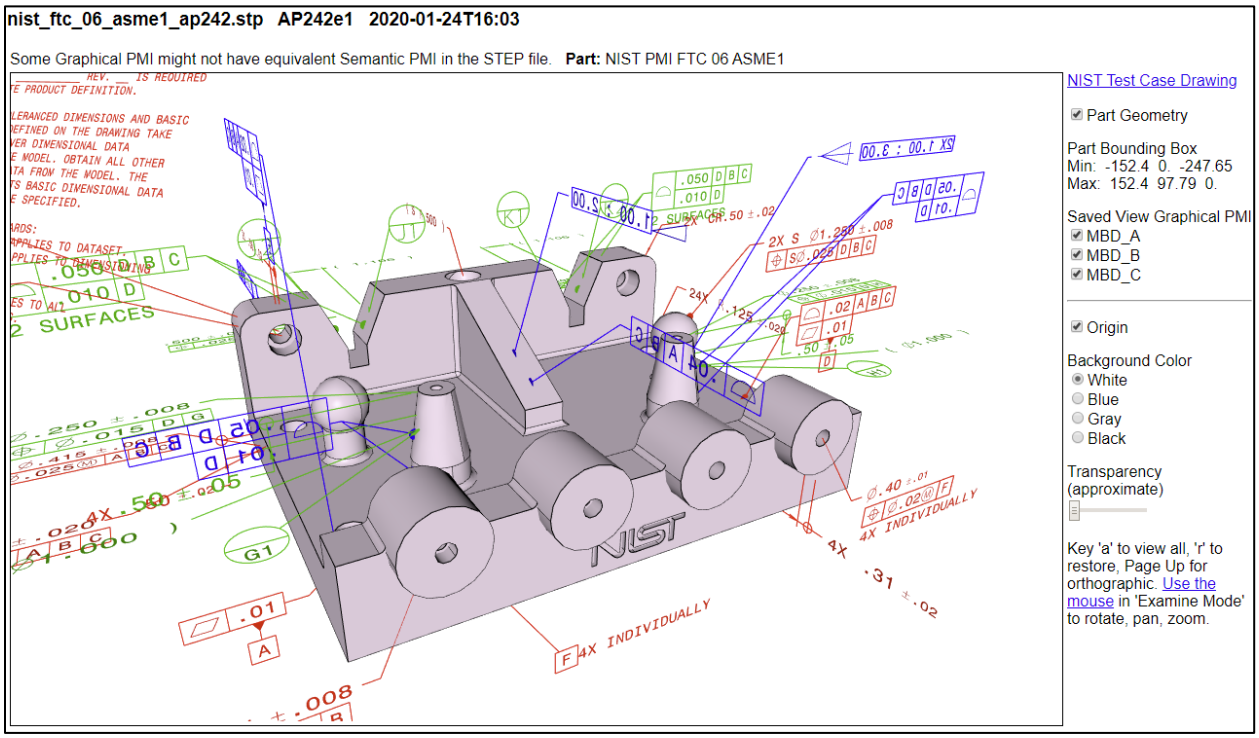


Figure 23: Graphical PMI with multiple saved views

4.2.1 Datum Targets

Datum targets are shown only if a spreadsheet is generated with analyze for semantic PMI selected in the Options tab and part geometry or graphical PMI is also viewed. Figure 24 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. 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.

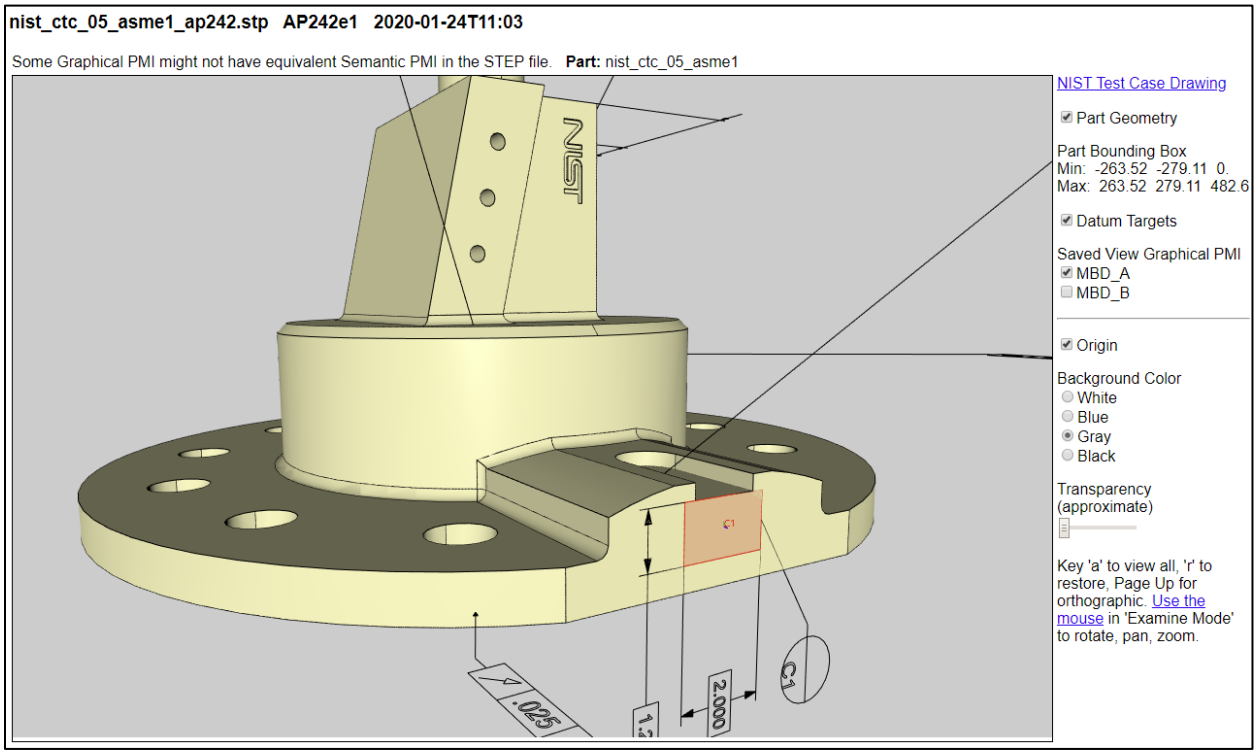


Figure 24: Graphical PMI with a datum target

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. Figure 25 shows tessellated part geometry where each tessellated facet is outlined.

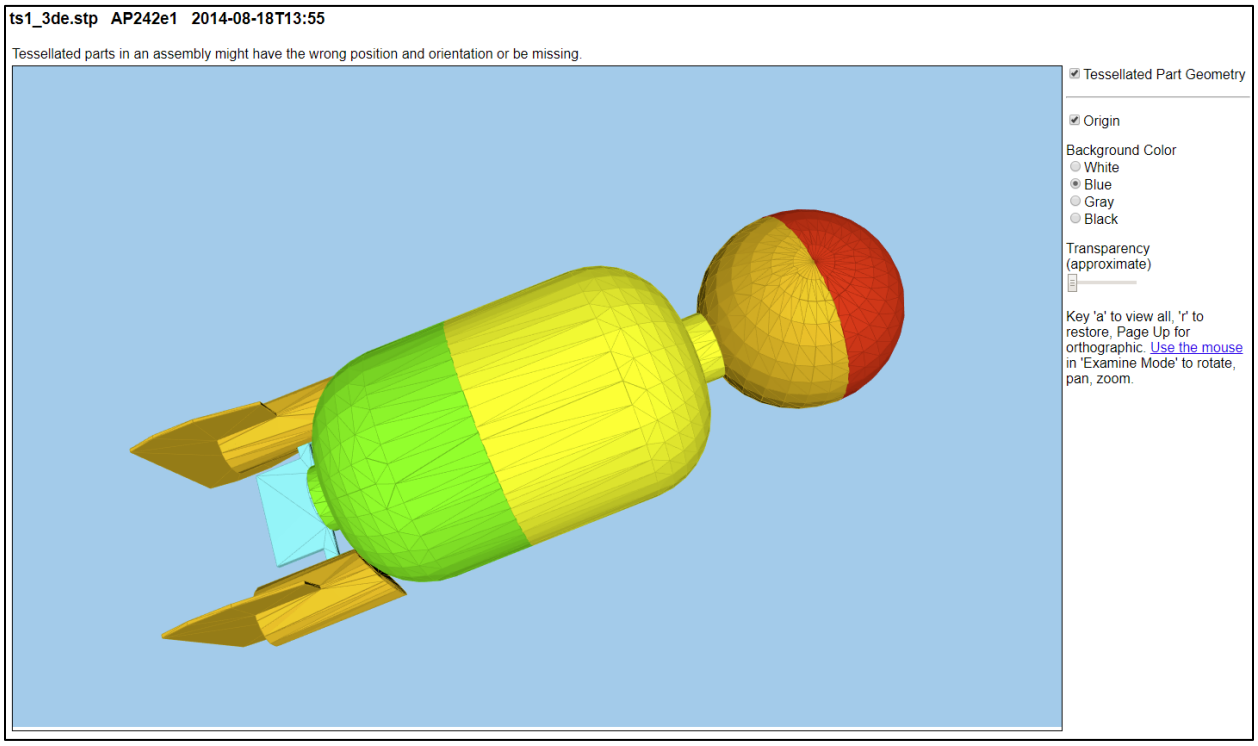


Figure 25: AP242 tessellated part geometry

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. Viewing 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 26 shows the view of the finite element model (FEM) of an ultra-lightweight glider [8]. 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.

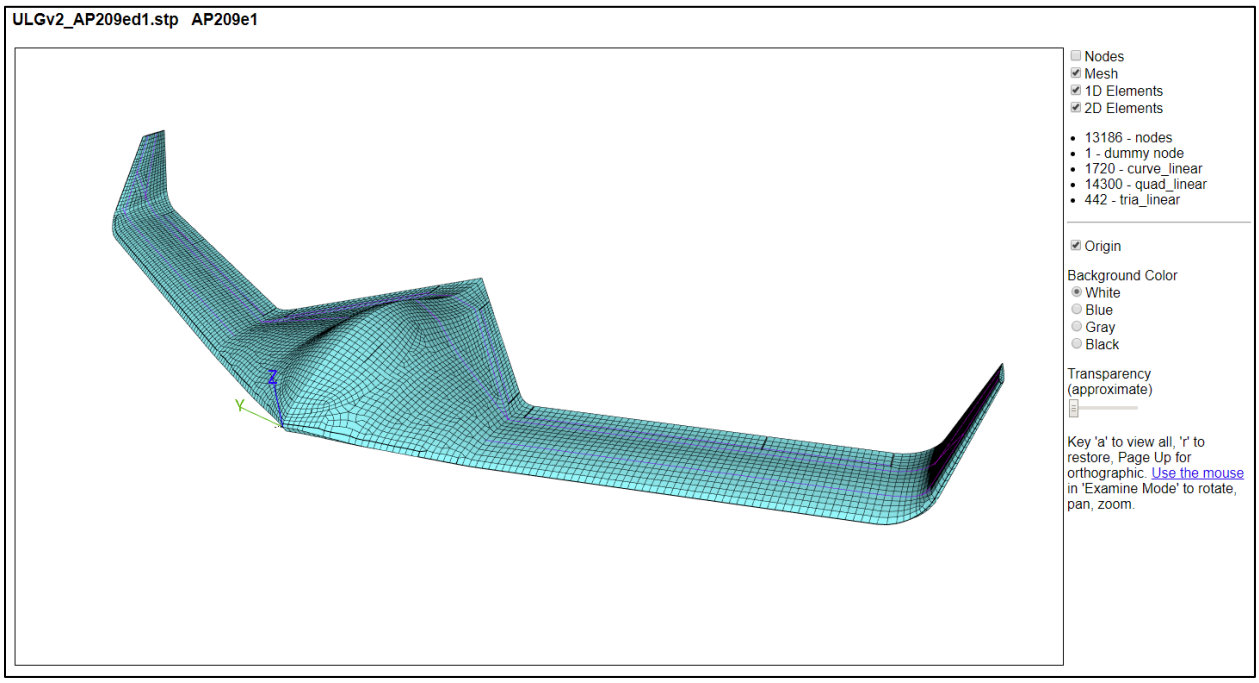


Figure 26: AP209 FEM of ultra-lightweight glider

Figure 27 shows the same FEM without the mesh where the magenta-colored 1D elements are visible because the 2D elements are partially transparent. Figure 28 shows only the nodes of the same FEM.

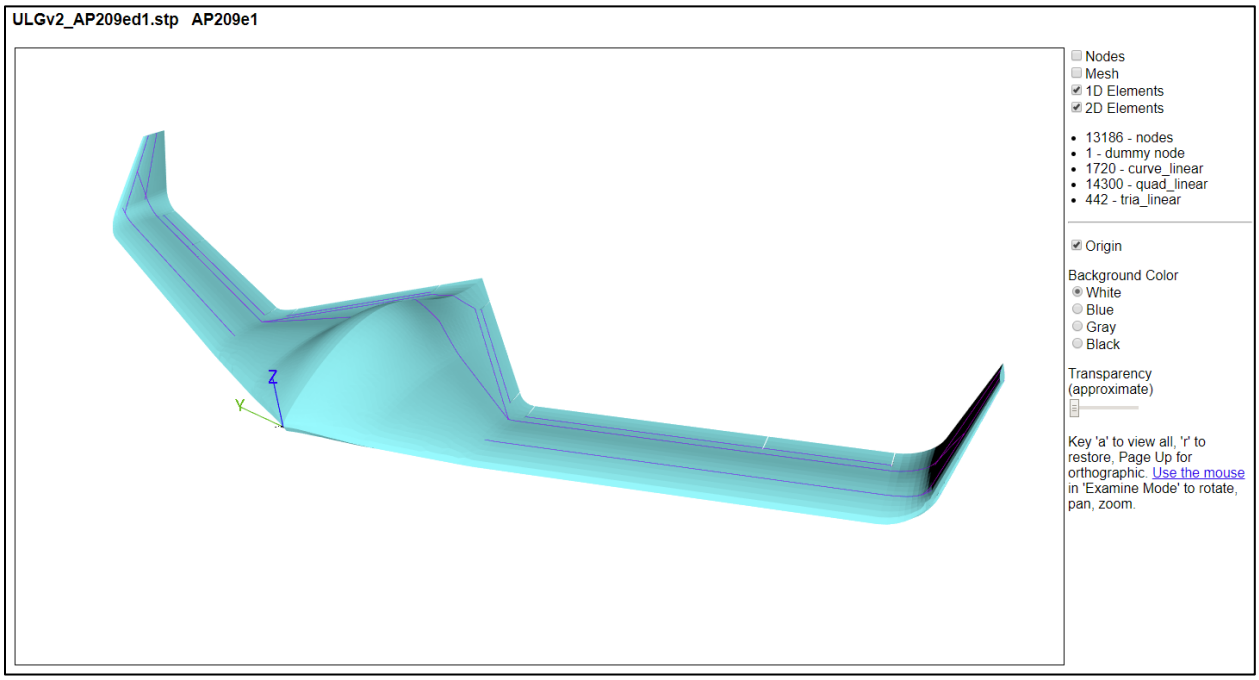


Figure 27: AP209 FEM, no mesh

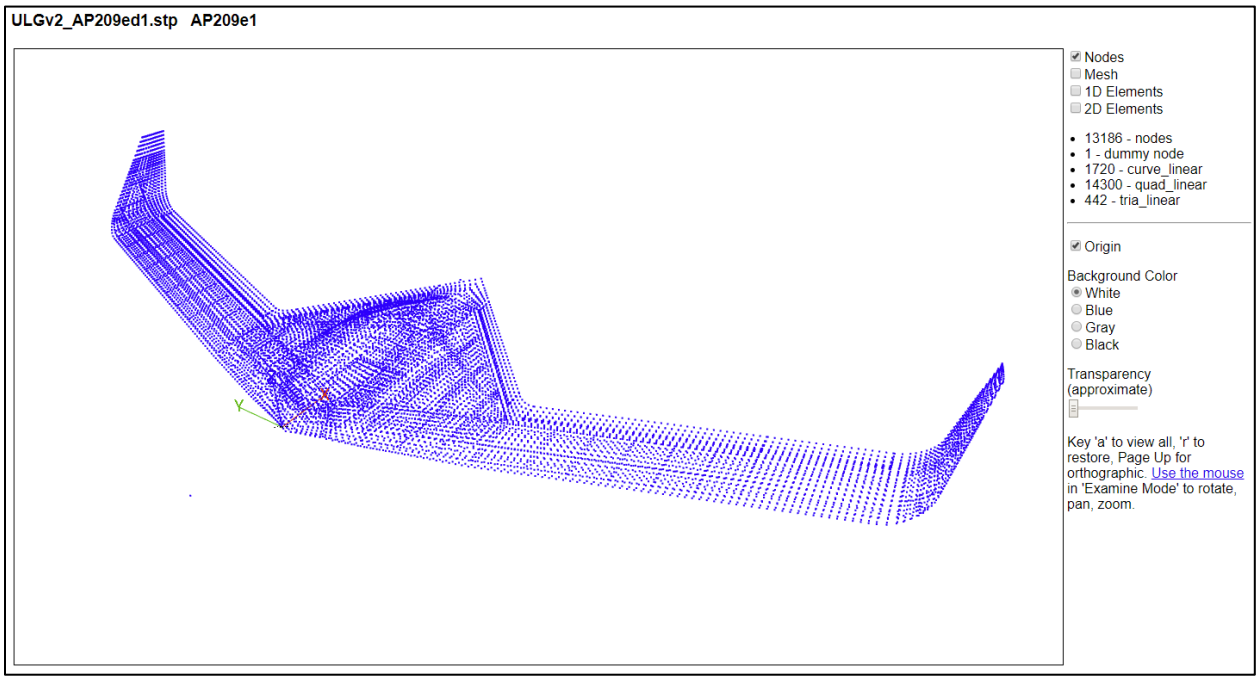


Figure 28: AP209 FEM, nodes only

4.4.2 Boundary Conditions, Loads, and Displacements

Figure 29 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.

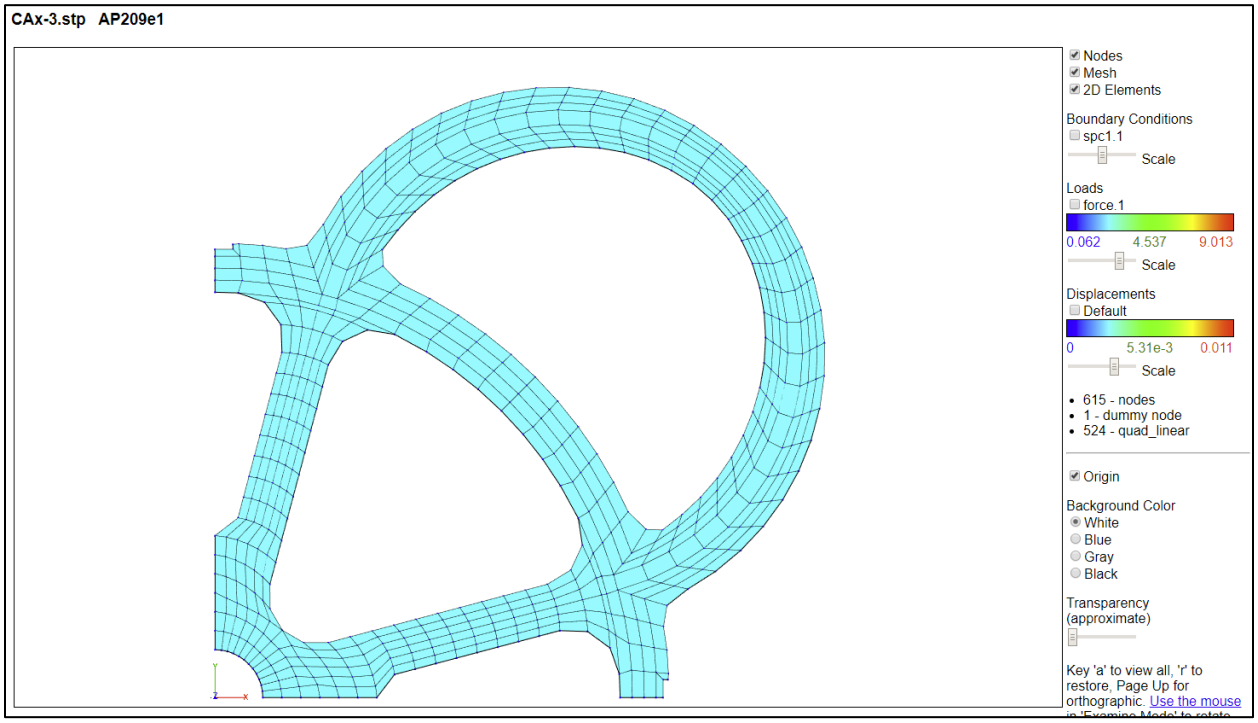


Figure 29: AP209 FEM

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 30 shows some of the nodal boundary conditions for the FEM in Figure 29. 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.

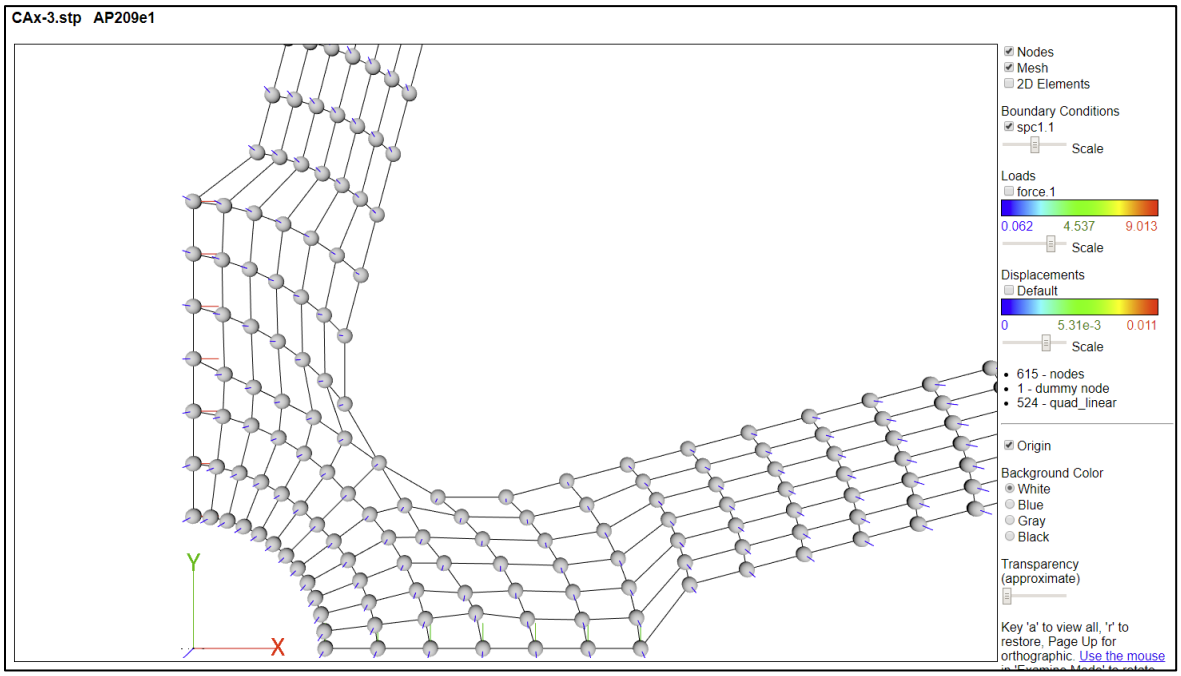


Figure 30: AP209 nodal boundary conditions

Figure 31 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.

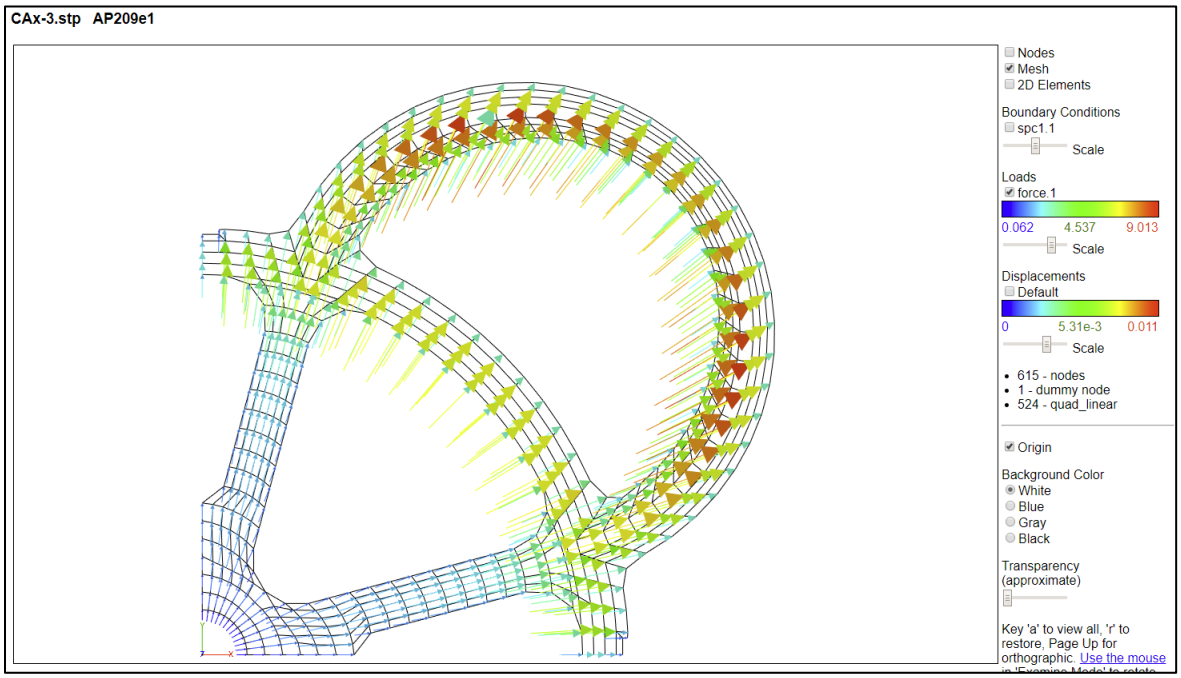


Figure 31: AP209 nodal load vectors

Figure 32 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.

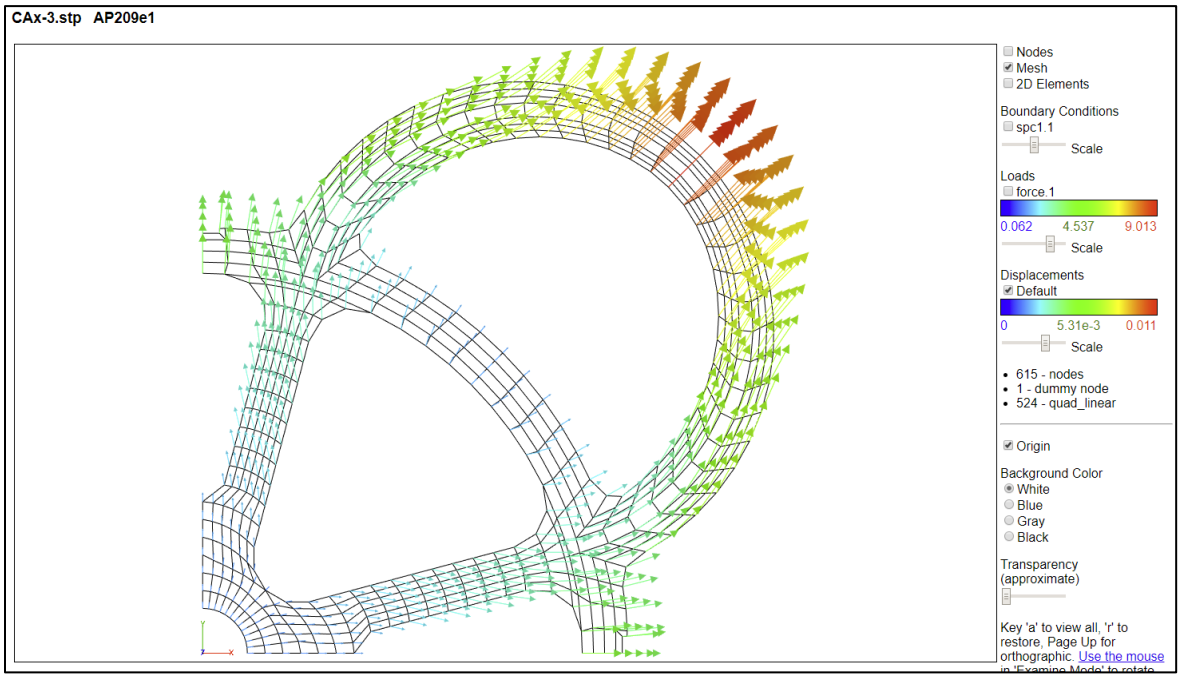


Figure 32: AP209 displacement vectors

Figure 33 shows the displacements for one of ten mode shapes of a connecting rod.

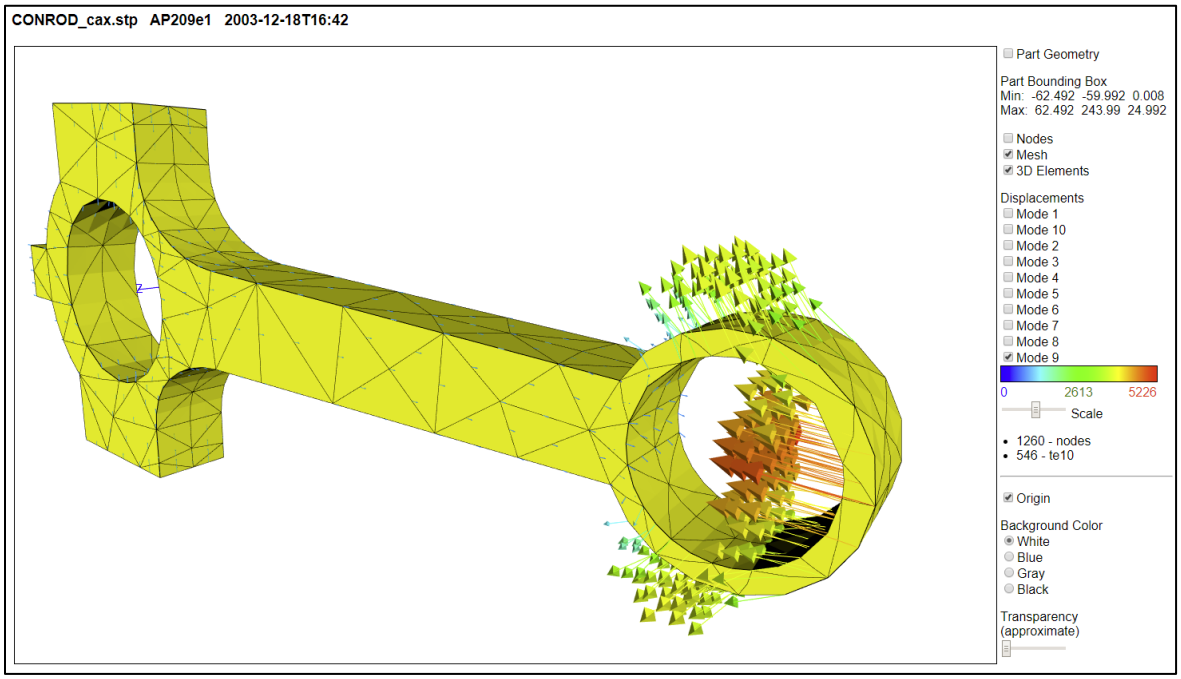


Figure 33: AP209 mode shape displacements

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 34. Rows 1-6 contain basic information about the STEP file including a link to documentation for the schema used in the file. Starting with row 9, 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\		
2	**STEP File**	Vertical Plate.stp		
3	**Excel File**	Vertical Plate_stp.xlsx		
4	**Application**	Autodesk Inventor 2011		
5	**Total Entities**	1848		
6	**Schema**	AP214		
7				
8	**Entity**	**Count**		
9	draughting_pre_defined_colour	1		
10	fill_area_style	1		
11	fill_area_style_colour	1		
12	presentation_style_assignment	1		
13	styled_item	1		
14	surface_side_style	1		
15	surface_style_fill_area	1		
16	surface_style_usage	1		
17	advanced_brep_shape_representation	1		
18	mechanical_design_geometric_presentation_representation	1		
19	shape_definition_representation	1		
20	shape_representation	1		
21	shape_representation_relationship	1		
22	application_context	1		
23	application_protocol_definition	1		
24	product	1		
25	product_context	1		
26	product_definition	1		
27	product_definition_context	1		
28	product_definition_formation	1		
29	product_definition_shape	1		
30	product_related_product_category	1		
31	advanced_face	58		
32	axis2_placement_3d	99		
33	cartesian_point	311		
34	circle	40		

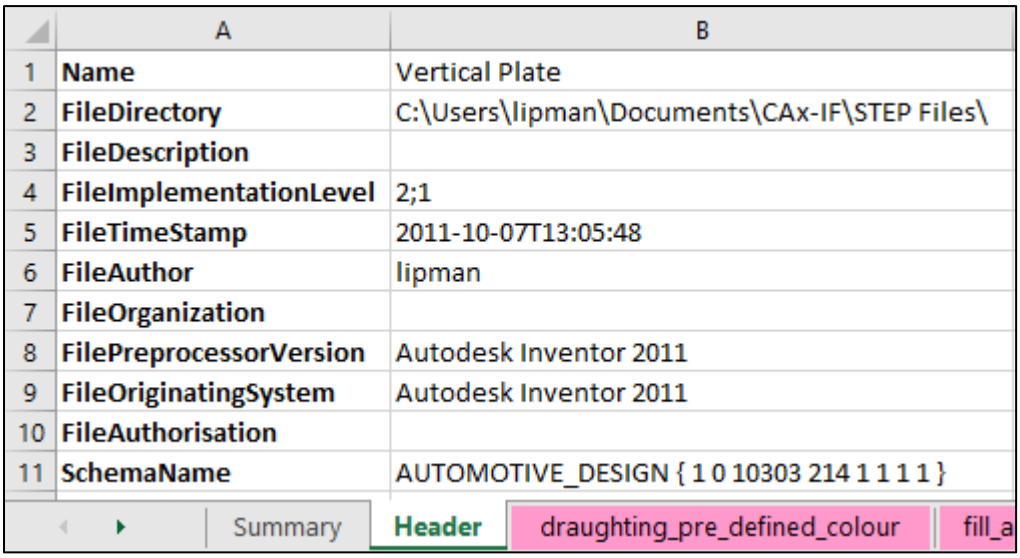
Summary | Header | draughting_pre_defined_colour | fill_area_style | fill_

Figure 34: 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 35. 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 }

Figure 35: 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 36. 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 36: datum_system entities

The resulting datum_system entity worksheet is shown in Figure 37. 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 37: Entity worksheet (datum_system)

In the draughting_model entity worksheet, shown in Figure 38, 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 38: 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 39 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 39: Entity worksheet (b_spline_surface_with_knots)

5.5 Unicode Characters

Text strings in STEP files can use Unicode characters [5]. However, SFA only supports Unicode characters using the \X\ and \S\ encoding. For example, \X\E9 represents the character é. However, the \X2\ and \X4\ encodings are not supported. Non-English characters in text strings, that are not Unicode, might have different or missing characters.

5.6 Options

5.6.1 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 [27] that is explicitly defined in a STEP schema.

Figure 40 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 40: Entity worksheet (shape_aspect_relationship)

Figure 41 and Figure 42 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 41: 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 42: Inverse Relationships and Used In example (columns G-H)

5.6.2 Tables

Figure 43 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 default ordering of the entity IDs in column A. The worksheet containing validation properties (section 6.3) is always sorted.

	A	B	C	D	E
1	shape_aspect (69)				
2					
3	ID	name	descriptio	of_shape	product_definitiona
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 43: Entity worksheet (shape_aspect) with tables for sorting

5.6.3 Number Format

By default, when a single real number is written to a worksheet cell, Excel might round the number. Figure 44, 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	2.999999999999695
5	103		axis2_placement_3d 102	2.999999999999695
6	128		axis2_placement_3d 127	2.999999999999792
7	145		axis2_placement_3d 144	2.999999999999792
8	170		axis2_placement_3d 169	2.999999999999695
9	187		axis2_placement_3d 186	2.999999999999695
10	212		axis2_placement_3d 211	2.999999999999803
11	229		axis2_placement_3d 228	2.999999999999803
12	358		axis2_placement_3d 357	3.375
13	388		axis2_placement_3d 387	3.375

Figure 44: Rounding numbers example

5.6.4 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 45 shows that only the first 100 of 43681 rows for the cartesian_point entities are written to the worksheet. Syntax errors (section 6.4) related to reports might be missed if some entities are not processed due to a small value 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 45: Maximum rows example

5.7 Anchor Section

ISO 10303 Part 21 Edition 3 [24] 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 46 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 46: ANCHOR section in a STEP file

Figure 47 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

Summary | Header | ANCHOR | PMI Representation Summary | PMI Representation Coverage

Figure 47: ANCHOR section worksheet

Figure 48 shows the ANCHOR IDs associated with the datum entities. ANCHOR IDs are also reported on the PMI Representation Summary worksheet (section 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 48: 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) [23, 25]. 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 section 6.1
2. PMI Presentation (graphical PMI) described in section 6.2
3. Validation Properties described in section 6.3

Product and manufacturing information (PMI) are annotations and attributes that define product geometry and product specifications [28]. 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 [29] and ISO 16792:2006 [30]. Some common tolerances include dimensional tolerances on length and diameter, and geometric tolerances on flatness, position, surface profile, and circular runout.

Figure 49 shows NIST test case CTC 3[3] 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.

[3] https://s3.amazonaws.com/nist-el/mfg_digitalthread/nist_ctc_03_asme1_rc.pdf

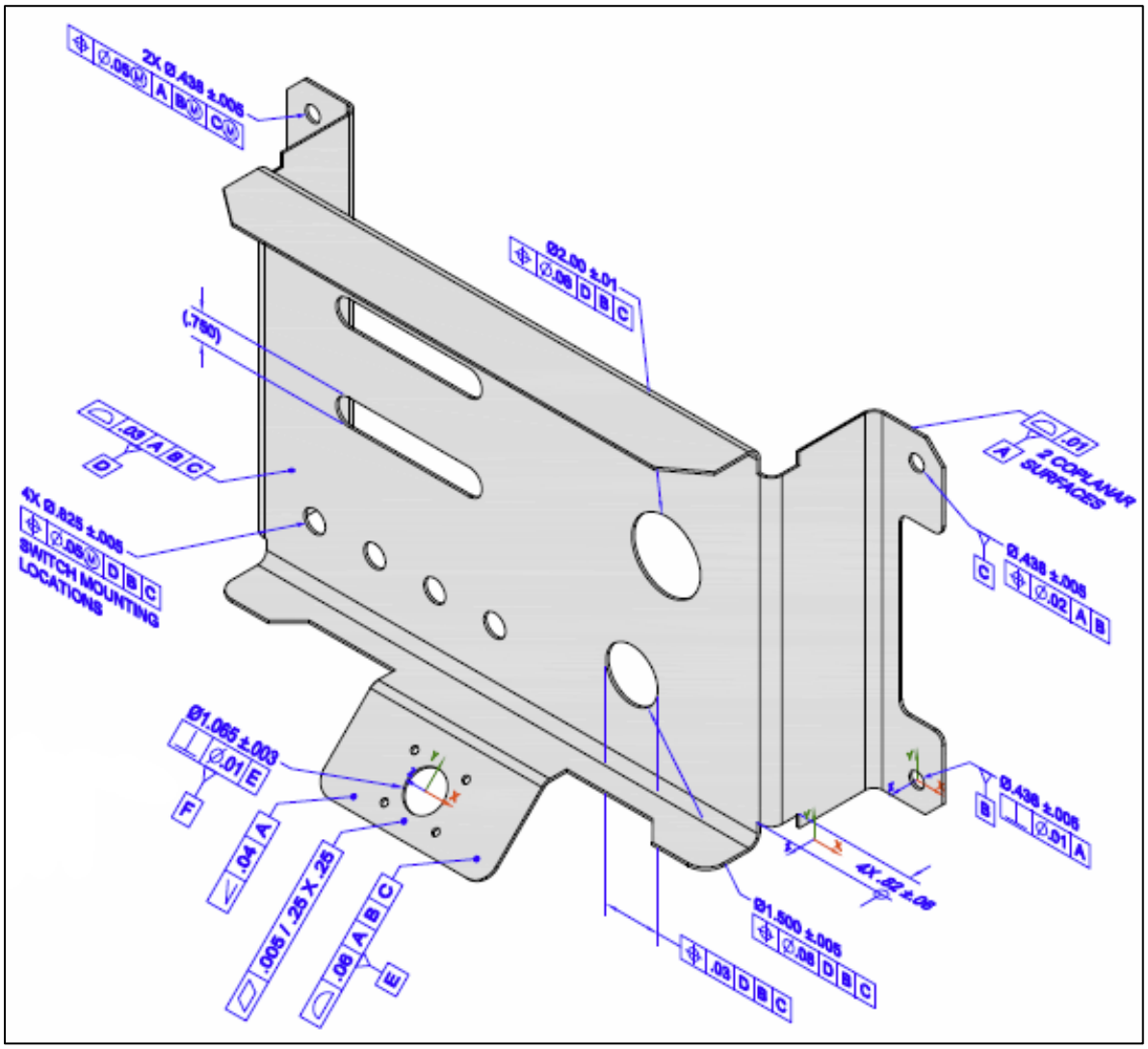


Figure 49: NIST test case CTC 3

Figure 50 shows the summary worksheet, similar to Figure 34, with entities highlighted that have information related to PMI Representation and PMI Presentation. Rows 10-13 are entities related to the datum reference frame. Row 14 is the dimensional_characteristic_representation entity which is associated with all dimensional tolerances. Rows 9 and 17-27 are entities related to geometric tolerances. Row 28 is the annotation_curve_occurrence entity which is associated with PMI presentation. The entity name in parentheses in cell A17 is for a complex entity (flatness_tolerance)(geometric_tolerance_with_defined_unit_area). 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_stp.xlsx				
4	Total Entities	17311				
5	Schema	AP242				
6	Dimension Units	INCH				
7						
8	Entity	Count				
9	angularity_tolerance_[PMI Representation]	1				
10	datum	6				
11	datum_feature_[PMI Representation]	6				
12	datum_reference_compartment_[PMI Representation]	26				
13	datum_system_[PMI Representation]	6				
14	dimensional_characteristic_representation_[PMI Representation]	10				
15	dimensional_location	2				
16	dimensional_size	8				
17	(flatness_tolerance) _(geometric_tolerance_with_defined_area_unit)_[PMI Representation]	1				
18	(geometric_tolerance_with_datum_reference) _(geometric_tolerance_with_modifiers) _(position_tolerance)_[PMI Representation]	2				
19	(geometric_tolerance_with_datum_reference) _(position_tolerance)_[PMI Representation]	4				
20	(geometric_tolerance_with_datum_reference) _(surface_profile_tolerance)_[PMI Representation]	2				
21	perpendicularity_tolerance_[PMI Representation]	2				
22	plus_minus_tolerance	8				
23	shape_dimension_representation	10				
24	surface_profile_tolerance_[PMI Representation]	1				
25	tolerance_value	8				
26	tolerance_zone	7				
27	tolerance_zone_form	7				
28	annotation_curve_occurrence_[PMI Presentation]	30				
29	annotation_plane	4				
30	colour	4				

Summary | Header | PMI Representation Summary | PMI Representation Coverage | PMI Present

Figure 50: Summary worksheet with entities highlighted for PMI

6.1 PMI Representation

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 [31]. Syntax errors related to nonconformance to the recommended practices are highlighted in red in the Status tab and in the relevant entity worksheets (section 6.4).

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 49. 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 6.5.1 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 51 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 51: Entity worksheet (datum)

Figure 52 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 [31].

	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 Ⓜ
9	51476	Position.3		product_definition_shape 56	TRUE	datum 40518	maximum_material_requirement	C Ⓜ
10	53681	Position.4		product_definition_shape 56	TRUE	datum 53676		D

Figure 52: Entity worksheet (datum_reference_compartment)

Figure 53 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Ⓜ
7	53696	Position.4		product_definition_shape 56	TRUE	(3) datum_reference_compartment 53681 53686 53691	D | B | C
8	70801	Position Surfacic 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 53: Datum reference frame example

6.1.3 Dimensional Tolerance

The following example shows how a dimensional tolerance is modeled in a STEP file. Figure 54 and Figure 55 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 49.
- 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 54: Dimensional tolerance example (columns A-C)

The visual presentation in Figure 55 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 49. 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	Ø.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	Ø.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 Ø.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 Ø.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	Ø2.00 ± .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	Ø1.500 ± .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	Ø1.5	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	Ø1.065 ± .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 55: Dimensional tolerance example (columns A, D-I)

6.1.4 Geometric Tolerances

The following examples show how geometric tolerances are modeled in a STEP file. Figure 56 and Figure 57 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 49.
- 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
4	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

Figure 56: 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 ▽ | [E]	datum_feature 70982	(1) plane 1081 (1) advanced_face 1696

Figure 57: Flatness tolerance example (columns I-K)

Figure 58 and Figure 59 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 59, Column J) and dimension Associated Geometry (Figure 55, cells I6 and I7).
- Column I shows the FCF of the dimensional tolerance, defined in Figure 55, associated with the position tolerance. The dimensional_size entities are referred to in column B of Figure 54.
- 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 58: 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 59: 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 57 and Figure 59 are constructed. Figure 60 shows one of the position tolerances from Figure 49 where the FCF contains a position tolerance, hole dimension, and datum feature.

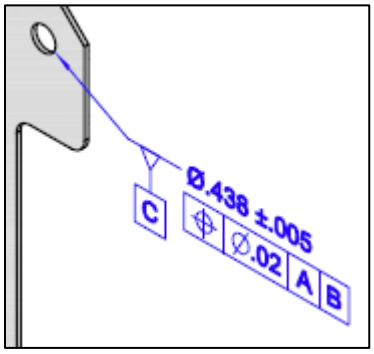


Figure 60: Position tolerance feature control frame

Cell G4 in Figure 61 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 section 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	Ø.438 ± .005 ⌖ | Ø.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 61: Toleranced geometry for position tolerance

Cell K5 in Figure 62 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 61, 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	Ø.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 62: Associated geometry for dimensional tolerance

Cell G5 in Figure 63 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 63: 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 49 datum feature 'E' is associated with a surface profile tolerance. Datum feature 'E' is the surface of the tab. However, in Figure 67, 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 64 shows the warning message when multiple dimensions are detected. Cells D9 and D10 in Figure 65 show the multiple dimensions. In this example, there are two diameter dimensions with and without a tolerance value. Cells K9 and K10 in Figure 66 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.

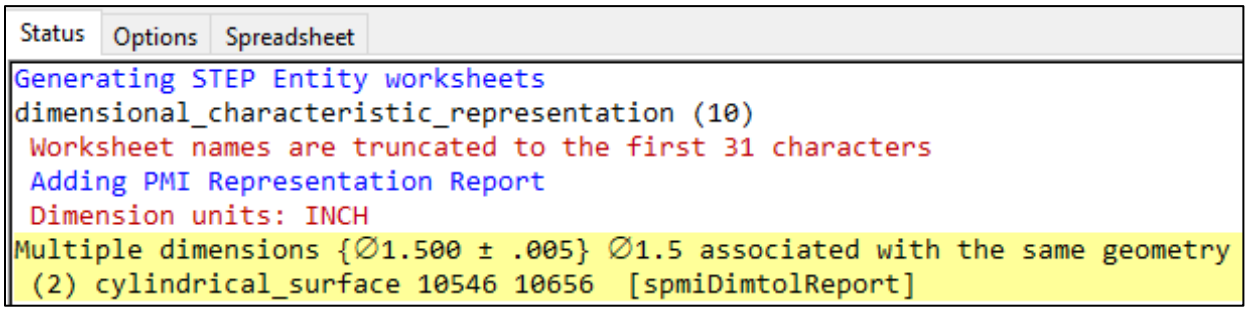


Figure 64: Warning message for multiple dimensions

	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 65: 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 66: 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 67. The annotations in column C are collected from column G in Figure 53, column D in Figure 55, column I in Figure 57, and column H in Figure 59. The annotations in column C correspond to the annotations shown in Figure 49.

	A	B	C
1		nist_ctc_03_asme1_ap242.stp	See CAx-IF Recommended Pra
2			
3	ID	Entity	PMI Representation
4	73706	angularity_tolerance	∠ | .04 | A ▽ | [E]
5	37106	datum_system	A
6	42046	datum_system	A | B
7	51481	datum_system	A | B Ⓜ | C Ⓜ
8	53696	datum_system	D | B | C
9	70801	datum_system	A | B | C
10	84091	datum_system	E
11	35831	dimensional_characteristic_representation	Ø.438 ± .005
12	40201	dimensional_characteristic_representation	Ø.438 ± .005
13	45336	dimensional_characteristic_representation	4X Ø.625 ± .005
14	48741	dimensional_characteristic_representation	2X Ø.438 ± .005
15	60541	dimensional_characteristic_representation	Ø2.00 ± .01
16	64886	dimensional_characteristic_representation	Ø1.500 ± .005
17	67011	dimensional_characteristic_representation	Ø1.5
18	69441	dimensional_characteristic_representation	.750
19	80071	dimensional_characteristic_representation	.82 ± .06
20	83181	dimensional_characteristic_representation	Ø1.065 ± .003
21	73111	(flatness_tolerance) (geometric_tolerance_with_defined_area_unit)	⏥ | .005 / 0.25 X 0.25 ▽ | [E]
22	51491	(geometric_tolerance_with_datum_reference) (geometric_tolerance_with_modifiers) (position_tolerance)	2X Ø.438 ± .005 ⌖ | Ø.05 Ⓜ | A | B Ⓜ | C Ⓜ
23	53706	(geometric_tolerance_with_datum_reference) (geometric_tolerance_with_modifiers) (position_tolerance)	4X Ø.625 ± .005 ⌖ | Ø.05 Ⓜ | D | B | C
24	42056	(geometric_tolerance_with_datum_reference) (position_tolerance)	Ø.438 ± .005 ⌖ | Ø.02 | A | B ▽ | [C]
25	62431	(geometric_tolerance_with_datum_reference) (position_tolerance)	Ø2.00 ± .01 ⌖ | Ø.06 | D | B | C
26	66861	(geometric_tolerance_with_datum_reference) (position_tolerance)	Ø1.500 ± .005 ⌖ | Ø.08 | D | B | C
27	68596	(geometric_tolerance_with_datum_reference) (position_tolerance)	Ø1.500 ± .005 ⌖ | .03 | D | B | C
28	70811	(geometric_tolerance_with_datum_reference) (surface_profile_tolerance)	⌓ | .06 | A | B | C ▽ | [E]

Summary | Header | PMI Representation Summary | PMI Representati

Figure 67: 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 [32] 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 (section 6.5.1).

6.1.7 PMI Representation Coverage Analysis

Coverage analysis counts the number of occurrences of a PMI element in a STEP file. Figure 68 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 [31] 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 (section 6.5.2).

	A	B
1	**sp3_1101_3de.stp (2014-08-13T12:42:32+02:00)**	
2		
3	**PMI Element (See Help > Analyze > PMI Coverage Analysis)**	**Count**
4	flatness_tolerance ▱	1
5	perpendicularity_tolerance ⊥	1
6	position_tolerance ⌖	5
7	surface_profile_tolerance ⌓	2
8	tolerance zone diameter (6.9.2, Table 11)	5
9	projected Ⓟ (6.9.2.2)	1
10	unequally_disposed Ⓤ or UZ (6.9.4)	1
11	dimensional location (5.1.1)	1
12	dimensional size (5.1.5)	5
13	angular location (5.1.2)	1
14	dimension association to geometric tolerance (5.1)	6
15	bilateral tolerance (5.2.3)	4
16	diameter Ø (5.1.5)	5
17	linear distance (5.1.1)	1
18	datum (6.5)	6
19	datum system (6.9.7)	8
20	multiple datum features (6.9.8)	3
21	datum feature association to geometric tolerance (6.1)	5
22	circle datum target (6.6)	2
23	free_state Ⓕ (6.9.3 or 6.9.7)	1
24	least_material_requirement Ⓛ (6.9.3 or 6.9.7)	3
25	maximum_material_requirement Ⓜ (6.9.3 or 6.9.7)	5
26	document identification (3, see Header worksheet)	5

Summary | Header | **PMI Representation Coverage**

Figure 68: 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 REQT (6.9.3)
angular location (5.1.2)	associated_minimum_inscribed_feature Ⓝ (6.9.3)	simultaneous_requirement SIM REQT
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

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 [31]. Syntax errors related to nonconformance to the recommended practices are highlighted in red in the Status tab and in the relevant entity worksheets (section 6.4).

Figure 69 through Figure 71 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 69: 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 70: 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 71: 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 72 shows the worksheet that is generated for coverage analysis of PMI presentation. Rows 4 through 35 of column A contain the recommended names [31] that can be associated with a PMI annotation. The names correspond to the values in column E in Figure 70. 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 71.

	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 72: 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 [33]. Syntax errors related to nonconformance to the recommended practices are highlighted in red in the Status tab and in the relevant entity worksheets (section 6.4).

Figure 73 and Figure 74 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 75. 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 73: Validation properties example (columns A-D)

	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 74: Validation properties example (columns E-O)

	E	F	G	H	I	J
1						
2	Validation Properties					
3	representation name	attribute	value name	attribute2	value	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 75: Validation properties example with expanded columns (columns E-J)

6.4 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 76 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 77 shows a warning message highlighted in yellow related to dimensional_characteristic_representation.

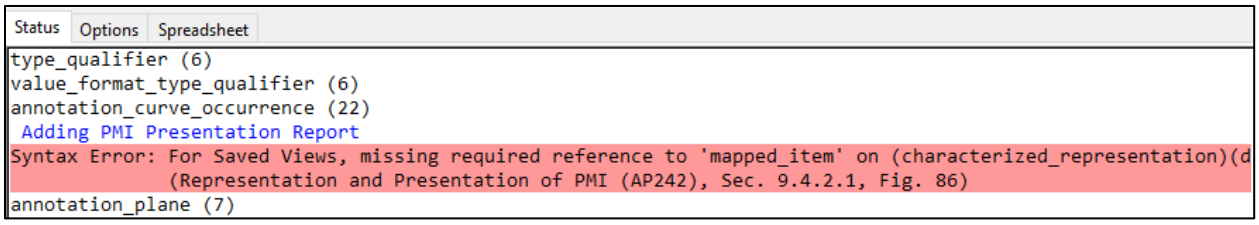


Figure 76: Syntax error related to annotation_curve_occurrence

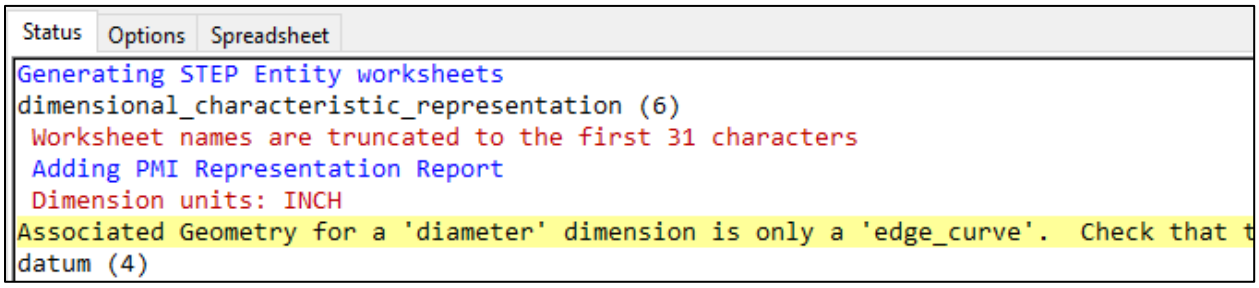
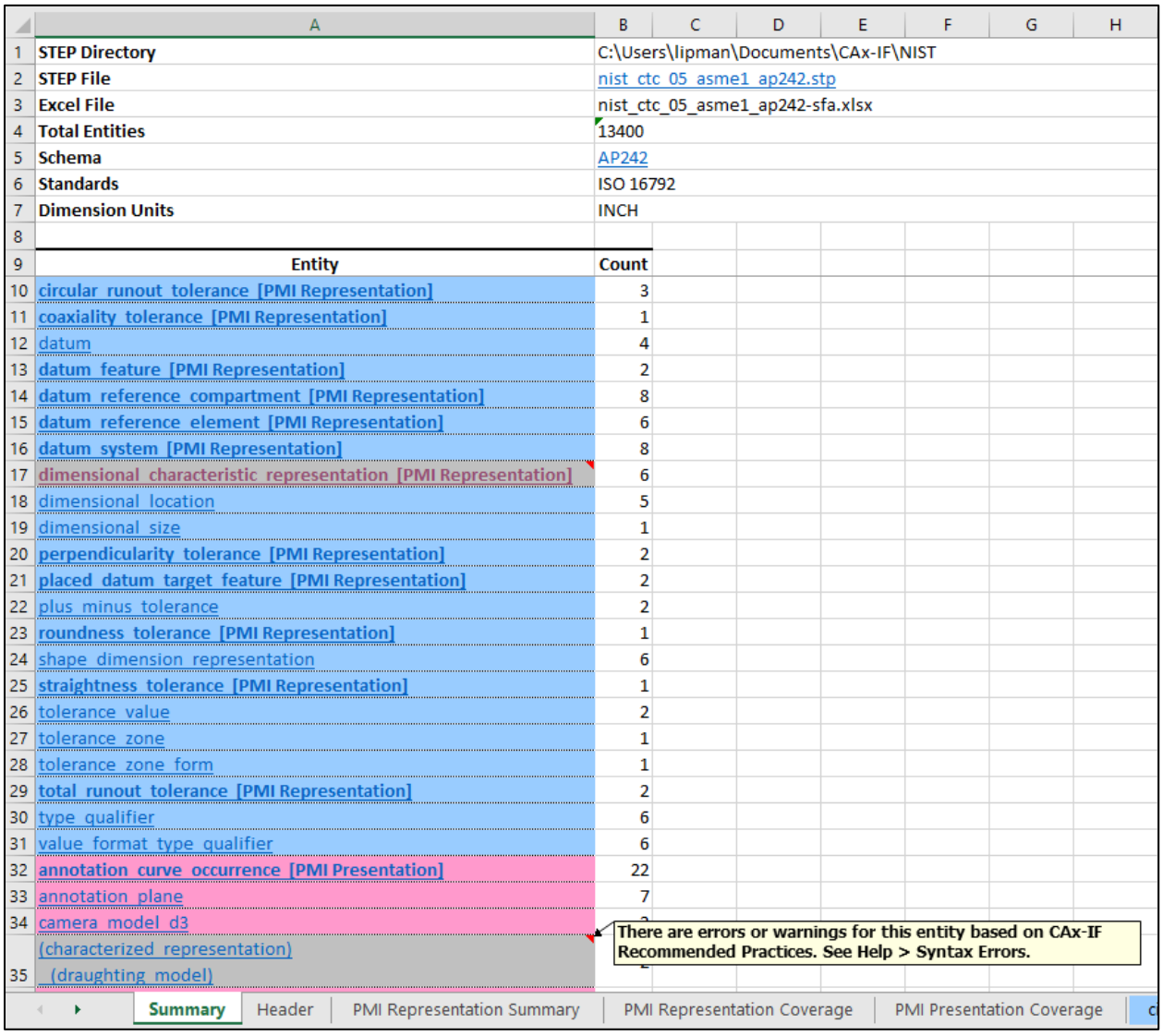


Figure 77: Warning message related to dimensional_characteristic_representation

Entity types that have any syntax or warning messages are highlighted in gray on the Summary worksheet as shown in Figure 78. 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
1	**STEP Directory**	C:\Users\lipman\Documents\CAx-IF\NIST
2	**STEP File**	nist_ctc_05_asme1_ap242.stp
3	**Excel File**	nist_ctc_05_asme1_ap242-sfa.xlsx
4	**Total Entities**	13400
5	**Schema**	AP242
6	**Standards**	ISO 16792
7	**Dimension Units**	INCH
8		
9	**Entity**	**Count**
10	circular_runout_tolerance [PMI Representation]	3
11	coaxiality_tolerance [PMI Representation]	1
12	datum	4
13	datum_feature [PMI Representation]	2
14	datum_reference_compartment [PMI Representation]	8
15	datum_reference_element [PMI Representation]	6
16	datum_system [PMI Representation]	8
17	dimensional_characteristic_representation [PMI Representation]	6
18	dimensional_location	5
19	dimensional_size	1
20	perpendicularity_tolerance [PMI Representation]	2
21	placed_datum_target_feature [PMI Representation]	2
22	plus_minus_tolerance	2
23	roundness_tolerance [PMI Representation]	1
24	shape_dimension_representation	6
25	straightness_tolerance [PMI Representation]	1
26	tolerance_value	2
27	tolerance_zone	1
28	tolerance_zone_form	1
29	total_runout_tolerance [PMI Representation]	2
30	type_qualifier	6
31	value_format_type_qualifier	6
32	annotation_curve_occurrence [PMI Presentation]	22
33	annotation_plane	7
34	camera_model_d3	
	(characterized_representation)	
35	(draughting_model)	

There are errors or warnings for this entity based on CAx-IF Recommended Practices. See Help > Syntax Errors.

Summary | Header | PMI Representation Summary | PMI Representation Coverage | PMI Presentation Coverage

Figure 78: Entities with errors or warnings highlighted on Summary worksheet

Figure 79 shows the (characterized_representation)(draughting_model) worksheet where the syntax errors from Figure 76 are highlighted in cells C4 and C5. The comment is same text displayed in the Status tab in Figure 76. 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.

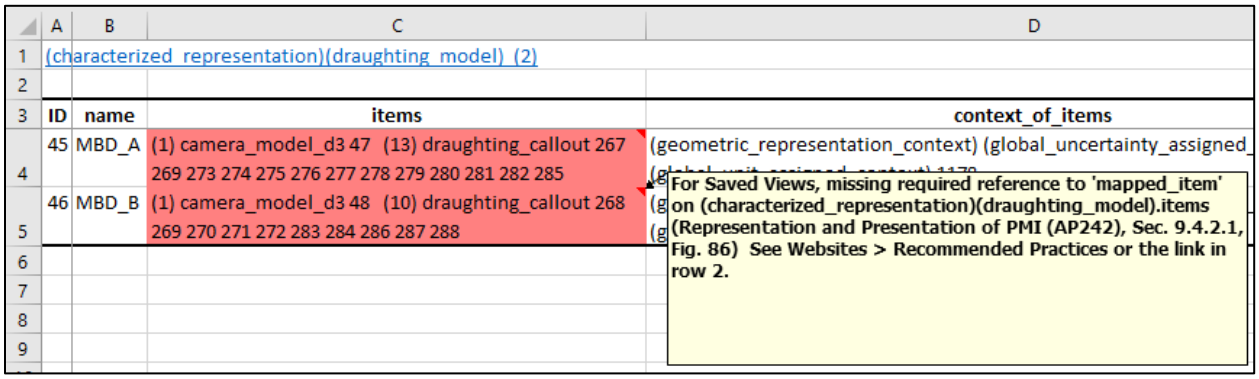


Figure 79: Syntax error on (characterized_representation)(draughting_model)

Figure 80 shows the dimensional_characteristic_representation worksheet where the warning message from Figure 77 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.

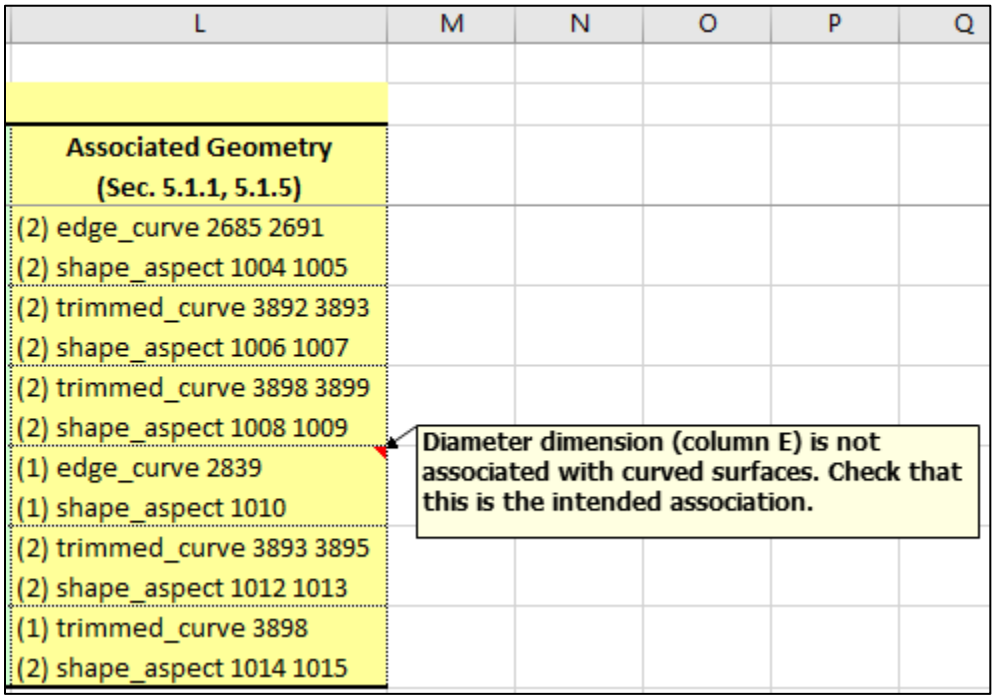


Figure 80: Warning message on dimensional_characteristic_representation

There are also some other explanatory comments for the headings in row 3 on several types of worksheets as shown in Figure 81.

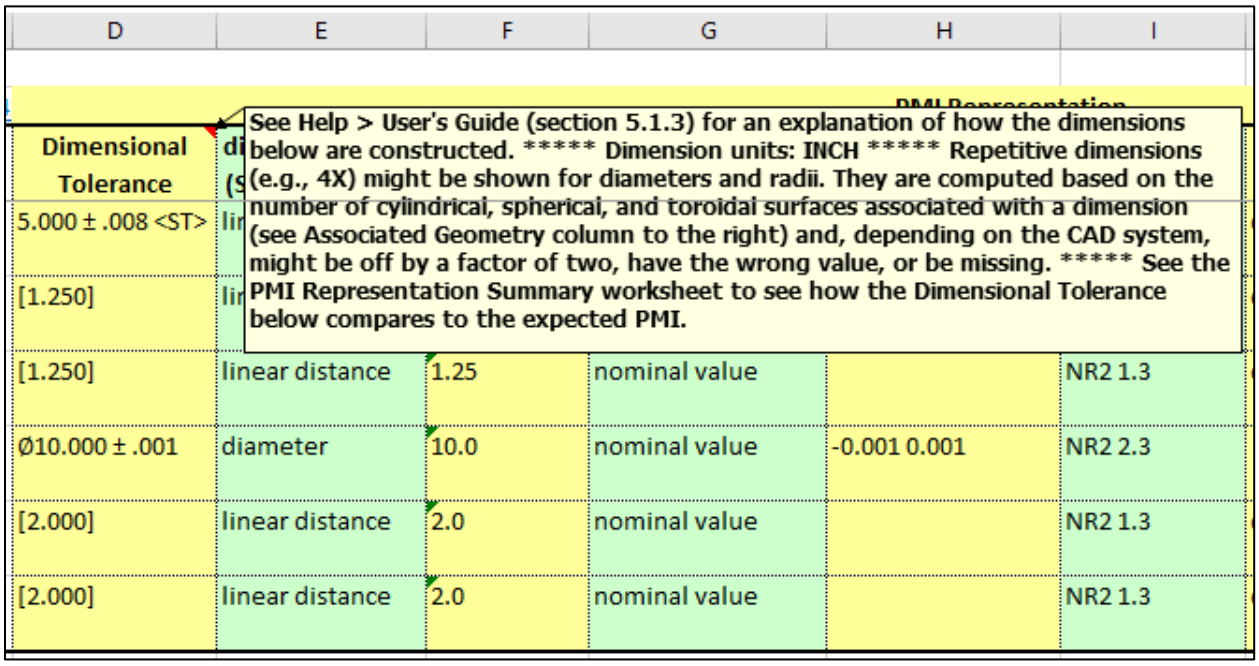


Figure 81: Cell comment for dimensional tolerances

6.5 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 [32] 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.

6.5.1 Representation Summary

The PMI Representation Summary worksheet is color-coded by the expected PMI annotations in a NIST test case drawing. Figure 82 is a color-coded worksheet for a STEP AP242 file generated from CAD model based on NIST test case CTC 5[4]. A similar worksheet based on NIST test case CTC 3, without color-coding, is shown in Figure 67.

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.

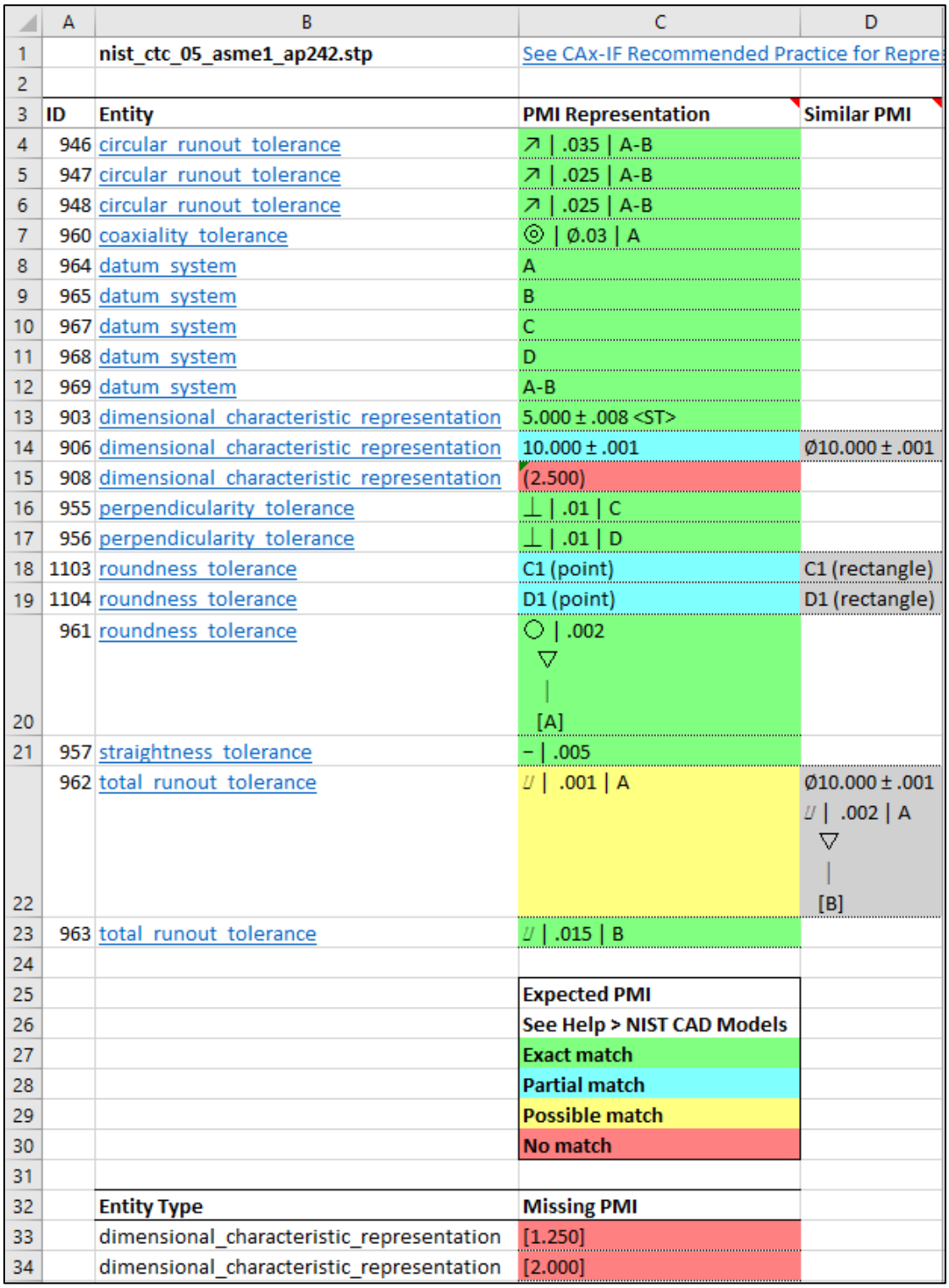
For partial and possible matches, the best match to expected Similar PMI is shown in column D. At the bottom of column C are the expected Missing PMI annotations not found in the STEP file. The red triangles in the upper right corners of cells C3 and D3 indicate that there is a cell comment that explains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

[4] 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	↗ | .035 | A-B	
5	947	circular_runout_tolerance	↗ | .025 | A-B	
6	948	circular_runout_tolerance	↗ | .025 | A-B	
7	960	coaxiality_tolerance	◎ | Ø.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 ± .008 <ST>	
14	906	dimensional_characteristic_representation	10.000 ± .001	Ø10.000 ± .001
15	908	dimensional_characteristic_representation	(2.500)	
16	955	perpendicularity_tolerance	⊥ | .01 | C	
17	956	perpendicularity_tolerance	⊥ | .01 | D	
18	1103	roundness_tolerance	C1 (point)	C1 (rectangle)
19	1104	roundness_tolerance	D1 (point)	D1 (rectangle)
20	961	roundness_tolerance	○ | .002 ▽ | [A]	
21	957	straightness_tolerance	– | .005	
22	962	total_runout_tolerance	⌰ | .001 | A	Ø10.000 ± .001 ⌰ | .002 | A ▽ | [B]
23	963	total_runout_tolerance	⌰ | .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 82: 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 83, 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 section 6.1.5.

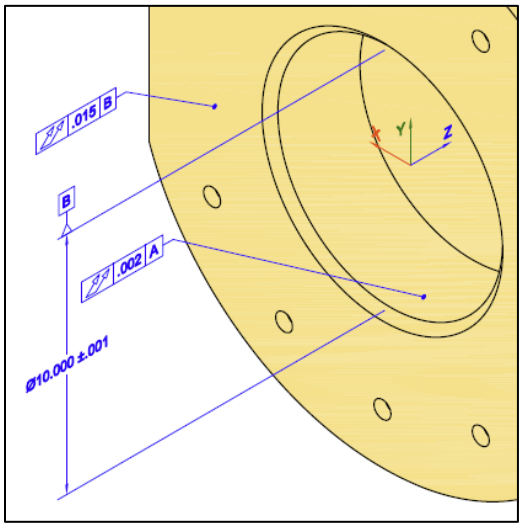


Figure 83: Feature from NIST CTC 5

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

6.5.2 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 49, for the NIST test cases. The color-coded worksheet is shown in Figure 84. A similar worksheet without color-coding is shown in Figure 68.

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 84.

- 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 [31],
- 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.

6.5.2.1 Color-coding Expected PMI

From the PMI Representation Summary results in Figure 82, 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 84 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 82. Those partial or possible matches would show up in the second table in Figure 84.

	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, Table 11)	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 5.1.3)	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 Ⓜ (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		

Summary | Header | **PMI Representation Coverage** | PMI Representation Summary | angularity_tolerance | d

Figure 84: 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. If errors and warnings are reported, the number in parentheses is the line number in the STEP file where the error or warning was detected.

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 section 6.4.

```
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 85: 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 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 86. 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.

	A	B	C	D	E	F	G	H
1	STEP Directory	C:\Users\lipman\Documents\Analyzer\User-Guide						
2								
3		Link (1)	Link (2)	Link (3)	Link (4)	Link (5)		
4		nist_ctc_01_asme1_ap242.stp	nist_ctc_02_asme1_ap242-1.stp	nist_ctc_03_asme1_ap242.stp	nist_ctc_04_asme1_ap242.stp	nist_ctc_05_asme1_ap242-1.stp		
5		15-02-16	15-02-17	14-12-19	15-02-16	14-12-19		
6								
7		AP242	AP242	AP242	AP242	AP242		
8		389 Kb	3548 Kb	1261 Kb	1073 Kb	851 Kb		
9	Entity	6137	48665	17311	17926	13058	Total Entities	Total Files
31	(geometric_tolerance_with_datum_reference) (surface_profile_tolerance) (unequally_disposed_geometric_tolerance)		3				3	1
32	(geometric_tolerance_with_modifiers) (perpendicularity_tolerance)		1				1	1
33	perpendicularity_tolerance	1	2	2		2	7	4
34	placed_datum_target_feature		9			2	11	2
35	plus_minus_tolerance	6	7	8	7	2	30	5
36	roundness_tolerance					1	1	1
37	shape_dimension_representation	8	7	10	9	2	36	5
38	straightness_tolerance					1	1	1
39	surface_profile_tolerance		1	1			2	2
40	tolerance_value	6	7	8	7	2	30	5
41	tolerance_zone		7	7	3	1	18	4
42	tolerance_zone_form		7	7	3	1	18	4
43	total_runout_tolerance					2	2	1
44	annotation_curve_occurrence		45	30		20	95	3
45	annotation_plane	22	9	4	25	5	65	5
46	camera_model_d3	1			1		2	2
47	(characterized_representation) (draughting_model)	2			2		4	2
48	colour		9	4		5	18	3
49	colour_rgb	1	684	156	2	207	1050	5
50	curve_style	1	46	30	1	21	99	5
51	draughting_callout	22			25		47	2
52	draughting_model		1	1		1	3	3
53	draughting_model_item_association	34	87	59	37	32	249	5
54	draughting_pre_defined_colour	1	45	30	1	20	97	5
55	draughting_pre_defined_curve_font	1	46	30	1	21	99	5
56	fill_area_style	1	680	160	2	210	1053	5

File Summary | PMI Representation Coverage | PMI Presentation Coverage

Figure 86: 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 87 shows the worksheet that is generated for coverage analysis of PMI representation. The information on the worksheet is the same as described in section 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 section 6.5, 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							
3	PMI Element (See Help > Analyze > PMI Coverage Analysis)	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	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, Table 11)		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 5.1.3)		0/2	2	3/8		5
30	dimension association to geometric tolerance (5.1)		4/7	8/7	2/3	0/1	14
31	bilateral tolerance (5.2.3)	2	6/7	8	7	2	25
32	non-bilateral tolerance (5.2.3)	4					4
33	value range (5.2.4)	2					2

File Summary | PMI Representation Coverage

Figure 87: PMI Representation Coverage worksheet, multiple files (rows 1-33)

34	diameter Ø (5.1.5)	7	7	8/7	5/6	1	28
35	linear distance (5.1.1)			2	2	5	9
36	curve length (5.1.5)				1		1
37	dimension basic (5.3)				2	4	6
38	reference dimension (5.3)			1			1
39	dimension qualifier (5.4)					6	6
40	datum system (6.9.7)	5	20	11	6/7	8	50
41	multiple datum features (6.9.8)					3	3
42	datum feature association to geometric tolerance (6.1)	1	6	8		1/2	16
43	all datum targets		9			2	11
44	point datum target (6.6)		8			2/0	10
45	rectangle datum target (6.6)					0/2	0
46	circle datum target (6.6)		1				1
47	least_material_requirement Ⓛ (6.9.3 or 6.9.7)		7				7
48	maximum_material_requirement Ⓜ (6.9.3 or 6.9.7)		5	4			9
49	statistical_dimension <ST> (5.3)					1	1
50	saved views (9.4)	1	3	0/1	1	2	7
51	ISO modeling standard (4, Fig. 2)					1	1
52							
53	Section numbers above refer to the CAx-IF Recommended Practice for Representation and Presentatio						
54							
55	**Expected PMI (% from PMI Representation Summary worksheets)**						
56	Exact match	100	90	96	74	88	
57	Partial match	0	9	4	17	4	
58	Possible match	0	2	0	0	0	
59	Missing match	0	0	0	9	8	
60	No match	0	0	4	0	8	
61	Total PMI	19	58	28	23	26	

File Summary | PMI Representation Coverage

Figure 88: PMI Representation Coverage worksheet, multiple files (rows 34-61)

8.2.2 PMI Presentation Coverage Analysis

Figure 89 shows the worksheet that is generated for coverage analysis of PMI presentation. The information in the worksheet is the same as described in section 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											
3	PMI Presentation Names	nist_ctc_01_asme1_ap242.stp	nist_ctc_02_asme1_ap242-1.stp	nist_ctc_03_asme1_ap242.stp	nist_ctc_04_asme1_ap242.stp	nist_ctc_05_asme1_ap242-1.stp	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 89: 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 90 shows the options available for the command-line version.

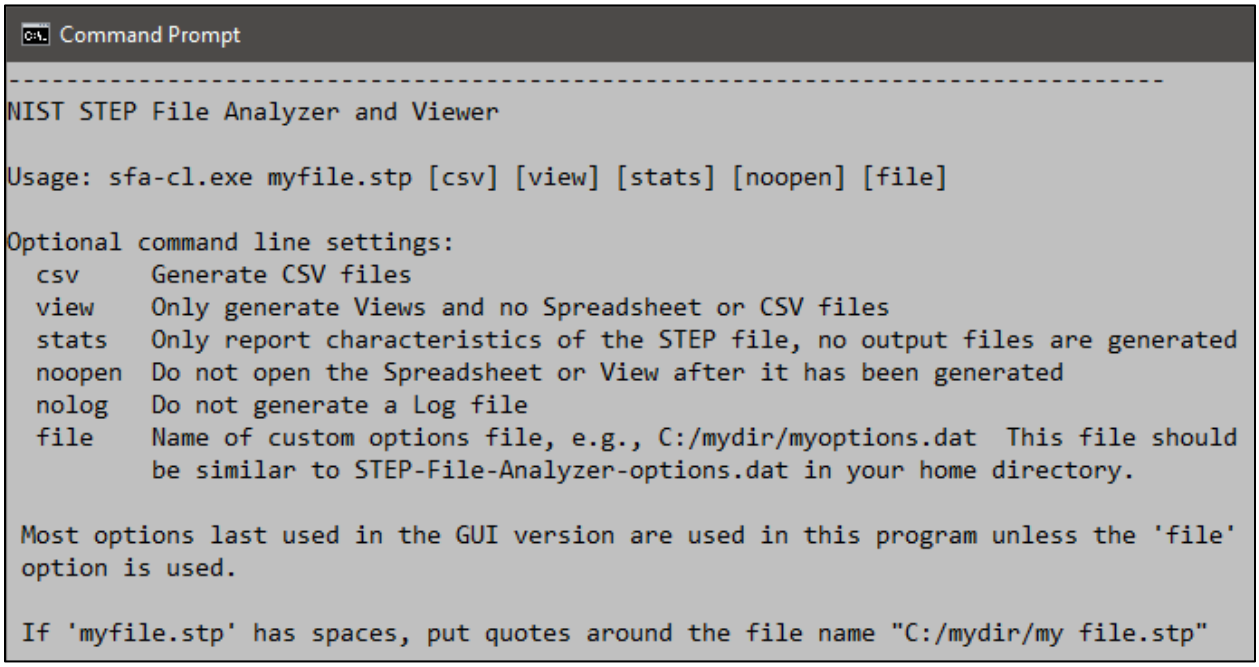


Figure 90: Command-line version options

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 91. Error and warning messages are preceded with three asterisks (***) and highlighted with a different font and background color.

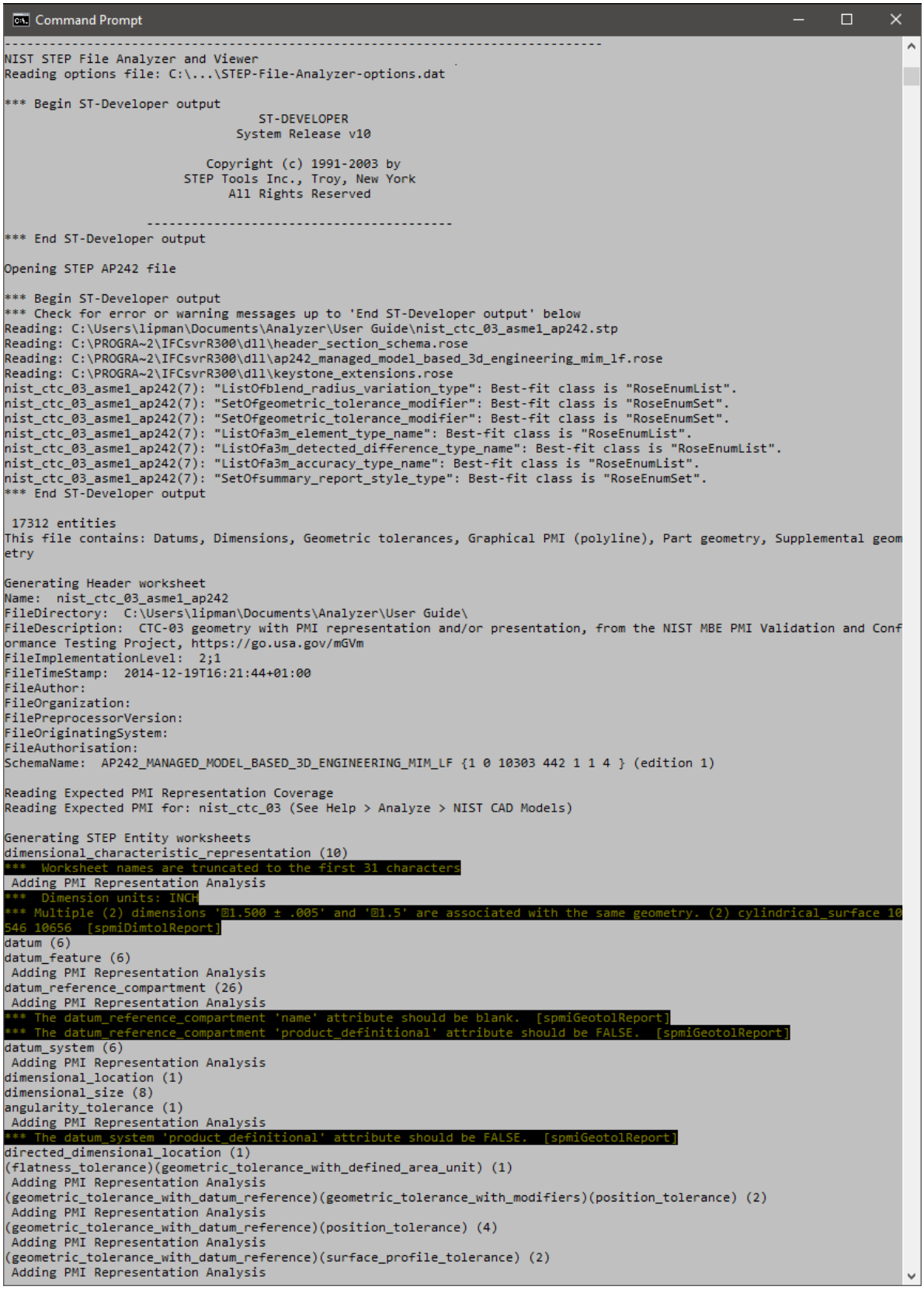


Figure 91: Command-line version output

10 Crash Recovery

As explained in section 2.4, sometimes SFA will crash when processing a STEP file. This is most likely due to either syntax errors in the STEP file or due to limitations of the IFCsvr toolkit. If a crash occurs, one or more of the dialogs in Figure 92 might be shown. If this happens, simply close the dialog(s), restart SFA, and process the same STEP file again by using function key F1 or F6 if processing multiple files. SFA keeps track of which entity type caused the crash for a particular STEP file and won't process that type again. A message will be shown in the Status tab if a particular type of entity won't be processed.

The entity types that won't be processed again are stored in a file *-skip.dat where '*' is the name of the STEP file. 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.

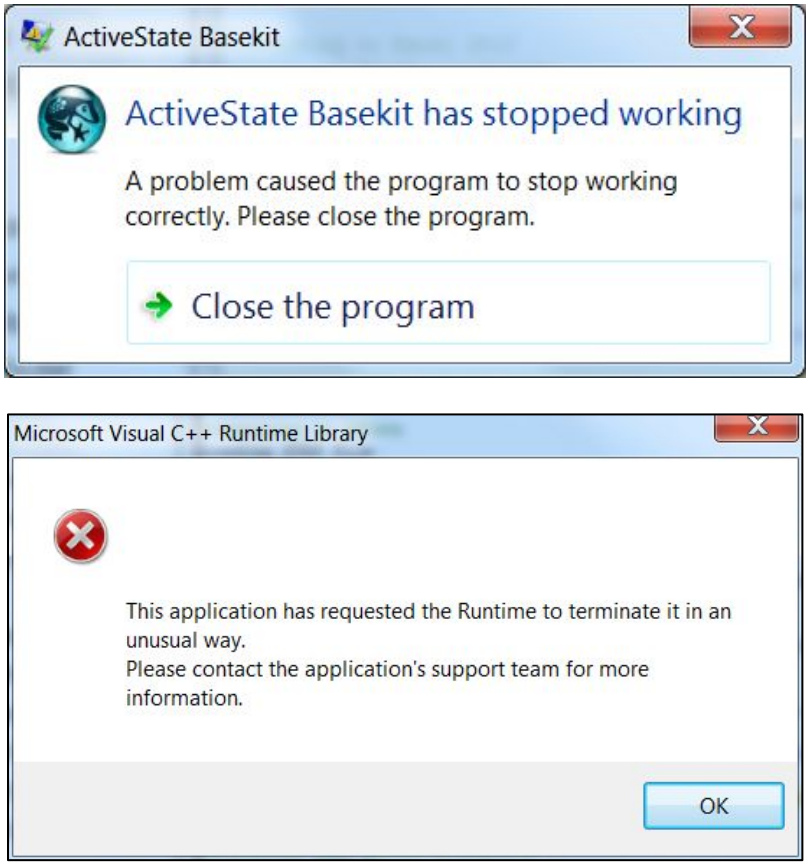


Figure 92: Dialogs displayed when the software crashes

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.

If SFA crashes, you can also see which entity type caused the crash. Figure 93 shows that SFA crashed when processing an annotation_plane entity. The entities of the type that caused a crash should be checked for syntax errors.

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

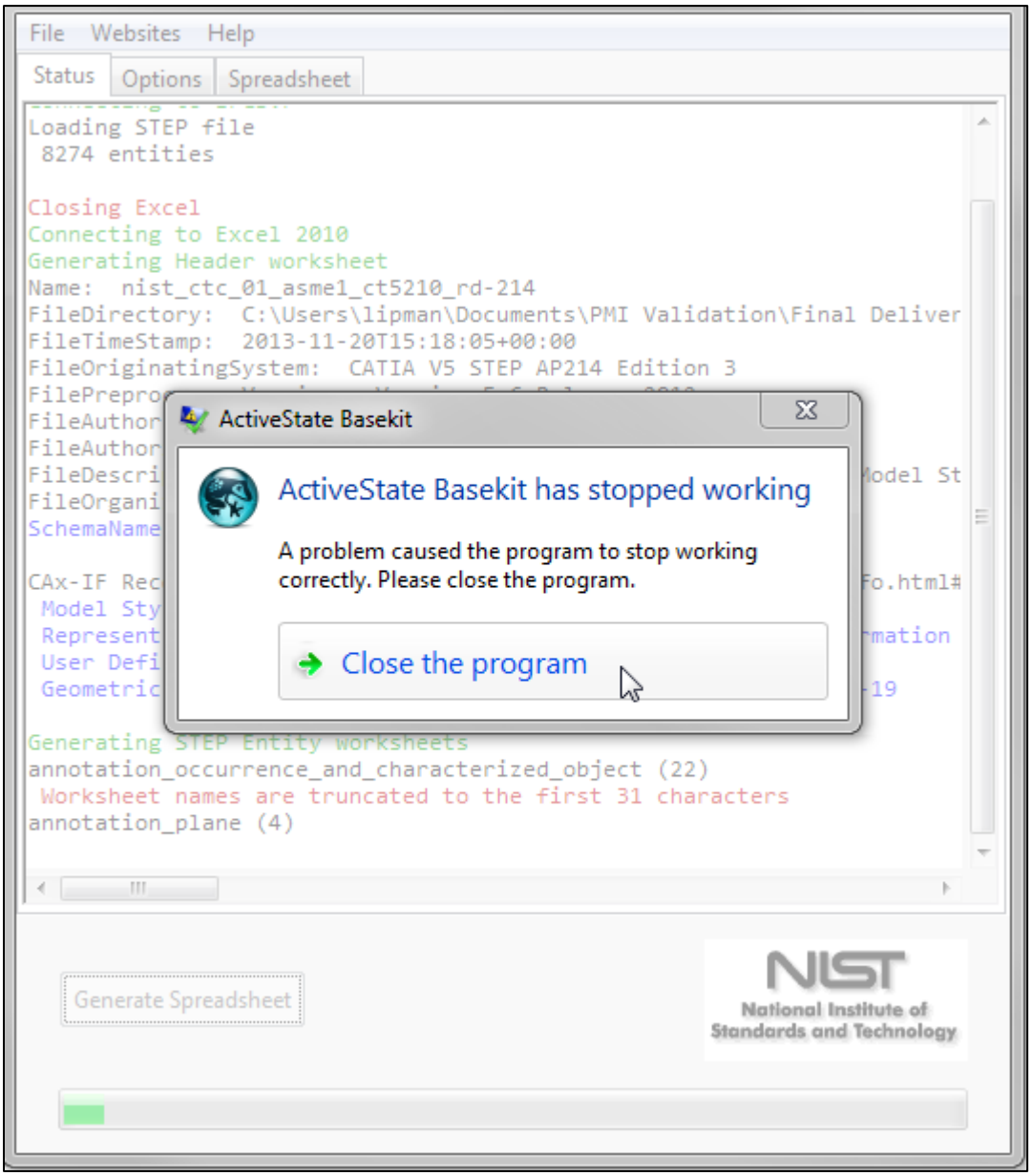


Figure 93: Which entity caused a crash

11 References

All websites were successfully accessed in June 2020.

[1] *Open CASCADE STEP Processor*, https://dev.opencascade.org/doc/overview/html/occt_user_guides__step.html.

[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] 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.

[7] 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.

[8] *ISO 10303-209 Multidisciplinary Analysis and Design*, http://www.ap209.org.

[9] 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.

[10] 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.

[11] 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.

[12] *ISO 10303-238 STEP-NC Standard*, http://www.ap238.org.

[13] 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.

[14] *AP239 - Product Life Cycle Support*, http://www.ap239.org.

[15] 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.

[16] *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.

[17] 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.

[18] ISO 16739-1:2018, "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries," International Organization for Standardization, Geneva, Switzerland.
[19] 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.
[20] *Industry Foundation Classes*, buildingSMART, https://technical.buildingsmart.org/.
[21] 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.
[22] R. Lipman, "SteelVis User's Guide," National Institute of Standards and Technology, NISTIR 7822, 2011.
[23] *CAx Interoperability Forum*, https://www.cax-if.org/cax/cax_introduction.php.
[24] *ISO 10303 STEP Standards*, STEP Tools, Inc., https://www.steptools.com/stds/step/.
[25] *CAx-IF Recommended Practices*, CAx Implementor Forum, https://www.cax-if.org/cax/cax_recommPractice.php.
[26] *X3DOM*, Fraunhofer IGD, https://www.x3dom.org.
[27] J. Lubell, "From Model to Markup," in *Proceedings of the 2002 XML Conference*, 2002.
[28] 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.
[29] ASME Y14.41-2012, "Digital Product Definition Data Practices - Engineering Drawing and Related Documentation Practices," American Society of Mechanical Engineers, 2012, New York.
[30] ISO 16792:2006, "Technical product documentation - Digital product definition data practices," International Organization for Standardization, Geneva, Switzerland.
[31] J. Boy and P. Rosche, "Recommended Practices for Representation and Presentation of Product Manufacturing Information (PMI) (AP242)," CAx Implementor Forum, 2020.
[32] 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.
[33] J. Boy and P. Rosche, "Recommended Practices for Geometric and Assembly Validation Properties," CAx Implementor Forum, 2019.