Examining Neutral Formats for Visualization and Data Exchange

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Final Report

Project Overview

With the proliferation of visualization formats in the past few years, there has been some confusion in industry with regard to the use of these formats relative to STEP and other standard data formats. As technology vendors advance the capability of “lightweight” file formats, selecting the appropriate file format for a specific purpose is critical to the communication and collaboration process. This project involved a series of tasks that examined the functionality of several of these formats and provided a basis for determining how to use them effectively in various business scenarios. While the scope is not meant to be all-encompassing, it examined issues that have received attention in industry to date. A common theme that pervades this work is informing industry regarding the use and timeliness of the STEP file compared to that of native CAD file formats and more recent “lightweight” formats.

Task 1 in the project dealt with comparing selected lightweight visualization formats (3DXML, JT, and U3D) to the functionality contained within the STEP AP 203 e2 format. In the absence of a standard method for comparing lightweight file formats, the criteria used for evaluating functionality within the STEP file was used for the comparisons made in Task 1. The results of Task 1 suggest that the JT format would provide an acceptable complement to the STEP file for visualization and communication purposes. The JT file provides complementary functionality with regard to metadata and PMI, while typically yielding a smaller file size than STEP. While the 3DXML file provided similar functionality to the other formats evaluated, it potentially has a limited reach due to the lack of adoption by software vendors other than Dassault at this time.

Task 2 in the project dealt with the development of a checklist that can be used to determine the applicability of particular lightweight formats to a given situation. The research team created a questionnaire to assess the relevant characteristics of lightweight file formats and presented that to relevant experts in industry for feedback. Taking that feedback, the survey was revised and then administered to 10 participants across various industries. The results of those interviews were compiled and used to generate a checklist of important characteristics to describe lightweight file formats in an industry usage scenario. Government and aerospace were the primary industry sectors represented in this survey, and it should be noted that these companies are currently the primary implementers of PLM philosophies.

Task 3 sought to address the development of use cases to aid industry in the selection and implementation of lightweight file formats for key tasks, including collaborative design evaluation, request for quote from a supplier, and transferring information from design to manufacturing. Tasks 1 and 2 provided a context in which these use cases were to be developed. A web-based survey was developed that examined the aforementioned preliminary areas, and data was obtained from aerospace, government and heavy equipment industries. The results of Task 3 yielded data that support the use of lightweight formats provided they maintain geometry integrity and the desired attributes that enable communication. However, the survey results also suggested that 2D drawings are still the entry point for collaboration for those people unsure of how to use the technology.

Task 1: Evaluating 3DXML, JT and U3D According toe STEP AP 203 Criteria

Three lightweight file formats – 3DXML, JT, U3D and one STEP file were produced for each test comparison. The first step was to produce a native CAD format with CATIA V5R17, and a native Unigraphics NX5.0 format. The CATIA file was then used as a basis for exporting into a STEP file, 3DXML file, and U3D file. STEP and 3DXML files were exported with CATIA's 'save as' function. The U3D file however was produced within the Adobe Acrobat 3D toolkit downloaded from Adobe's website. This toolkit that came with Adobe Acrobat 3D is able to import native CATIA file and export it as a U3D file. For the JT file, a Unigraphics NX native file was exported within NX itself. This research study used specific software tools and specific versions of those tools available to Purdue University through its academic software licensing channels. It is acknowledged that as technology evolves in the various vendor offerings, the results from a similar study with similar methodologies may be different in the future.

For comparison, STEP files were viewed with CATIA, 3DXML was viewed with its own 3DXML viewer, and the JT file was viewed with the JT 2 Go viewer. For U3D files however, a PDF file has to be created with the U3D file using Adobe Acrobat 3D, and then viewed with any Adobe reader. For some other comparisons that deal with file contents, these files were attempted to be opened with a text editor – Microsoft Window's notepad. Figure 1 shows an overview of the testing flow path used in this portion of the study.

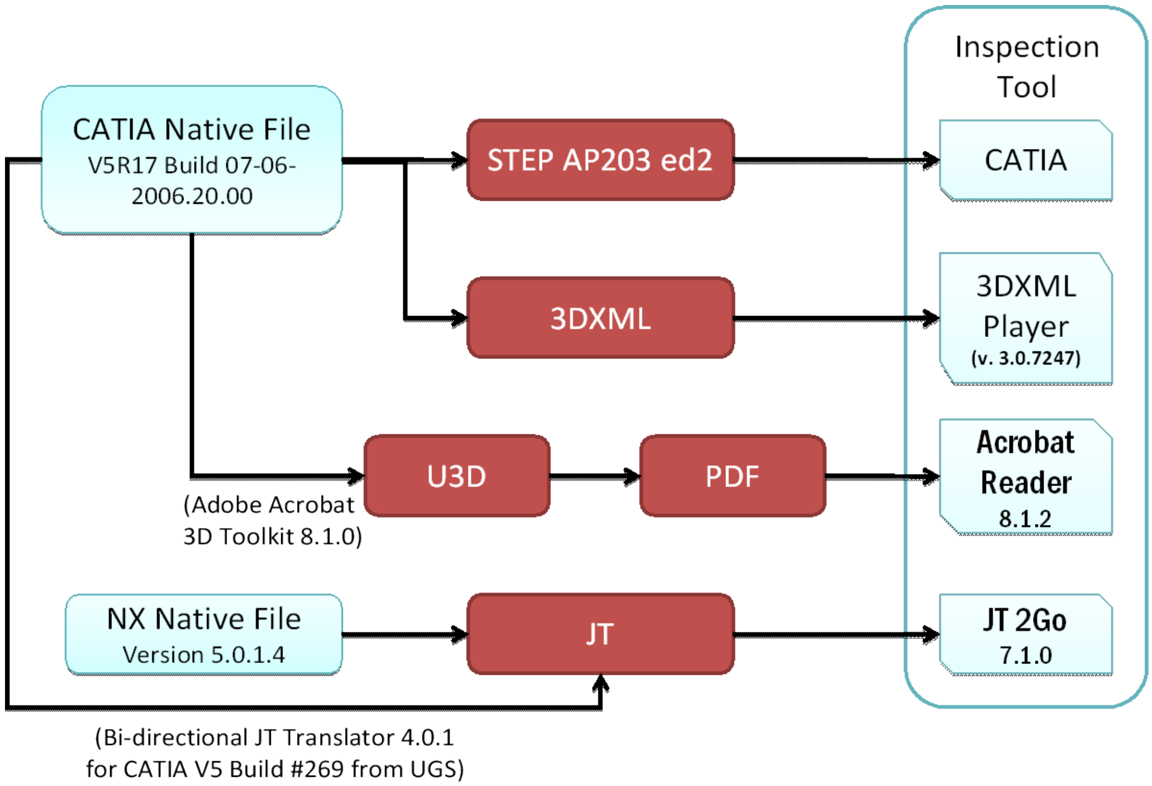


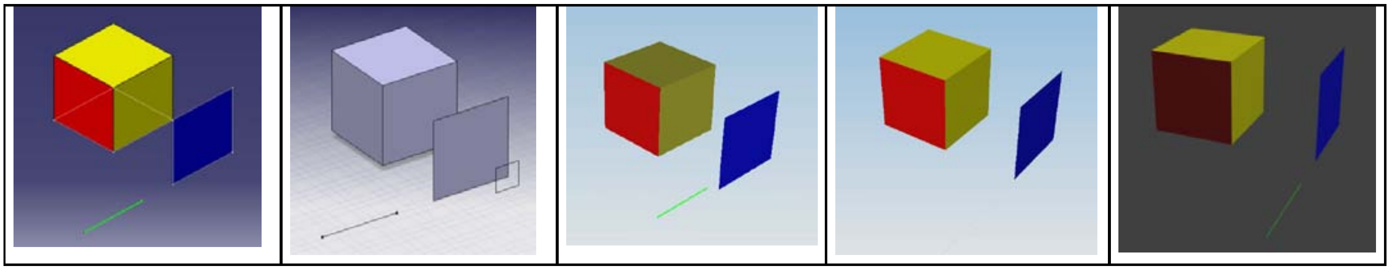
Figure 1: Schematic Diagram for Testing Methodology

Test 1: Colors & geometries

The goal of this test was to confirm that the lightweight file formats support solid colors and different geometry types. A screenshot from the CAx Implementor Forum website – test R18j-C1 is used as a reference for this test. A solid cube, square surface, and a straight wireframe line were produced with consistent units. The whole cube was then colored as yellow using the cosmetic functionality within the CAD system, followed by a single red surface on the cube, blue on the square surface, and green on the line. The following screenshots in the table below are the results for this test.

Table 1: Color and geometry test results: STEP file; 3DXML file; JT file; U3D file as PDF.

STEP	3DXML	JT (NX)	JT (CATIA)	U3D



It appears that solid colors were supported successfully in all except the 3DXML file format. Simple solid, surface, and wireframe geometries were successfully exported and viewed within each file's respective viewer program.

Test 2: Form features, Construction history

Several features were tested within the same model for Test 2. The model in Figure 2 was produced consistently in CATIA and NX. The rectangular solid extrusion was modeled first, followed by a simple blind hole, a blind hole defined with threads, a counter-bore blind hole, and a counter-sunk blind hole at their respective locations. The goal of this test was to validate if specific form feature properties (e.g., the different hole-definitions) were stored in the file formats rather than plain geometry information. The second objective was to validate if construction history of the model was saved and stored inside the lightweight file as well. Official reference documentations for the three lightweight file formats have no indication of any support for these features.

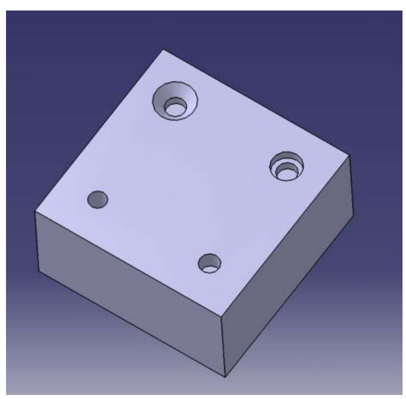


Figure 2: Native CATIA model used for Test 2.

The respective file format viewers are first used to check if any of the form-feature or construction history information can be obtained. The files were then attempted to be opened and read with a plain text editor – Microsoft Window's Notepad.

As expected, no specific form feature information or construction history could be obtained from the lightweight file viewer programs. When the files were opened in a text editor, the STEP file only has a single line of "SHAPE_ASPECT" and no

"GEOMETRIC_OPERATION_SEQUENCE" found. This indicated that the STEP exporting function in CATIA did not fully support these two features. It should be noted that future versions of this translator may indeed support such functionality. The 3DXML file had to be unzipped using a file compression software (i.e. WinZip) before the file could be opened with a text editor. Once unzipped, contents within the file were inspected. However, no identifiable form-feature or construction history information can be found. For JT and U3D, these files could not be successfully opened with plain text editors, and thus its code could not be checked for this test. This is expected from the file format's documentation as it was been indicated that a bit-coding algorithm is needed for translating the files into readable code. The results are summarized in Table 2 below.

Table 2: Summary results from Form Features test

STEP (V5R17)	3DXML (V5R17)	JT (NX 5)	JT (CATIA)	U3D (V5R17)
Not translated	Unsupported	Unsupported	Unsupported	Unsupported

Test 3: Mechanical Properties and Geometric Validation Properties

The model used for Test 2 above was re-used for this test. This time, a STEEL material was applied to the model from the native CAD systems' material list before being exported. For geometric validation properties (GVP) comparison, the model properties were first recorded within the native CAD systems. Similar to Test 2, the lightweight files were first inspected with its viewer program for any material ID or GVP properties, and then inspected with a text editor.

For the 3DXML file, no material information could be found within the viewer program. The color of the model however was slightly different from Test 2, indicating that the material's color properties were being stored successfully. Looking at the file's content, the following lines of code were found:

<Material xsi:type="BasicMaterialType" name="Steel" ambientCoef="0.2" diffuseCoef="0.39901" specularCoef="0.9" specularExponent="0.0548643" transparencyCoef="0" reflectivityCoef="0.3" refractionCoef="1">

As shown, only lighting properties of the material were found. No mechanical properties regarding the material could be found. Since there are no tools to inspect for GVP within the 3DXML viewer, the file was opened inside CATIA to inspect for GVP. Table 3 compares the two format's GVP.

Table 3: Results from GVP Evaluation of 3DXML Format

Properties	CATIA native	3DXML	Difference (%)
Volume (m3)	4.957 x 10-4	4.958 x 10-4	0.020173492
Surface (m2)	0.041	0.041	0.000
Cx (mm)	50.054	50.054	0.000
Cy (mm)	50.012	50.010	0.00399904023
Cz (mm)	24.825	24.831	0.0241691843
Mass (kg)	3.896	.496	87.2689938
Density (kg m3)	7860	n/a	n/a

For the JT file format, a limited GVP and mechanical property inspection features are found within the JT viewer. Only centroid information cannot be checked within the JT2Go viewer out of the other properties compared in the following table. All of the other values show close to zero percent difference. It should also be noted that the examination of the JT format required a software key code from the vendor in order to access the desired functionality within the free viewer. See Table 4 for these results.

Table 4: Results from GVP Evaluation of JT Format

Properties	NX 5.0 native	JT (NX)	Difference (%)
Volume (m3)	7829.00	7829.00	0.0
Surface (m2)	0.000803650	0.000803650	0.0
Cx (mm)	0.0500	N/A	N/A
Cy (mm)	0.1000	N/A	N/A
Cz (mm)	0.0250	N/A	N/A
Mass (kg)	6.291779445	6.29178	8.8221e-8
Density (kg m3)	0.077853982	0.077854	2.3120e-7

For the U3D file, no STEEL material was found when the CATIA native file is opened with Adobe Acrobat 3D Toolkit, indicating that the toolkit did not import CATIA's material property successfully. Although another material could be applied to the model within the toolkit, no inspection tool was available to identify the material id or GVP within the PDF file. Table 5 summarizes the overall results of the mechanical/GVP evaluation.

Table 5: Summary results for Mechanical/GVP Evaluation

STEP (V5R17)	3DXML (V5R17)	JT (NX 5)	JT (CATIA)	U3D (V5R17)
Not translated	Unsupported (partial)	Successful	Not translated	Not translated

Test 4: Draughting

For this test, the model for Test 2 was used to create a drawing file derived from the CAD model. Standard front-top-side views of the model and an isometric view were captured into the native systems' drafting module. These drawing files were then exported into the STEP format and into the lightweight file formats. These files were then viewed in the corresponding viewer programs.

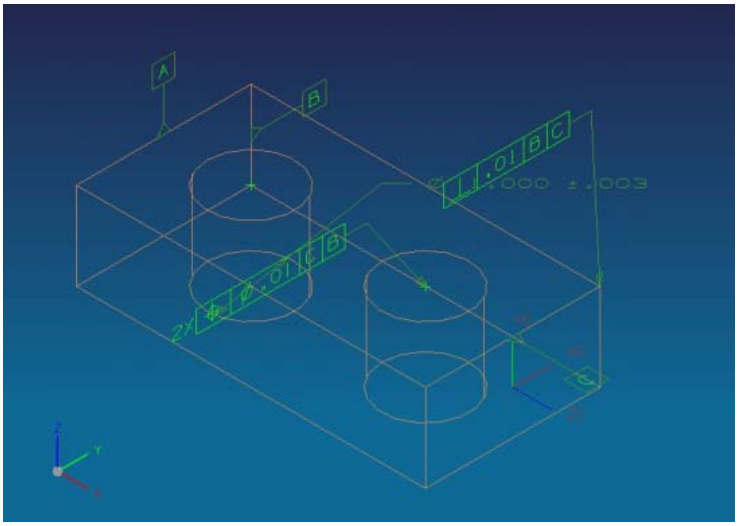
There was no option to export a .CATDrawing file into a STEP file, however this drawing file was able to be exported into a 3DXML file. When viewed with the 3DXML viewer however, the 3D model was displayed instead of the drawing. A similar result was obtained with the JT file where the native .prt drawing file was being exported into JT – only the 3D model of the test object was being displayed. The Adobe Acrobat 3D Toolkit was unable to import a .CATDrawing file. However, it was able to take a .DWG file instead. The CATIA drawing file was then exported as a .DWG, imported into the toolkit, exported as U3D, and finally the PDF was created. With these steps, the drawing was displayed correctly with Adobe Reader. Table 6 includes a summary of these results.

Table 6: Summary of Draughting Capabilities in the Lightweight Formats

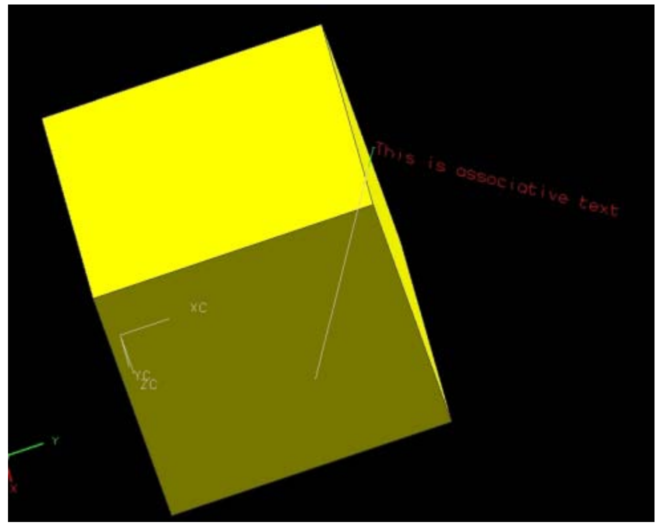
STEP (V5R17)	3DXML (V5R17)	JT (NX 5)	JT (CATIA)	U3D (V5R17)
Not translated	Unsupported	Unsupported	Unsupported	Successful

Test 5: GD & T, 3D Associative Text

The purpose of this test was to check for any successful transfer of geometric dimensioning and tolerancing (GDT) information or plain 3D associative text from the native systems to lightweight formats. These types of entities typically fall into a category of entities that have come to be called product manufacturing information (PMI) in industry circles. Native NX files were provided from PDES, Inc. for this test, as shown below in Figure 3. Native CATIA files were then reproduced to correspond to the two NX models to be exported. As with previous tests, the exported files were inspected with its respective viewer software.



GD&T on UGS NX native file.



3D text on UGS NX native file.

Figure 3: Native UGS files for testing GD&T and 3D associative text.

None of the converted lightweight files, or the STEP file, showed any text annotation for either of the models when inspected visually with their respective viewer program. The STEP file was then inspected with Microsoft Notepad by searching for the word “text” and “dimension”, such as “ANNOTATION_TEXT_OCCURRENCE” or “DRAUGHTING_PRE_DEFINED_TEXT_FONT”, which would indicate some use of 3D text annotation or GD&T according to the recommended practices documentation from the CAx-IF, The search returned no relevant reults, indicating that 3D text or GD&T information was not being exported from CATIA. Looking at both the 3DXML file that implemented the 3D text and GD&T, the following similar block of codes are found when the file is being extracted and opened.

```
<ReferenceRep xsi:type="ReferenceRepType" id="4"
name="3DText_Annotations3D_ReferenceRep" format="ANNOTATIONS3D"
associatedFile="urn:3DXML:TechRep:loc:1"/>
```

<SpecificExtensionSet>

<SpecificExtension id="1" name="ANNOTATIONS3D">

These blocks of code indicated some storage of information regarding the 3D annotation or GD&T that otherwise would not be present, such as in the model in Test 1. This perhaps indicates some storage of information regarding 3D Text or GDT information as an extended feature of the 3DXML format. However, no further information could be found in this particular file. It should be noted that some part of the file was not stored as human-readable code, indicating some storage of encoded information, which could be considered as not being made open. When the researchers referred back to the 3DXML documentation, it did not mention the use of encoded information. Unfortunately, no further investigation can be made on the JT and U3D files as they are not readily readable when opened with a text editor. In addition, the JT2Go viewer required a key code from the vendor in order to view the desired GDT/PMI information within the JT file. Table 7 summarizes the results for this test.

Table 7: Summary Results of Examining Support for 3D Annotations

STEP (V5R17)	3DXML (V5R17)	JT (NX 5)	JT (CATIA)	U3D (V5R17)
Not translated	Unsupported	Successful	Not translated	Not translated

Discussion

Tests of the lightweight file formats showed many negative results when compared to the STEP file features. Many STEP AP203 ed2 features were not available with the lightweight formats (consistent with supporting format documentation), such as Form features, Construction history, and Drafting capabilities. It is conceivable that some features are not available by default and need to be extended manually. This suggested a difference in the fundamental roles these lightweight formats were built upon compared to the STEP file format. Currently these formats would likely support collaboration and visualization, but need to be enhanced in order to support long-term storage or archival scenarios.

Examination of these sorts of formats relies on the use of viewing technology that could come from multiple sources. Due to the examination methodology selected for this study, the researchers only used the free viewing technologies provided by the CAD vendors. Therein lies a potential issue that needs to be addressed in future studies – low-cost or free viewers (vis-à-vis less functional viewers) compared to higher-cost, (potentially) more functional viewers. However, this issue may ultimately be addressed by the user community as they migrate towards the technology that provides the best cost/functionality ratio. Another factor that must be considered in a study such as this is the separation between viewer functionality and the functionality that persists within the format upon translation. An example of this can be seen in the current work being undertaken by ISO in searching for a lightweight visualization complement to the STEP file when used for data archival and retention.

In addition to the more obvious tuning of the STEP standard (as a neutral format), which has been relatively optimized for information exchange between different CAD systems, these lightweight formats were built for mainly presentation or visualization purposes for non-CAD users. These can be seen in features such as better lighting systems for a more visually appealing models, robust integration with commonly used software, such as word documents, web browsers, or PDFs; compression technologies for efficient file sharing, and even support for animation. In addition, the lightweight formats seem to support some level of file compression and basic support for varying the levels of detail included in the file.

Task 2: Development of a Checklist for Selecting Lightweight Formats

The focus of this task in the research study was to develop a set of metrics (in the form of a checklist) that could be used to determine which of the commercial lightweight formats in questions would be most appropriate to use in a given situation. The importance of this checklist is summarized in the following points:

- No standard method of assessing visualization formats.
- Industry looking for a way to display/store/retain data in lightweight formats
- Some "lightweight" formats are not lightweight
- Visualization formats are used in different ways

The research team applied techniques from developing metrics and from developing interviews and questionnaires to construct a survey that was used to gather input from industry expert users. In addition, relevant literature regarding the examination of lightweight formats was also employed. Upon examining relevant literature topics, the survey was organized into five sections:

1) Openness
2) Extensibility
3) Accessibility
4) Interoperability
5) Security

A format is considered **open** if:

- it can be described as widely available,
- non-proprietary practices,
- the services implementing the data are explicitly described and documentation of the format and services were readily available,
- the use of the standardized data and documentation is freely available,
- the updating process of the associated components were described and well-accepted by the community of involved parties and all organizations are able to participate in the ballot process,
- the responsibility for maintaining the standard are clearly defined and held by a responsible organization,
- the open standard and its documentation are not restricted by royalties, patents, or other Intellectual Property (IP) restrictions,
- is publicly available (independent of citizenship or membership in a specific organization or Community), and,
- if copyrighted, are available at reasonable cost (Harris, 2008).

Extensibility is defined as a system design principle where the implementation takes into consideration future growth (Johnson, 2007).

Accessibility is defined as the act of ensuring that access to information is available to the widest possible audience (IRS, 2007).

Interoperability is defined as the ability of a system or a product to work with other systems or products without special effort on the part of the customer, which is made possible by the implementation of standards (IEEE, 2005).

Security is defined as measures taken to guard against espionage or sabotage, crime, attack, or escape (Merriam-Webster, 2007).

Based on these characteristics, ten industry experts were interviewed during the PDES, Inc. Offsite Meeting in April 2008 based on their expertise, their regular use of lightweight formats, and their representation of particular industry segments. The objective was to determine if this initial rubric for lightweight formats matched the expectations and experiences held by industry experts. The industry segments represented in these results are government, aerospace, manufacturing, defense, and consulting/professional services. Conspicuously missing from this group is automotive and consumer products sectors. Appendix A includes a copy of the questionnaire used for this portion of the study. The questionnaire is characterized by Likert scale responses (1=low, 5=high) and open-ended questions.

Results

Table 8 and Table 9 show summary data related to the responses given by the participants. Table 7 shows the average rating for each characteristic, while Table 8 shows the average rating for each industry segment.

Table 8: Average Ratings for Format Characteristics

	Openness	Extensibility	Accessibility	Interoperability	Security
AVERAGES	4.25641	4.1	4.068966	4.428571	4.2

Table 9: Average Ratings for Format Characteristics in Industry Segments

INDUSTRY	Openness	Extensibility	Accessibility	Interoperability	Security
Aerospace	4.10	3.83	4.05	4.375	4.33
Government	4.75	4	4.33	4.5	3
Consulting	4	5	4	4.66	5
Manufacturing	4.75	3	4	4	1
Defense	4.08	4	4.11	4.56	5

Table 10 shows the industry segment that considered each format characteristic as the most and least important.

Table 10: Maximum and Minimum Ratings for Format Characteristics

	Openness	Extensibility	Accessibility	Interoperability	Security
MAX	4.75	5.00	4.33	4.67	5.00
	Manufacturing/	Consulting	Government	Consulting	Consulting/

	Government				Defense
MIN	4.00	3.00	4.00	4.00	1.00
	Consulting	Manufacturing	Consulting	Manufacturing	Manufacturing

As a result of the ratings collected in the Likert-style questions and the responses gathered during the open-ended questions, a rubric emerged that allows users to compare file formats relative to important criteria. Figure 4 represents the final rubric that was developed as a result of the participants' responses.

Visualization Format Metrics	No	Partial	Yes
OPENNESS			
Is it a proprietary format?			
Does the format have an explicity described implementation method?			
Does the format have documentation & services pertaining itself?			
Is the format publically available?			
Totals			
EXTENSIBILITY			
Does the format have the ability to contain various types of geometry?			
Does this format support validation?			
Does this format support animation?			
Does this format support assemblies?			
Does the format support annnotations?			
Does the format support geometric dimensioning and tolerancing (GD&T)?			
Does the format support various forms of graphical properties?			
Does the format retain metadata?			
Totals			
ACCESSIBILITY			
Does the format need to be viewed in a specific viewer?			
Can the format be edited with a simple text editor?			
Can the training for this format be achieved in a limited time relative to the capacity of the format?			
Totals			
INTEROPERABILITY			
Does this format have a broad functionality?			
Can this format be applied to its intended application without the use of add-ons?			
Totals			
SECURITY			
Can this format be secured with passwords?			
Can this format be secured by using estimated geometry?			
Can this format be IP restricted?			
Can this format handle limited use technologies?			
Totals			

Figure 4: Rubric for Assessing Lightweight Format Characteristics

In an effort to explain the factors behind the items in Figure 4, the list below has been included. It represents information gleaned from the interviews with the participants.

- Openness
  - Non-Proprietary
  - Explicitly described implementation
  - Documentation of the format and services.
    - Consistency in the file format
    - Including updating process
    - All documents and data are freely available
  - Publicly available
    - Royalty free
    - Patents
    - IP Restrictions
    - Copyrights
    - Licenses
- Extensibility
  - Geometry
  - Validation
  - Animation
  - Assemblies
  - Annotations
  - GDT
  - Graphical properties
  - Metadata
- Interoperability
  - Functionality

        - Print/Plot
        - Image capture
        - Comparison
            - Native format
            - Older versions
            - Other visualization formats
        - Clearance/Interference/Fits analysis
        - Area Selection Filter
            - Bounding Box
            - Cross Boundary
        - Hold tolerances
        - Rendering styles
    - Out-Of-Box
        - Import
            - Visualization Formats into NX, CATIA, Pro/E, SolidWorks
        - Export
            - Visualization Formats from NX, CATIA, Pro/E, SolidWorks
    - Extra Modules
        - Import
            - Can import Visualization formats with extra modules
        - Export
            - Can export Visualization formats with extra modules
- Accessibility
    - Software
        - Viewers
            - Internet Browsers
            - Specific Format Reader

                - Adobe Acrobat Reader
                - Capabilities
                    - Sectioning
                    - Orientation
                    - Collaboration
                    - Transformation/Manipulation
                    - Grouping
        - Cost
        - Training
            - Time
            - Cost
- Security
    - Passwords
    - Estimated Geometry
    - IP Restrictions
    - Limited file use

Discussion

Based on these results, it is clear that the importance and relevancy of certain characteristics varies by industry segment. Industry is looking for a complimentary lightweight format to go along with standardized formats. They would also like the ability to edit levels of detail and functionality given the different needs for lightweight formats within organizations. The rubric should help users quantify what is needed by their business, and it should be adaptable to other lightweight formats (and not necessarily just the ones examined in this study).

Task 3 Development of Use Cases for Lightweight Formats

Task 3 focused on the development of use case scenarios in which the lightweight file formats were used, with a focus on moving the files between systems involved in the use case. A survey was developed by the research team at Purdue University that focused on three common use cases that have been outlined in industry literature:

- Collaborative design evaluation,
- Request for bid/quote, and

- Communication from design to manufacturing.

A copy of the survey is included in Appendix C. The following use case descriptions are informed and supported by the discussion of survey responses and the recommendations included later in the report.

Use Case Descriptions

1. Collaborative Design Evaluation

- Description of Activity: Load design, interrogate, annotate, propose changes, and finalize design among engineers and decision makers both located locally or remotely.
- Requirements:
    - Geometry – high accuracy
    - 3D annotations
    - GD&T
    - Mechanical properties
    - Sender/Receiver information, revision version, purpose of activity – review/ finalize design

Usage: Visualization formats only

- Process:
    - Sender exports native file into visualization format and sends out to reviewer
    - Reviewer inspects with visualization format reader, make annotations, and sends it back to sender
    - Sender makes appropriate changes to native file according the annotations on visualization file.
- Success Factors:
    - Ability to communicate on design via annotations without a CAD system on the receiver end

Usage: STEP only

- Process:
    - Sender exports native file into STEP format and sends out to reviewer
    - Reviewer inspects with any STEP-supported software, make annotations, exports as STEP, and send back to sender.

- o Sender either imports STEP as native file replacement or makes appropriate changes to native file according the annotations on the STEP file.

- Success Factors:
    - o Ability to communicate on design via annotations with CAD system of choice on the receiver end

Usage: STEP + Visualization formats

- Process:
    - o Sender exports native file into both STEP and visualization format and sends out to CAD and non-CAD reviewers
    - o Reviewer inspects with either STEP-supported CAD software, or visualization format viewer. Reviewer make annotations, exports as STEP or save changes in visualization formats, and send back to sender.
    - o Sender either imports STEP as native file replacement or makes appropriate changes to native file according the annotations on STEP or visualization file.
- Success Factors:
    - o Ability to communicate on design via annotations with both CAD (any STEP-CAD system) and non-CAD users

2. Request for Bid/Quote

- Description of Activity: present design to bidder for review while maintaining intellectual property rights.
- Requirements:
    - o Geometry – low accuracy
    - o 3D annotations
    - o Sender/Receiver information, purpose of activity – review/ bid design

Usage: Visualization formats only

- Process:
    - o Sender exports native file into visualization format and sends out to reviewer
    - o Reviewer inspects with visualization format reader
- Success Factors:
    - o Ability to present design without a CAD system while maintaining intellectual property rights

Usage: STEP only

- Process:
    - o Sender exports native file into STEP format and sends out to reviewer
    - o Reviewer inspects with STEP-supported CAD software
- Success Factors:

    - Ability to present design with CAD system of choice on the receiver end while maintaining intellectual property rights

Usage: STEP + Visualization formats

- Process:
    - Sender exports native file into both STEP and visualization format and sends out to CAD and non-CAD reviewers
    - Reviewer inspects with either STEP-supported CAD software, or visualization format viewer.
- Success Factors:
    - Ability to present design with both CAD (any STEP-CAD system) and non-CAD users while maintaining intellectual property rights

3. Design to Manufacturing

- Description of Activity: communicate finalized design to manufacturer to be produced either for a prototype or large-scale manufacturing. Manufacturer could be in-house or out-sourced.
- Requirements:
    - Geometry – high accuracy for manufacturing analysis
    - GD&T
    - 3D annotations
    - Mechanical properties
    - Sender/ Receiver information, revision version

Usage: Visualization formats only

- Process:
    - Sender exports native file into visualization file and sends to manufacturer
    - Manufacturer inspects geometry and PMI with visualization format reader
- Success Factors:
    - Ability to communicate design with comprehensive manufacturing details without a CAD system

Usage: STEP only

- Process:
    - Sender exports native file into STEP and sends to manufacturer

    - Manufacturer inspects with any STEP-supported CAD system of choice, and possibly perform manufacturing analysis with their CAD system
- Success Factors:
    - Ability to communicate design with comprehensive manufacturing details on any STEP-supported CAD system on the receiver end
    - Ability to perform additional manufacturing analysis with STEP supported CAD system

Usage: STEP + Visualization formats

- Process:
    - Sender exports native file into STEP for manufacturing manager for review and analysis
    - Sender exports native file into visualization format for shop-floor worker for inspection
    - Manufacturing manager inspects with any STEP-supported CAD system of choice, perform manufacturing analysis with their CAD system, and exports into visualization format for shop-floor workers
    - Shop-floor worker inspects geometry and PMI with visualization format reader possibly from original sender or manufacturing manager
- Success Factors:
    - Ability to communicate design with comprehensive manufacturing details both CAD (any STEP-CAD system) and non-CAD users
    - Ability to perform additional manufacturing analysis with STEP supported CAD system

Description of Survey Results

This section describes the results of participants' responses to each question organized according to each use case. The researchers were able to gather 12 complete responses from the anonymous participants, and 59 partial responses in which participants answered a portion of the survey, typically for one use case. However, due to the response rate and the inclusion of "partial" responses, the total values for each question may total less than 71 responses.

In a **collaborative design evaluation** scenario, the designers present their CAD design to other engineers, company decision makers, or perhaps customers. This could take place within a company, or between companies. The original designers could either send out their native CAD file or the appropriate exported formats to the receiver end. The receivers would load the file, interrogate, annotate, propose changes, and eventually finalize the design for manufacturing.

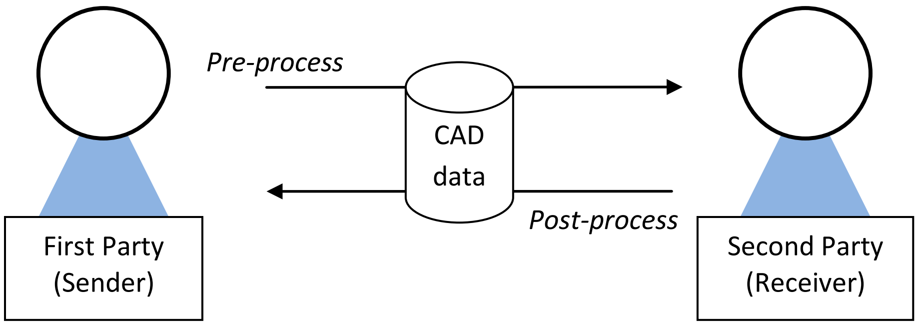
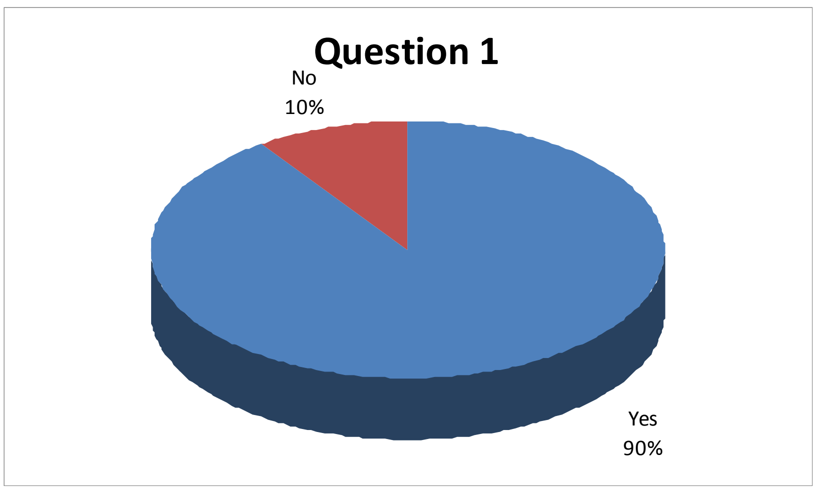


Figure 1: Collaborative Design Evaluation Process Diagram

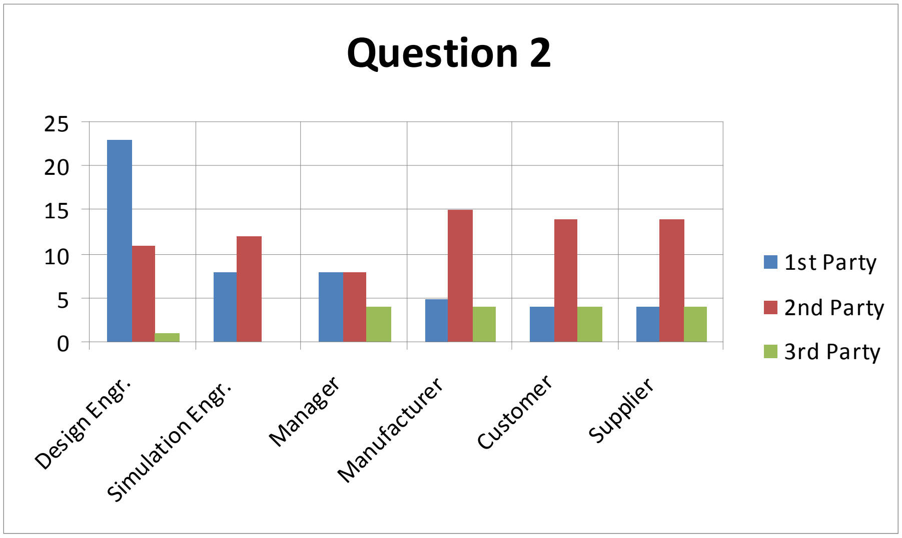
1. **Are you involved in and/or familiar with your company's collaborative processes during the design and evaluation of your product?**

   Fifty-one people responded to this question. Approximately 90% indicated that they are involved in the collaborative processes during the design and evaluation of their company's products. Approximately 10% of the respondents to this question stated they were not involved.



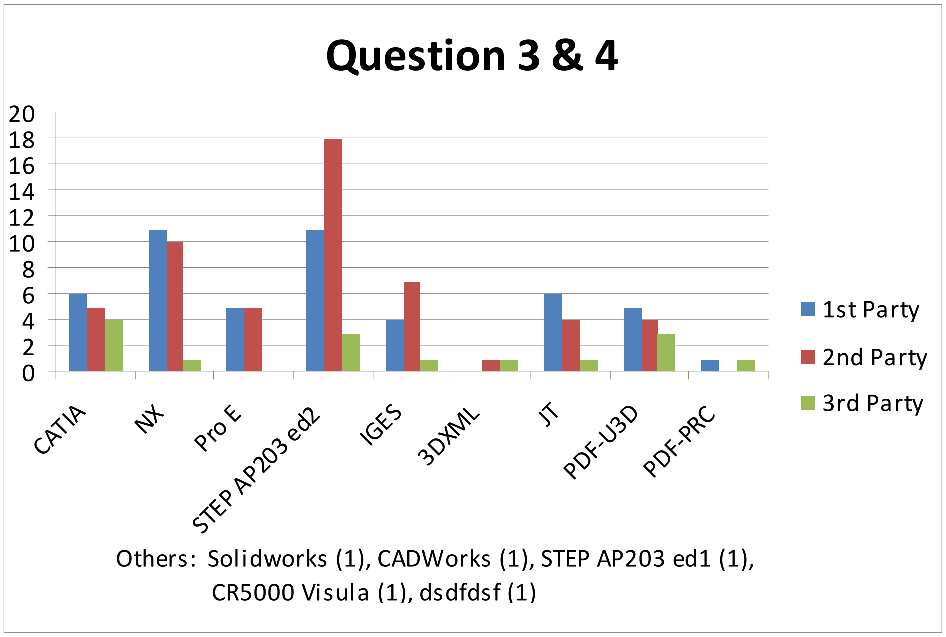
2. **In a typical collaborative design evaluation process at YOUR Company, check the following individuals who are involved.**

   This question refers to the diagram in Figure 1 above – the First Party is the sender of the information, and the Second Party is the receiver. Twenty-five (25) participants responded to this question. The five job roles typically involved in this collaborative process are design engineer, simulation engineer, manager, manufacturer, customer, and supplier. As can be seen from the chart below, the Design Engineer typically initiates the collaboration process in the organization based on the responses to this question, and the receiver is typically either the manufacturer or the customer. A third party is generally not involved, but if it is, it would most likely be a manager or supplier.



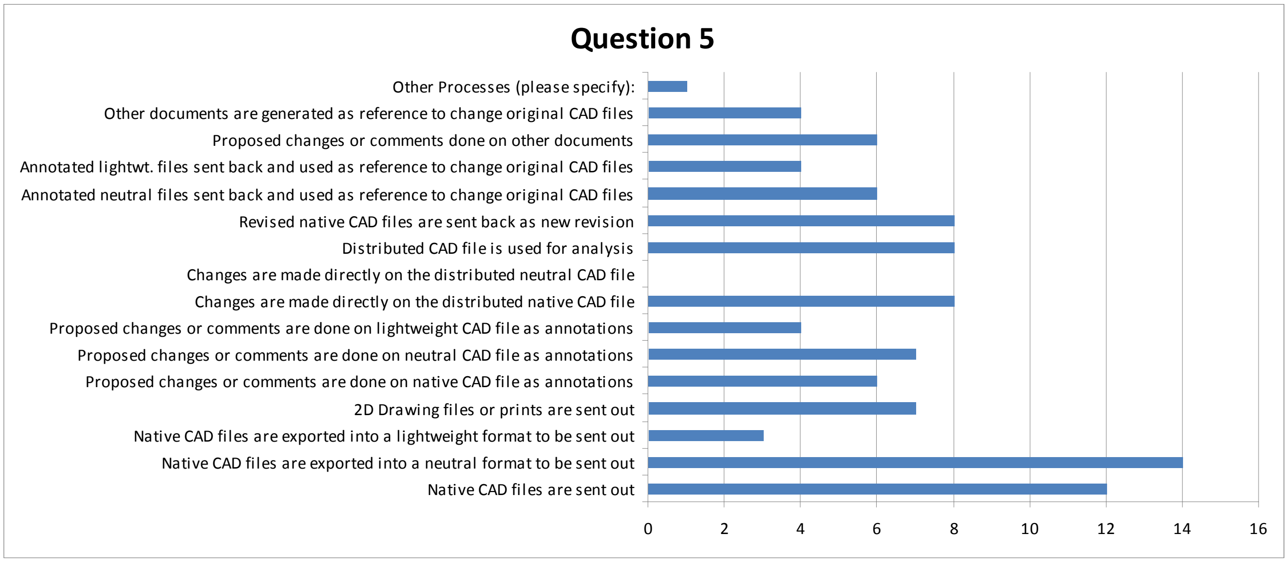
3. **Specify all CAD tools and formats used in a Collaborative Design Evaluation at your Company, and by whom.**
4. **Please specify OTHER software or formats used, but not listed.**

Questions 3 and 4 also refer to the diagram in Figure 1 above – the First Party is the sender of the information, and the Second Party is the receiver. While Question 3 is listed above, Question 4 was a free-response question and can be found in the survey in Appendix A. Twenty-one (21) participants responded to this question. The participants used NX nearly 2 to 1 compared to CATIA and Pro/ENGINEER as their CAD system of choice for both the Sender and Receiver in this scenario. This seems reasonable given the presence of NX in the aerospace industry. STEP AP203E2 appears to be the data exchange format of choice for these participants, with a 2 to 1 ratio over JT and 3DXML for Senders, and a 3 to 1 ratio for Receivers relative to those same formats. This is not necessarily a surprise given the long-term archival implications of the aerospace industry represented by a majority of the respondents.



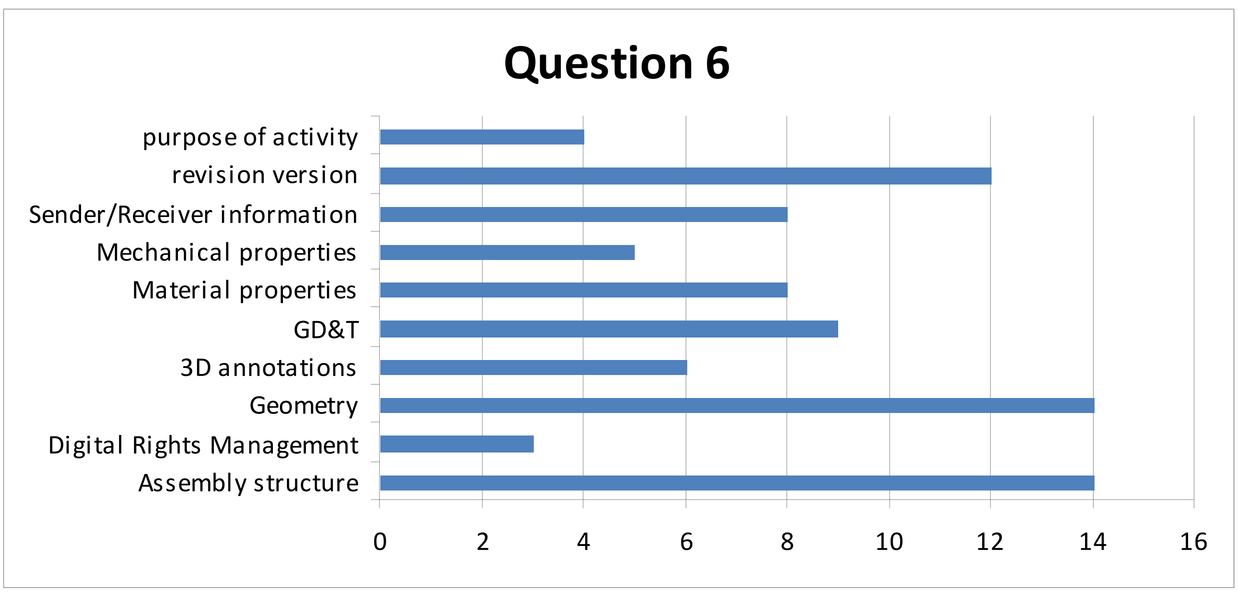
5. What are the specific Collaborative Design Evaluation processes involved in your Company?

The focus of this question was to gain an understanding of the types of actions involved in the collaborative design process relative to data exchange. Twenty (20) participants responded to this question. The survey question was divided into three areas: pre-process, process, and post process, which attempts to describe the time frame in which these activities occur. In this case, either native CAD files are sent directly, or they are converted to *neutral* formats prior to collaboration. During the collaboration process, changes are made directly on the shared native CAD file, or proposed changes and comments are entered as *annotations* on the *neutral* file format. Finally, during post-collaboration, the revised native CAD files are typically sent back as a new revision, while some participants do use the annotated neutral or lightweight formats as the basis for changes.



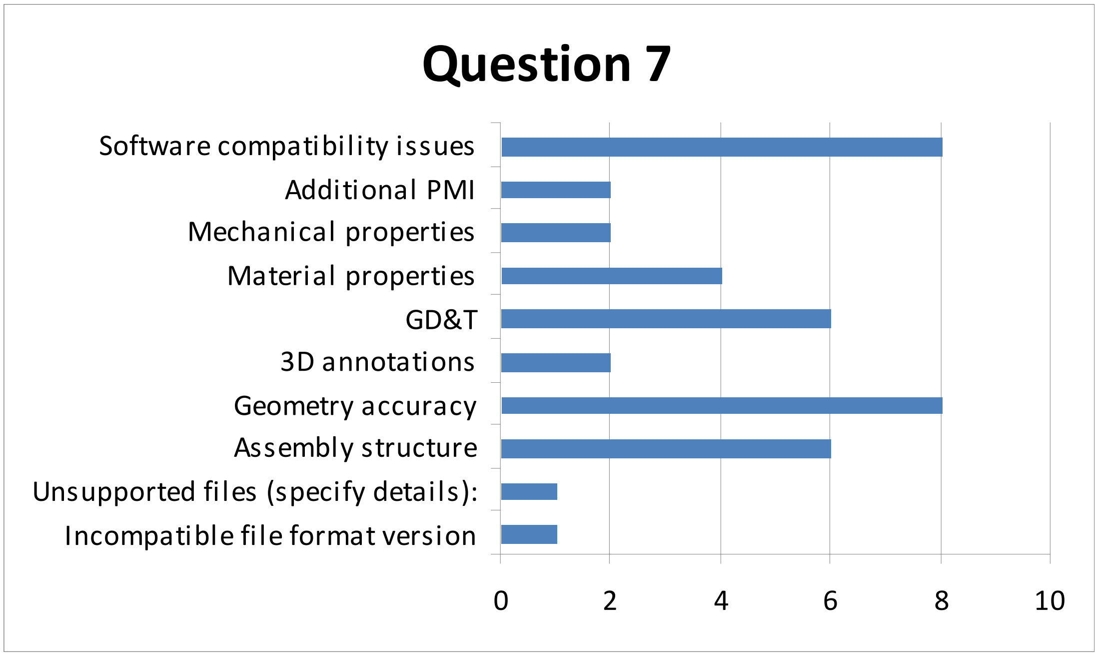
6. **List specific CAD data requirements involved in a Collaborative Design Evaluation process.**

This question addresses the specific data requirements necessary during design collaboration for the participants in this study. Fifteen (15) participants responded to this question. Maintaining the assembly structure, revision/version information, and geometry integrity are all critical CAD data requirements during the collaborative process.



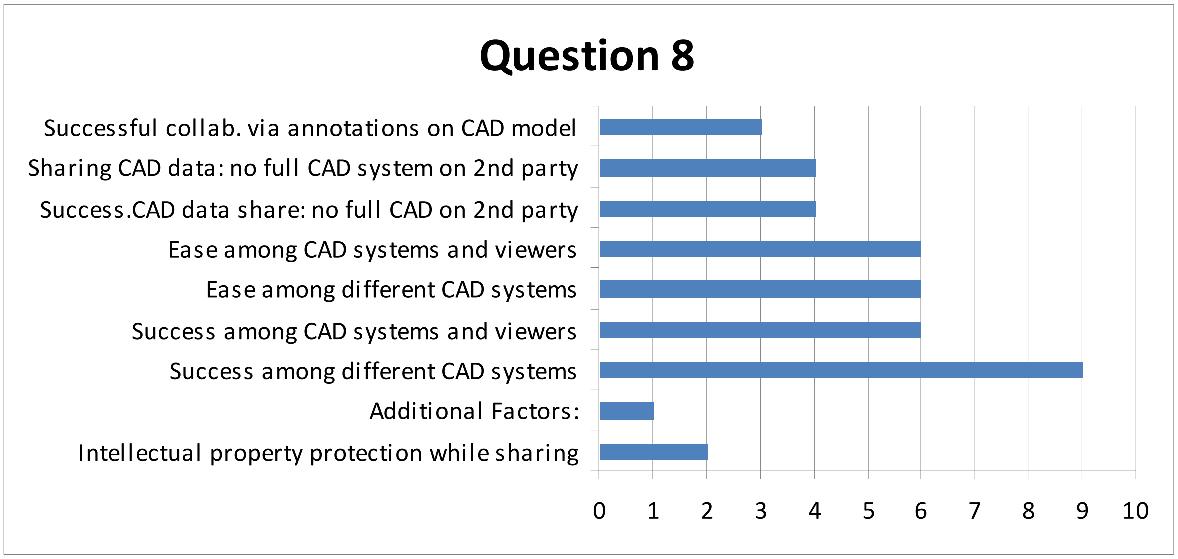
7. **Have there been any major problems in this Collaborative Design Evaluation process currently or in the past?**

This question seeks to address the problems that participants have encountered during the collaborative process relative to data formats. Fourteen (14) people responded to this question. The major challenges faced by the respondents were software compatibility and geometric accuracy. This information coupled with the responses to Question 6 paint an interesting picture – the items of most concern to the participants during the collaborative process are also the items that tend to be the most problematic for them.



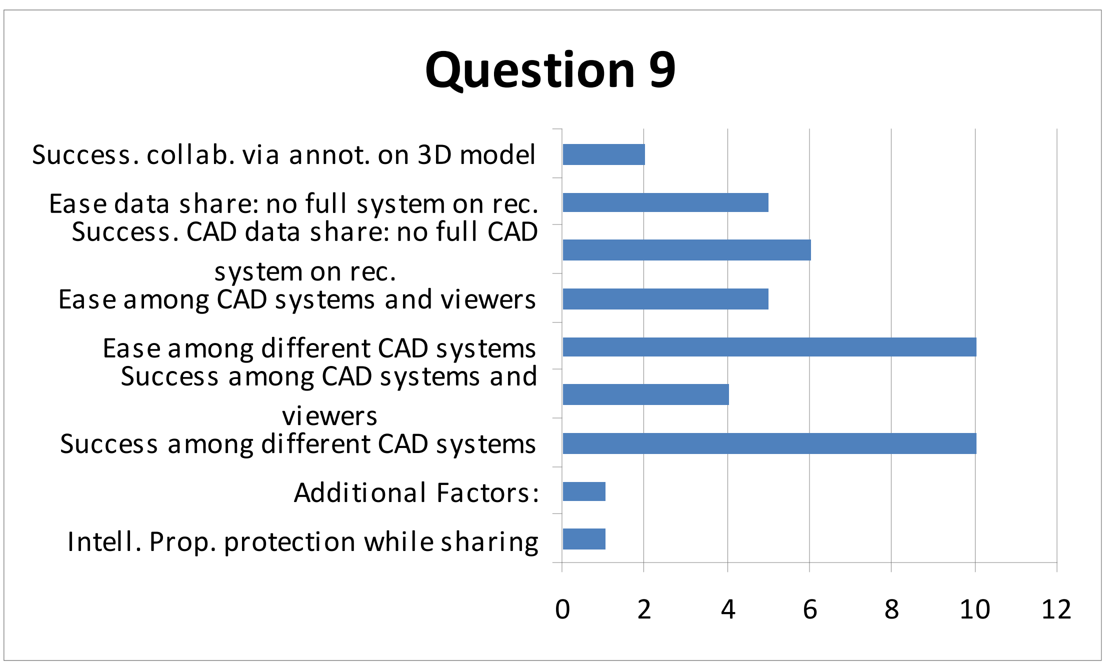
8. **In your opinion, what are the current important success factors in the use of *lightweight* formats for the purpose of collaborative design evaluation in your company?**

Question 8 seeks to understand the current important success factors for determining a successful digital collaboration environment within the participants' companies using *lightweight* formats. Eleven (11) participants responded directly to this question. The answers were organized according to "successful" translation and the "ease" of translation. Successful translation between different CAD systems was the most important factor according to these participants, with additional emphasis on the ease of translation between CAD systems and the ease of movement of data between systems.



9. In your opinion, what are the current important success factors in the use of *neutral* formats for the purpose of collaborative design evaluation in your company?

Question 9 seeks to understand the current important success factors for determining a successful digital collaboration environment within the participants' companies using *neutral* formats. Eleven (11) participants responded directly to this question. The answers were organized according to "successful" translation and the "ease" of translation. In this case, the majority of the responses dealt with the ease and success of moving files and data between differing systems, with each receiving a ten out of eleven response.



In a **request for quote** process, a company invites several suppliers to present and bid on their design based on the company's requirements. The company will then select the best design at the best price. In other cases, the company provides their own design to the best manufacturer. Several important factors during the transactions of CAD data in this bidding process are the protection of intellectual property of the supplier's or the company's; and design review capabilities such as the ones for a collaborative design evaluation process.

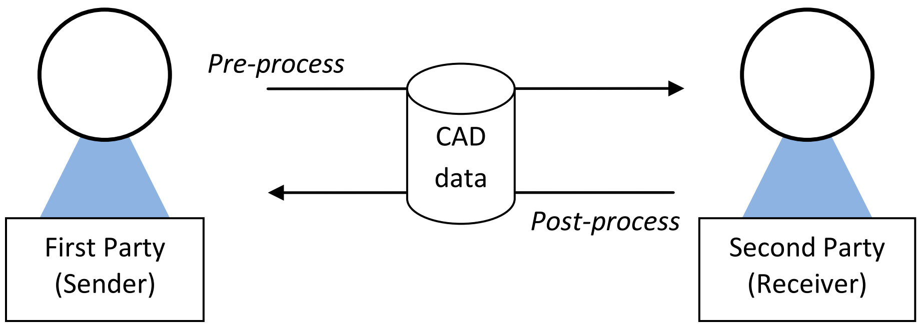
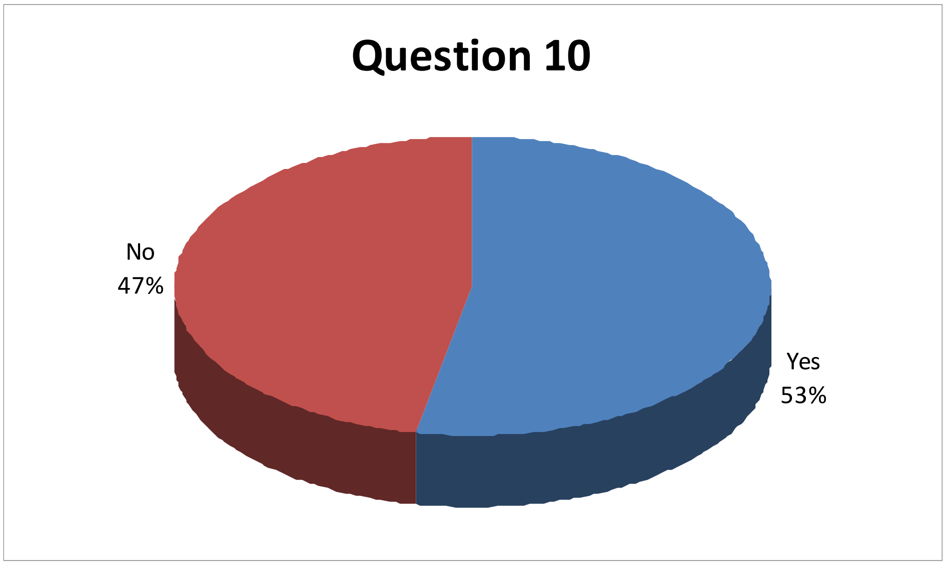


Figure 2: Request for Quote Process Diagram

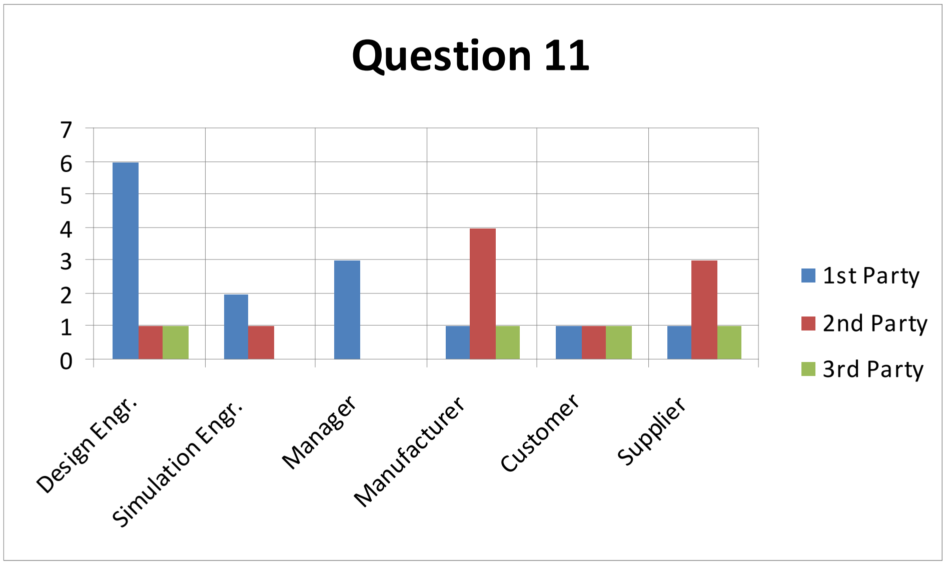
10. Are you involved or familiar with your company's Request for Quote process?

Seventeen (17) participants responded to Question 10. Of that number, slightly over half said they were involved in the Request for Quote process within the digital collaborative environment.



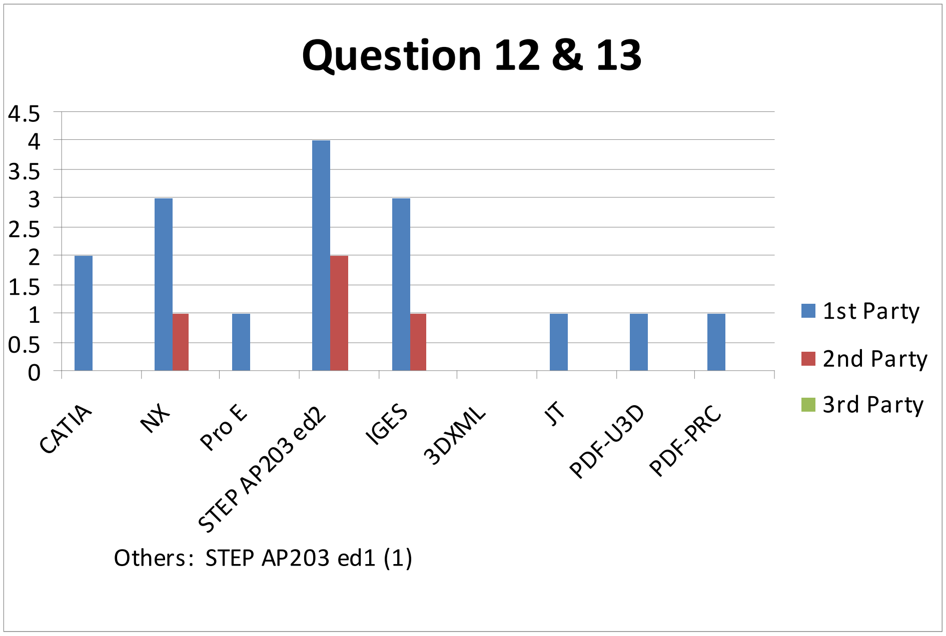
11. In a typical request for quote process at YOUR Company, check the following individuals who are involved.

This question refers to Figure 2 above relative to the Request for Quote process. Seven participants responded to this question, with either a design engineer or a manager being the person who initiates the quoting process as the Sender. The manufacturer or supplier is typically the Receiver.



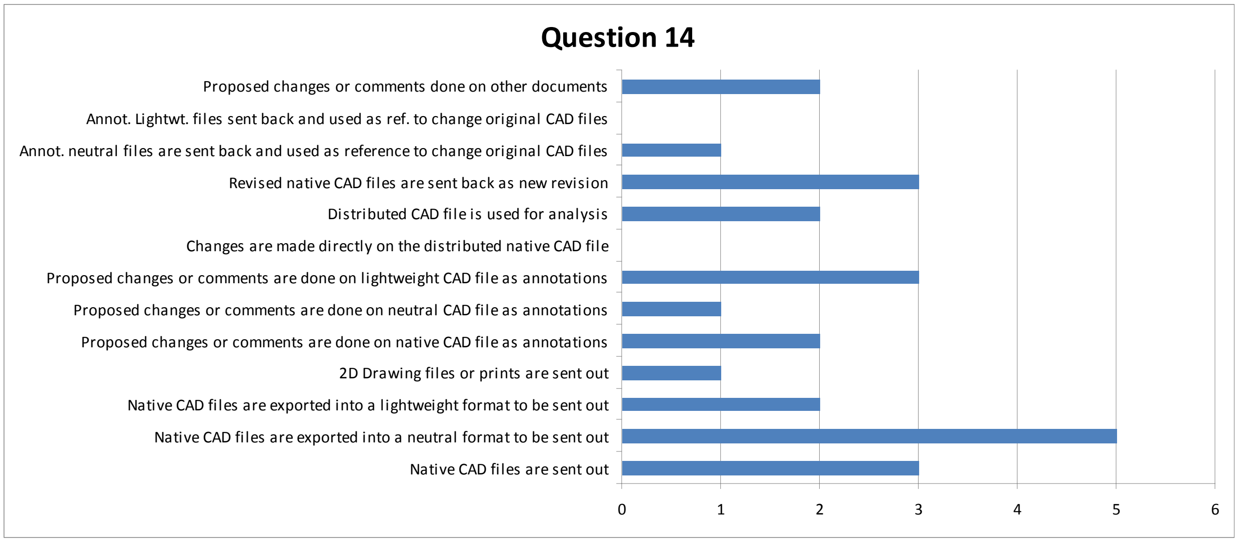
12. Specify all CAD tools and formats used in a request for quote at your Company, and by whom.
13. Please specify OTHER software or formats used, but not listed.

This question also refers to Figure 2 above relative to the Request for Quote process, and is a combination of Questions 12 and 13 on the original survey. Five total responses were given for this question so the generalizations from these results are limited, but similar to Questions 3 and 4 on the survey, NX and STEP AP203 edition 2 tend to be the CAD system and format of choice respectively for translation.



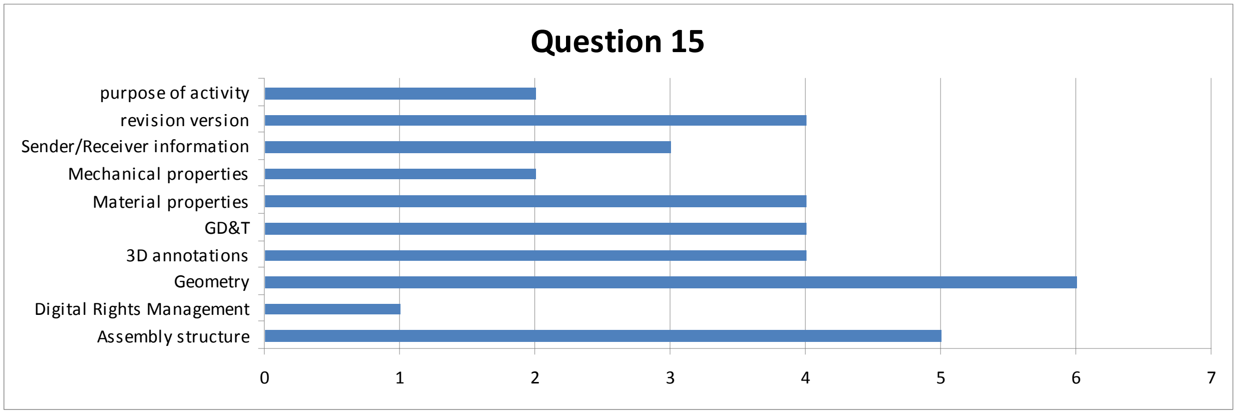
14. Check the specific Request for Quote processes are involved in your Company.

The focus of this question was to gain an understanding of the types of actions involved in the request for quote process relative to data exchange. Seven (7) participants responded to this question. This survey question was divided into three areas: pre-process, process, and post process, which attempts to describe the time frame in which these activities occur. In this case, native CAD files are converted to *neutral* formats to be sent out during the pre-process stage. During the process stage, *lightweight* formats are typically annotated and shared. And during the post-process stage, revised *native* CAD files are sent back for revisions. Interestingly, lightweight files tend to be used during the quoting process, and but changes are then made (in some cases by the supplier) and sent back to the original creator.



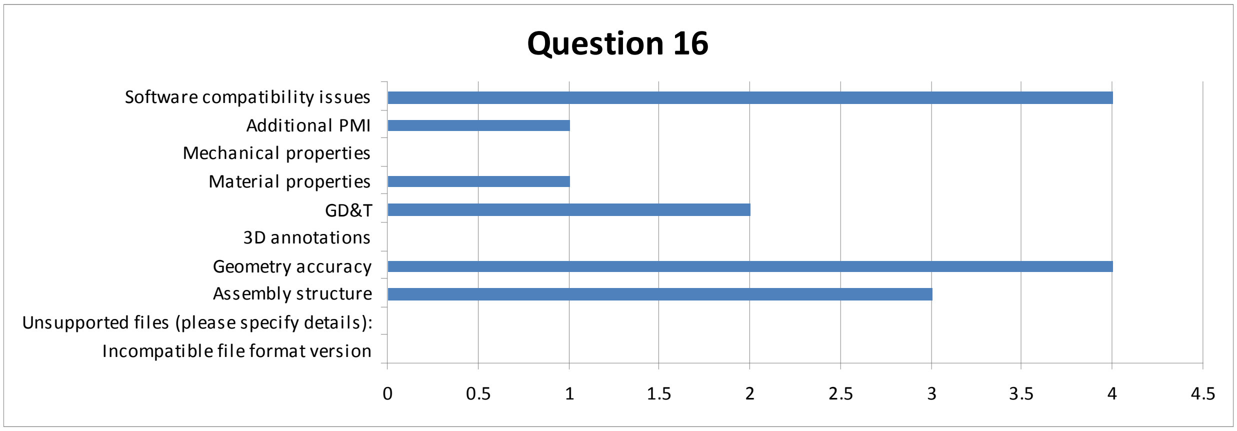
15. List specific CAD data requirements involved in a request for quote process:

This question addresses the specific data requirements necessary during design collaboration for the participants in this study. Seven (7) participants responded to this question. Maintaining the assembly structure, revision/version information, and geometry integrity are all critical CAD data requirements during the collaborative process.



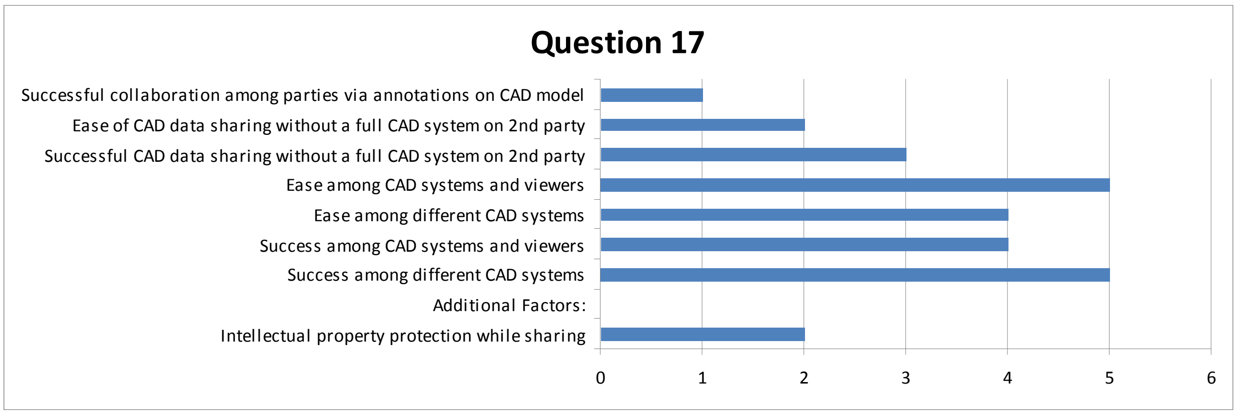
16. Have there been any major problems in this request for quote process currently or in the past?

This question seeks to address the problems that participants have encountered during the collaborative process relative to data formats. Six (6) people responded to this question. The major challenges faced by the respondents were software compatibility and geometric accuracy. This information coupled with the responses to Question 14 paint an interesting picture – the items of most concern to the participants during the collaborative process are also the items that tend to be the most problematic for them.



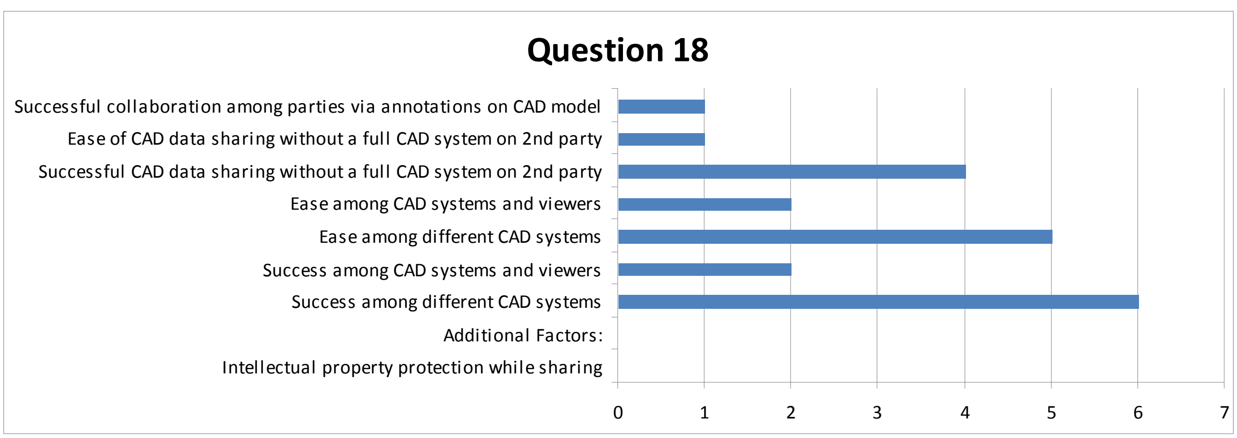
17. In your opinion, what are the current important success factors in the use of *lightweight* formats for the purpose of request for quote in your company?

Question 16 seeks to understand the current important success factors for determining a successful digital collaboration environment within the participants' companies using *lightweight* formats. Seven (7) participants responded directly to this question. The answers were organized according to "successful" translation and the "ease" of translation. Successful translation between different CAD systems was the most important factor according to these participants, with additional emphasis on the ease of translation between CAD systems and the ease of movement of data between systems.



18. In your opinion, what are the current important success factors in the use of *neutral* formats for the purpose of request for quote in your company?

Question 17 seeks to understand the current important success factors for determining a successful digital collaboration environment within the participants' companies using *neutral* formats. Six (6) participants responded directly to this question. The answers were organized according to "successful" translation and the "ease" of translation. In this case, the majority of the responses dealt with the ease and success of moving files and data between differing systems, with each receiving a five out of six response.



In the process of **design to manufacturing**, design engineers communicate their design to the manufacturers for prototyping or large-scale manufacturing. The manufacturer in this case could be in-house or out-sourced to another party. The designers present their CAD data in the appropriate format that contains manufacturing information such as material properties, mechanical properties, geometric dimensioning and tolerance, and important annotations. In some cases, a highly accurate geometry data is also provided for the manufacturer to perform a manufacturing analysis.

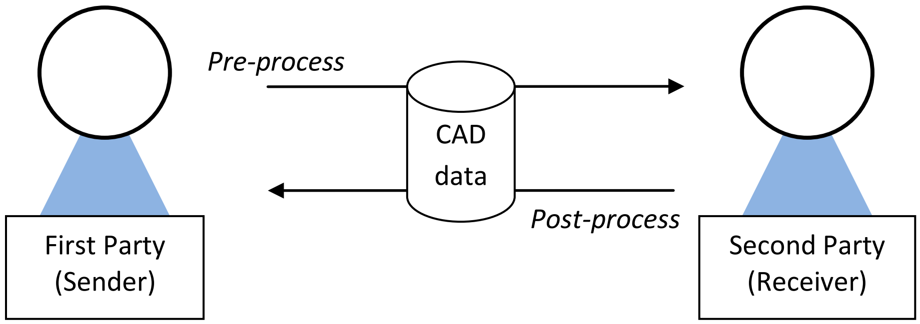
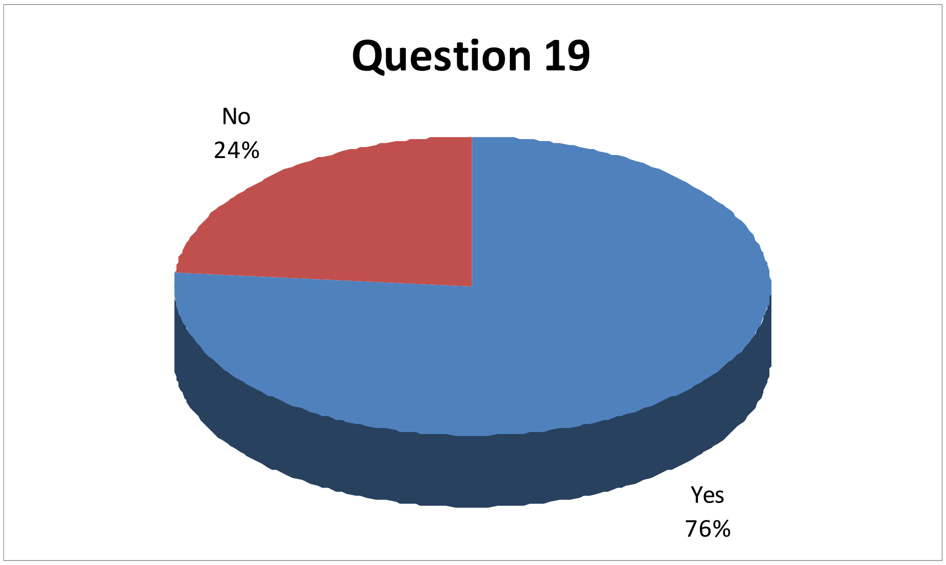


Figure 3: Design to Manufacturing Process Diagram

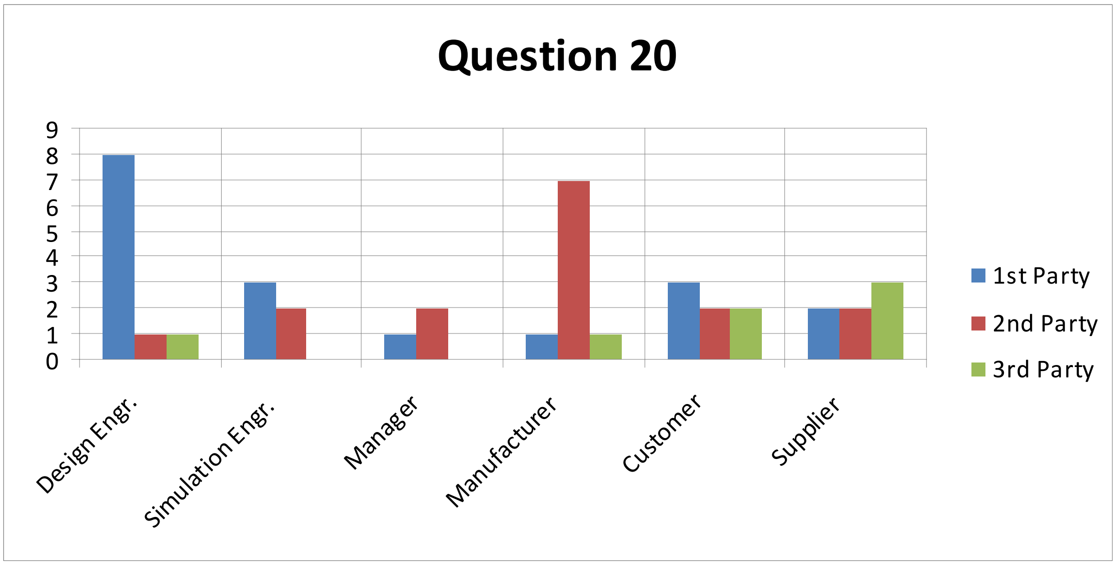
19. Are you familiar with and/or involved in your company's collaborative process between design and manufacturing?

Question 19 details the involvement of the participants' in their company's communication of information in the design-to-manufacturing process. Seventeen (17) participants responded to this question, with approximately 77% stating they are familiar with their company's design-to-manufacturing process.



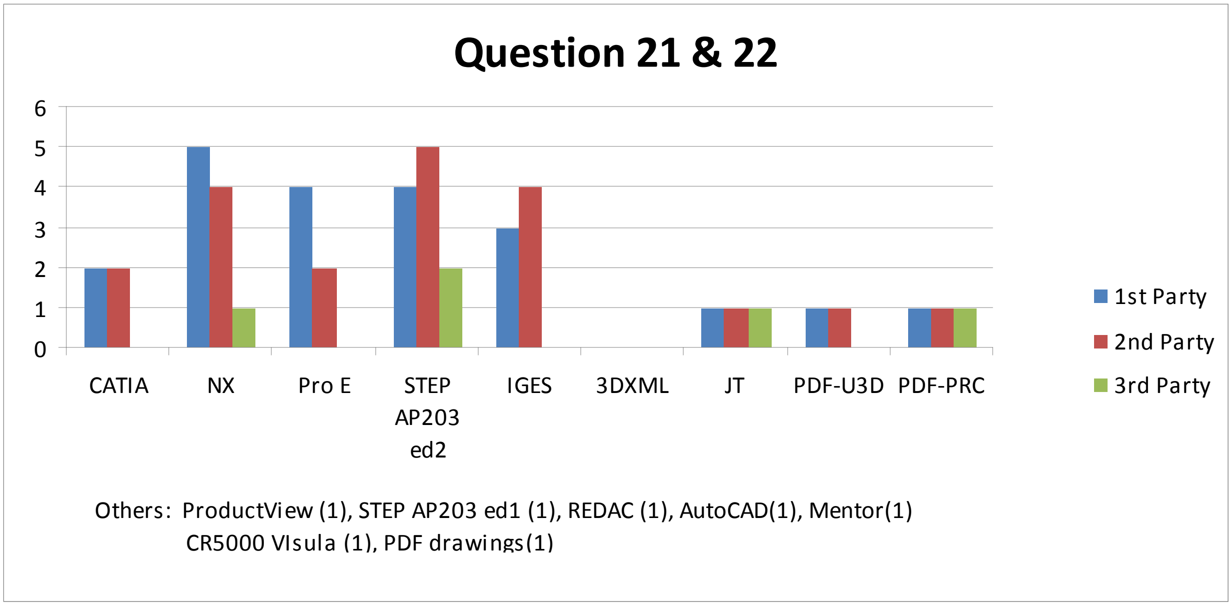
20. In a typical design to manufacturing process at YOUR Company, check the following individuals who are involved.

The data from Question 20 details the roles of the people typically involved in the design-to-manufacturing process as outlined in Figure 3. Eight (8) participants provided data for this question. Not surprisingly, the Design Engineer is the primary Sender of information, and the Manufacturer is the typical Receiver.



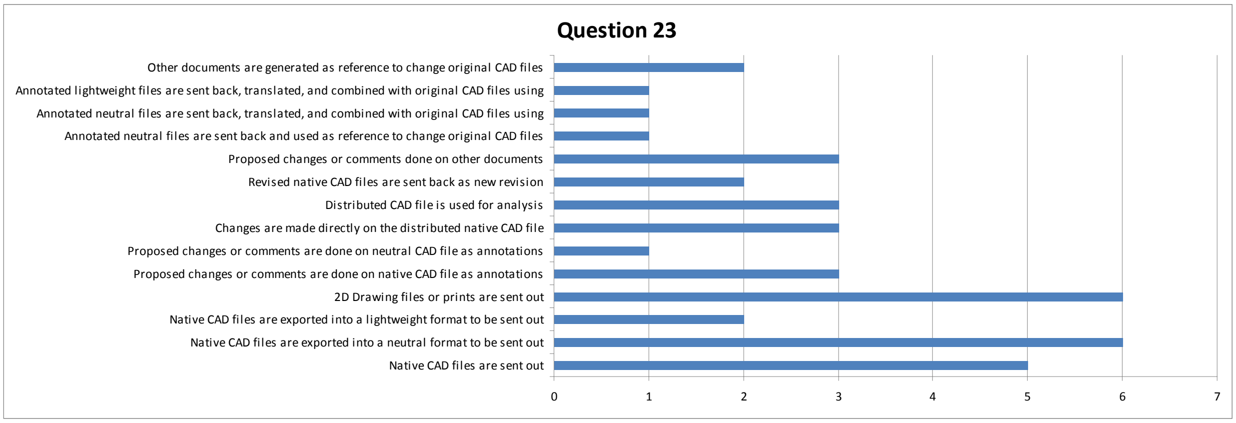
21. Specify all CAD tools and formats used in a design to manufacturing at your Company, and by whom.
22. Please specify OTHER software or formats used, but not listed.

Questions 21 and 22 examine the software tolls and the data formats used in the collaborative design to manufacturing process. Seven (7) participants responded to these questions. The results for these questions are slightly different that in the first two sections of this report. NX and Pro/ENGINEER are the primary CAD tools used by the Sender (as depicted in Figure 3) with a mixture of tools used by the Receiver. The primary CAD format of choice was again STEP AP 203 ed.2; however, nearly as many participants also used IGES.



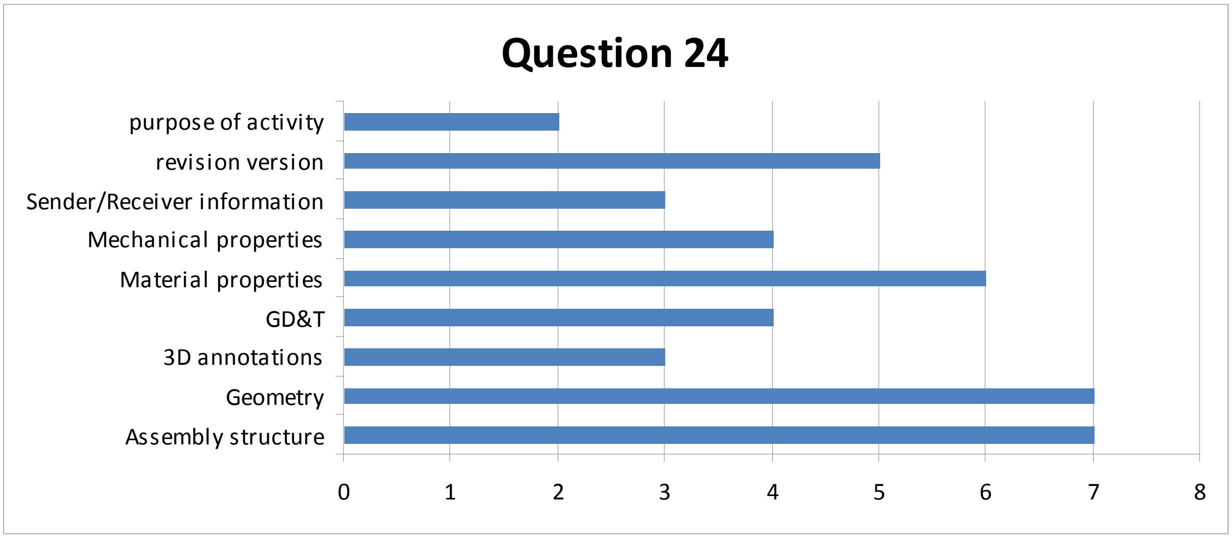
23. Check on the specific Design to Manufacturing processes involved in your Company.

Question 23 seeks to address the various pre-, post-, and current processes involved in the Design to Manufacturing collaborative process as shown in Figure 3. Seven (7) participants responded to this question. In the pre-process stage, either 2D prints were sent out or the native CAD file was converted to a neutral file as the methods of choice for communication. During the collaborative process, annotations were either made on separate documents, or they were created on the *native* CAD model and sent back to the original source. After the collaborative process, annotations are typically made on separate documents and sent back to the designer to make changes.



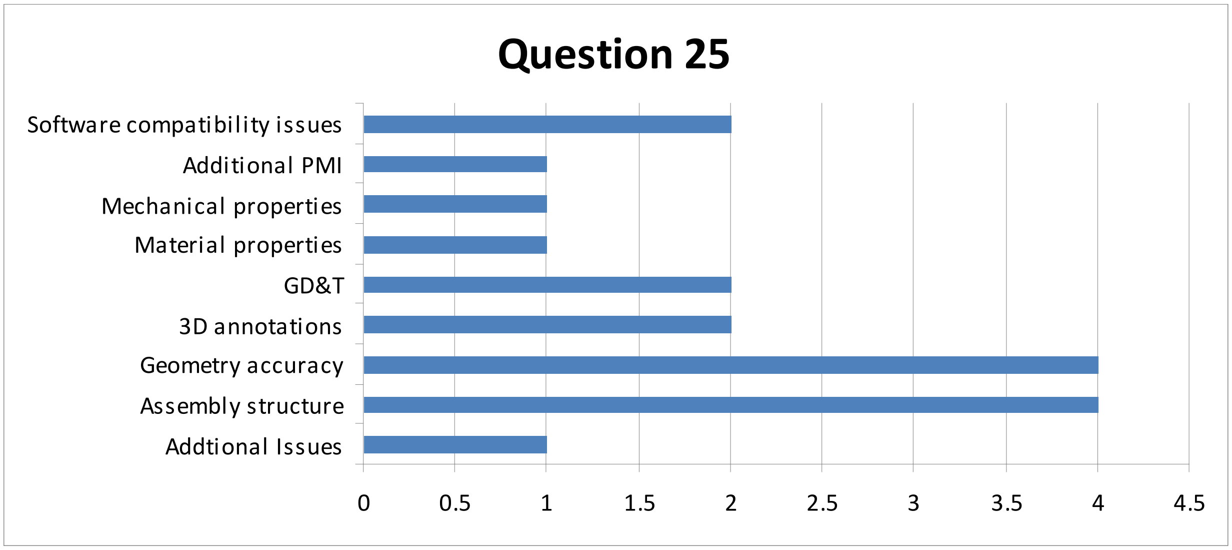
24. List all of specific CAD data requirements involved in a design to manufacturing process.

Question 24 addresses the CAD data requirements in the Design to Manufacturing environment. Seven (7) participants responded to this question. In this case, geometry accuracy and persistence of the assembly structure were the most important requirements for this process.



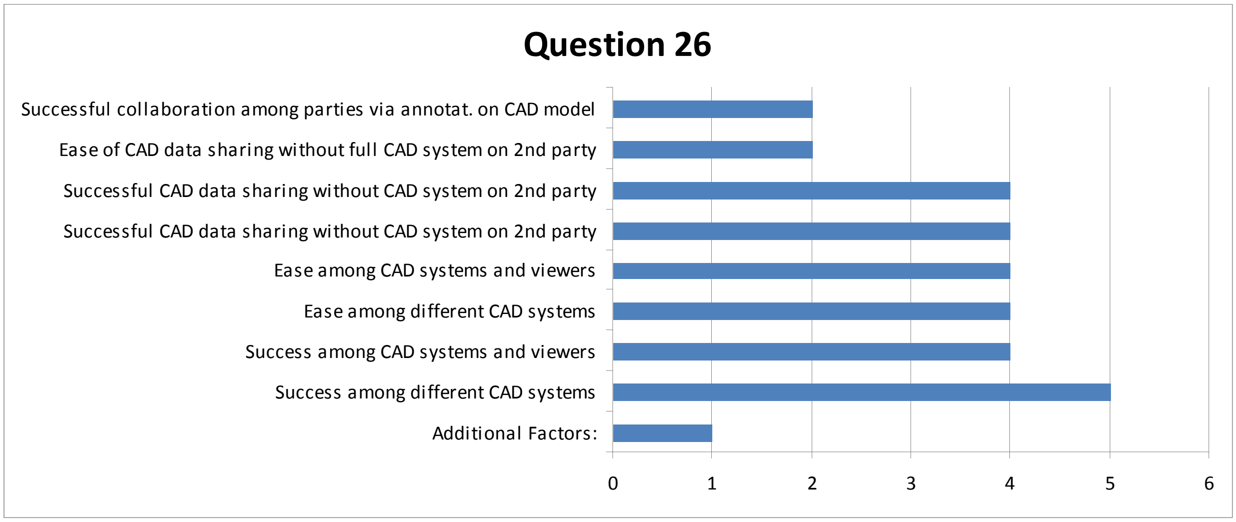
25. Have there been any major problems in this design to manufacturing process currently or in the past?

Question 25 addresses the major challenges encountered in the Design to Manufacturing collaborative process. Five (5) participants responded to this question. The major problems listed are the geometric accuracy and the persistence of the product assembly structure, which parallels the results of the previous question.



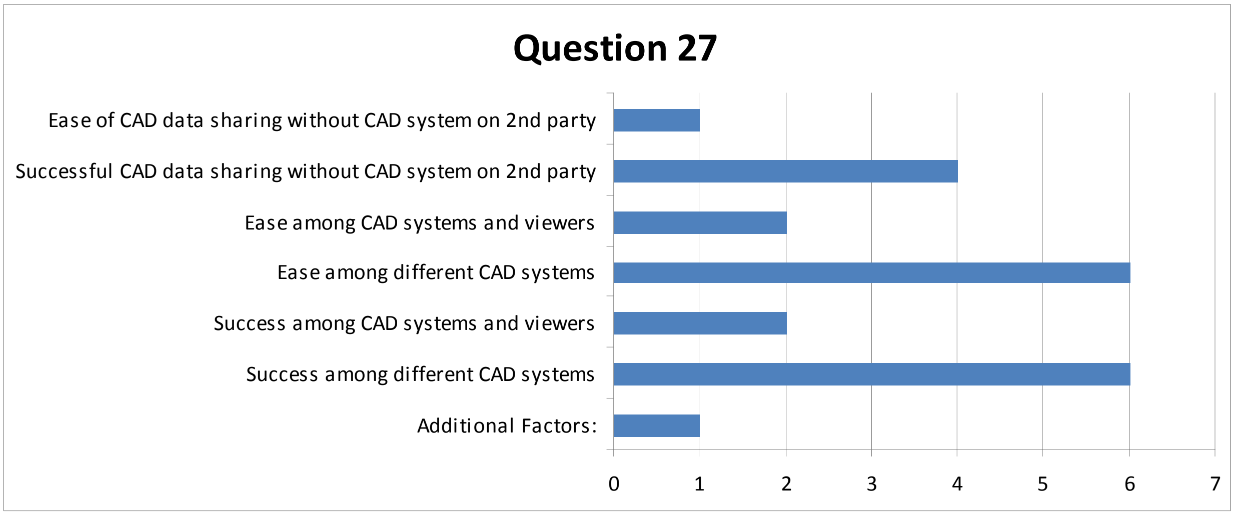
26. In your opinion, what are the current important success factors in the use of *lightweight* formats for the purpose of design to manufacturing in your company?

Question 26 on the survey addresses the successful use of *lightweight* formats in the collaborative Design to Manufacturing process. Six (6) participants responded to this question. Five out of six participants thought that the successful exchange of information *between CAD systems* using the lightweight format was the most important factor.



27. In your opinion, what are the current important success factors in the use of *neutral* formats for the purpose of design to manufacturing in your company?

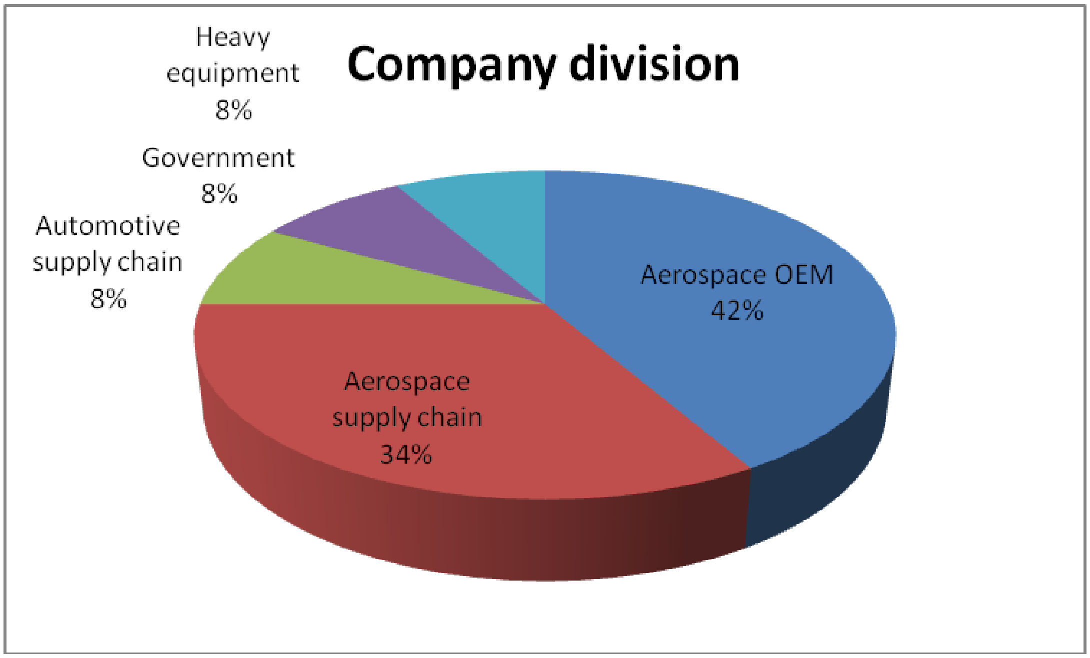
Question 27 seeks to understand the current important success factors for determining a successful digital collaboration environment within the participants' companies using *neutral* formats. Six (6) participants responded directly to this question. The answers were organized according to "successful" translation and the "ease" of translation. In this case, the majority of the responses dealt with the ease and success of moving files and data between differing systems, with each receiving a five out of six response.



Demographics Information

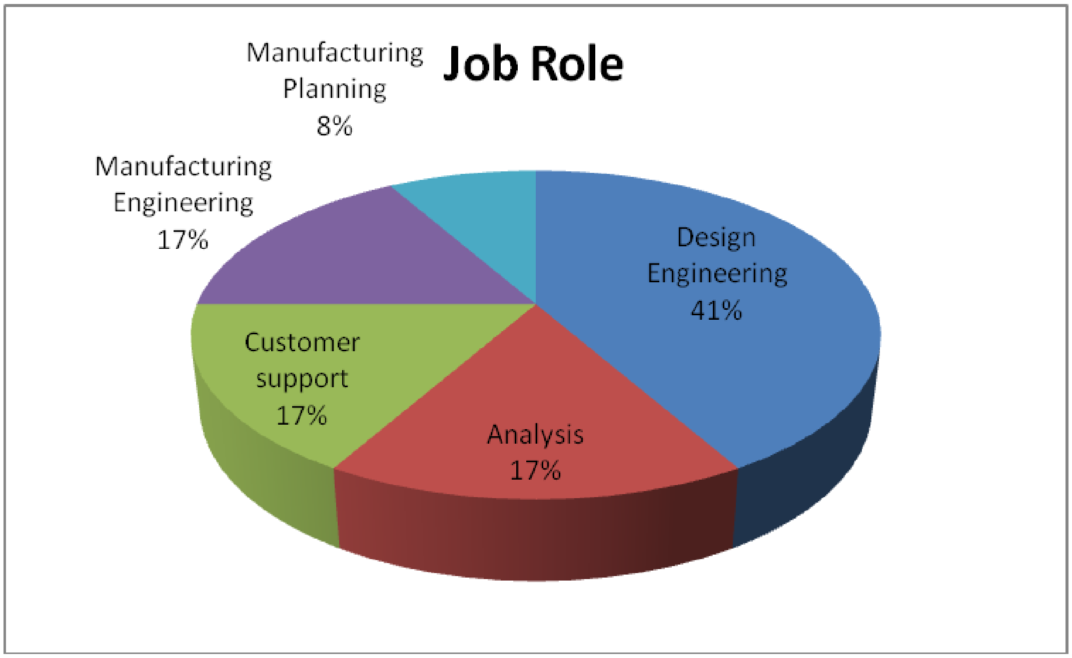
28. Select the choice that best represents your company or the company division in which you work.

The participants that gave complete responses also included a description of the company or company division in which they work. Those twelve responses are outlined in the chart below. While this data is heavily slanted towards aerospace industries, the topics and challenges addressed in this survey are common amongst industries.



29. Select the choice that best represents your primary job role.

The participants that gave complete responses also included a description of the company or company division in which they work. Those twelve responses are outlined in the chart below. From this chart, it can be seen that Design Engineering often plays a primary role in the collaboration process (at least within aerospace companies). If the proportions shown in this chart are indeed representative of the larger industry segments on whole, it is encouraging to see that Analysis, Manufacturing Engineering, and Customer Support are actively involved in the use of collaborative tools.



Discussion and Conclusions

Use Case 1 – Collaborative Design Evaluation

During the collaborative design process, most of the people that initiated digital collaboration (the Sender) in this study were the design engineers, followed by simulation engineers and then managers. They tended to export the CAD files they were sharing into neutral file formats (with STEP AP203E2 being the preferred choice) or they would send the native file directly. Manufacturers, customers, and suppliers tended to be the parties on the receiving end of the translation. They would then either change the native CAD file directly or they would annotate the neutral or original CAD files and send them back. However, the collaborative design process often followed the following steps:

- Revised native CAD sent back as revision
- Annotated neutral file sent back and the Sender makes changes
- Proposed changes done on other docs – text, email, PDF

During this process, when *lightweight* files were used, these files were annotated and sent back as reference and the Sender would make the necessary changes. It should also be noted that there tended not to be a combination of using neutral files and lightweight files by these participants. They typically preferred one format over the other.

While doing collaborative design, these respondents had several requirements as noted in the data section of this report, with the most important ones being persistence of the geometry integrity and the product structure, as well as revision control. This is only natural given the iterative nature of the product design process. In parallel, they also experienced several challenges in using neutral and lightweight files in this manner, especially geometric accuracy issues associated with software incompatibility, as well as the frequent loss of GD&T

information and assembly product structure. When comparing the important factors for determining successful translation using neutral and lightweight formats, the participants favored successful data translation relative to the aforementioned factors over ease of use. However, there were some indications that the expectation level relative to the emerging lightweight formats is that they should be both easy to use and robust in their translation abilities.

Use Case 2 – Request for Quote

In the request for quote use case, design engineers were the ones to typically initiate the process as the Sender (followed by managers and simulation engineers). Suppliers and manufacturers tended to be the Receivers according to the participants in this study. This communication channel followed a similar trend as found in Use Case 1. Native CAD files were exported to neutral formats for distribution or native files were distributed directly, commented upon, and then sent back for revision. In some cases, the lightweight files were sent out for quote, but the annotations/mark-ups came back in different document formats (i.e., text or PDF).

The request for quote process had several important requirements:

- 1- maintaining geometry integrity
- 2- maintaining assembly structure
- 3- maintaining annotations, material properties, GD&T, and revisions

However, the participants often experienced common challenges during this process, particularly geometry accuracy and software incompatibility problems and loss of assembly structures. As in Use Case 1 it is interesting to note that the very things that are critical requirements for using lightweight and neutral formats are the things that users often cause problems for the users. When comparing the important success criteria between lightweight & neutral formats, there is a desire by the survey respondents to have successful translation *between* CAD systems relative to *lightweight* and *neutral* file formats. Ease of use was secondary to accurate and complete (i.e., successful) data translation. There was also a desire to be able to chare CAD data without requiring both the Sender and the Receiver to have CAD software installed.

Use Case 3 – Design to Manufacturing

The use case for Design to Manufacturing has noticeable differences when compared to the first two use cases in this study. The anticipated process would be that the design engineer would be the Sender and the manufacturer would be the Receiver. While this indeed holds true based on the respondents' answers to the survey, the collaborative process in this case uses an unanticipated combination of *neutral* file formats and 2D drawings as communication media. *Native* CAD files are also used. A seemingly low usage level of lightweight formats exists.

However, it was deemed important by the participants that geometry integrity and assembly structure were maintained by the lightweight formats. In addition, material properties and revision control were desired attributes to be retained as well. This makes sense given the information often required by manufacturing. As with the first two use cases, maintaining geometry accuracy and assembly structure were critical elements of the lightweight file formats being examined, and these were also challenges during the collaborative process. Finally, when examining the key success factors for using lightweight and neutral file formats, a high fidelity translation (i.e., maintaining geometric accuracy and assembly structure) was more desirable than ease of use. This is the same result experienced in the first two use cases.

Conclusions

This part of the larger study attempted to give insight into the use of lightweight 3D file formats in industry settings. More specifically, this study examined three use cases for these formats – collaborative design review, request for quote from a supplier, and passing data from design to manufacturing. With regard to many questions in this survey, there was much commonality between the three use cases, yet still noticeable differences among them. The following conclusions are a result of this study:

- Most people are not yet utilizing lightweight formats across all use cases. It appears that many organizations are using some combination of *neutral* and *lightweight* file formats. In addition, comments from the participants indicate that much of the data requirements important to them are only now becoming viable options within the lightweight formats.

- For a variety of reasons, this study includes the most data for Use Case 1. Therefore, the generalizations one can draw from this survey are limited. In addition, there is a noticeable drop in data points in use cases 2 and 3.

- Geometry & Assembly structure were the most important attributes to the respondents in each use case. This makes sense, although maybe not for reasons people first anticipate. Each of the use cases could conceivably rely on the sharing of hierarchical assembly information, which builds on a desire to retain geometric integrity as a result of translation.

- Successful data translation is the most desired criterion when using lightweight file formats, regardless of choosing lightweight or neutral export options. In all use cases this was important due to the use of model-generated data throughout the enterprise. Ease of translation was secondary in this discussion, which is consistent among all three uses cases examined.

- The use of 2D Drawing files and/or prints is still utilized a great deal within the Design to Manufacturing use case – possibly due to inconsistent treatment of annotations, symbols and dimensional information. The 2D paradigm is often the entry point for people unsure about the nature of 3D and the role that it plays within an organization. While there are myriad reasons for the 2D communications medium, it is still desirable. It is fast, cheap and easy to use, where as the use of the lightweight format will likely continue to be slow until the technology vendors decide to address geometry integrity and the maintenance of product structures.

References

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Appendix A: Questionnaire for Establishing Lightweight Format Checklist

Study introduction:

Thank you for participating in our research study. Your answers to these questions will not be shared with anyone in a way that would personally identify you. When reporting results from this survey, they will be reported in aggregate form only. You may choose to withdraw from this study at any time without repercussions, and you may choose to not answer a question at any time. Members of the research team will transcribe your responses to the interview questions (or retain your typed responses for those participants that choose to type their answers) and retain those transcripts for the duration of the research study. They will remain in Professor Hartman's office in a secure location. Relative to the final questions regarding job title and industry segment, your answers to these questions will not be used to personally identify you.

On this form there are two types of questions, scaling questions and open-ended questions. The scaling questions are to be answered with a range from 1 to 5, with 5 representing highest rating (or most important), while 1 represents the lowest rating (or least important). These questions are designed to quantify the importance of different issues pertaining to lightweight file formats for visualization. The open-ended questions are designed to get general opinions, making sure that important issues pertaining to the topic of lightweight files are not being over looked.

If you have questions or concerns regarding this research study you may contact:

Professor Nathan Hartman at 765-496-6104 or nhartman@purdue.edu"

Openness

<u>Non-Proprietary</u>

In your experience and in your opinion how important is it for a lightweight visualization format to be non-proprietary?

1 2 3 4 5

<u>Explicitly described implementation</u>

How important is it to you that documentation on implementation of lightweight visualization format be readily available to you?

1 2 3 4 5

On a scale of 1 to 5 do you feel that your current uses of lightweight visualization formats are meeting your needs for implementation documentation?

1 2 3 4 5

How would you go about finding information on implementation of a lightweight visualization format? (e.g., Vender websites, Training seminars, 3rd Party Web Documents)

What do you feel is the best way for implementation information to be distributed to its intended audience? (Internet, Text File, Handbook, etc…)

<u>Documentation of the format and services</u>

On a scale of 1 to 5 how big of an issue is it for your utilization of lightweight visualization formats to have free access to informative documentation about that format.

1 2 3 4 5

On a scale of 1 to 5 do you feel that within your current utilization of lightweight visualization formats that informative documentation is freely available?

1 2 3 4 5

On a scale of 1 to 5 do you feel that within your current utilization of lightweight visualization formats that informative documentation is up to par with your needs?

1 2 3 4 5

How often is the availability of documentation on lightweight visualization formats an issue in your day to day business?

Is vendor supplied documentation enough to fulfill your lightweight visualization format need/problems, or is 3rd party input needed to have a successful lightweight visualization product.

<u>Publicly Available</u>

With our analysis of lightweight visualization formats we have used the term publicly available to stand for such issues as royalty free, patents, intellectual property restrictions, copyrights, and licenses on a scale of 1 to 5 how big of an issue are these topics for your purpose of lightweight visualization formats?

1 2 3 4 5

Would you add anything else to this list of subjects under publicly available?

Are these 5 topics equal in stature when it comes to openness or is one or more of these hold greater importance than the others (i.e., *royalty free, patents, intellectual property restrictions, copyrights, and licenses*?

Extensibility

Within our research we have used the word extensibility to encompass the light weight format's ability to deal with geometry, assemblies, annotations, metadata, etc…, how important is extensibility to the roll of lightweight visualization formats?

1 2 3 4 5

Accessibility

<u>Software</u>

Lightweight visualization viewers like internet browsers, specific format readers, and Adobe Acrobat Reader, etc… how important of a roll do these viewers play when it comes to differentiating the best lightweight visualization format?

1 2 3 4 5

On a scale of 1 to 5 do you feel that current lightweight visualization formats need more attention when it comes to their ability to be viewed?

1 2 3 4 5

When using lightweight visualization formats what is your most used and/or most convenient way of viewing such models? (e.g., Internet Browsers, Specific Format Reader, Adobe Acrobat Reader)

Are you or your company willing pay for viewing/editing software if the Lightweight Visualization Format has no direct cost?

What would be a reasonable cost per seat for viewing software?

<u>Training</u>

How much influence does the amount of training involved with the implementation of a lightweight visualization format dictate which format is best for your company?

1 2 3 4 5

How much training is reasonable to learn how to use a new lightweight visualization? (e.g., Time, Days, Weeks, Months.)

How much are you or your company willing to spend on training of a new lightweight visualization?

Interoperability

Our use of the word Interoperability has come to mean that ability for a lightweight visualization format to work with different CAD packages either with our without installed add-ons. On a scale of 1 to 5 do you feel that current lightweight visualization formats are meeting you goal in terms of interoperability?

1 2 3 4 5

Is Interoperability an issue that is important to the effectiveness of a lightweight visualization format?

1 2 3 4 5

<u>Out-of-Box</u>

How big of an issue is it relative to lightweight visualization formats not being able to perform their intended purpose with a standard CAD system no add-ons attached?

1 2 3 4 5

<u>Extra Modules</u>

How big of an issue is it relative to lightweight visualization formats not being able to perform their intended purpose with an upgraded CAD system with add-ons attached?

1 2 3 4 5

Security

With your specific application of lightweight visualization files in mind, how important of an issue is the security of that data.

1 2 3 4 5

Do you feel that current lightweight visualization format is meeting your needs of security?

1 2 3 4 5

Within our investigation into the idea of security with lightweight visualization formats we have realized there are many different levels of security; from pass word protected documents to estimated geometry to protect intellectual property. What do you feel your needs are for lightweight visualization formats within the context of security?

Would one form of security be enough to meet your security needs or would the option to chose appeal more to your businesses needs?

Do you feel that too much security could hinder your ability to use lightweight visualization formats effectively?

Wrap up

Are there any issues with lightweight visualization formats that concern you or your company that we have not talked about that you believe need attention?

Do you feel that a list of metrics for comparing how “open” a lightweight visualization format is would be a useful tool for your business?

Do you use any such measurement or comparison devices now when selecting your lightweight visualization formats?

What industry segment do you represent?

What is your job title?

Appendix B: Preliminary Outlines for Lightweight Visualization Use Cases

Use Case: Collaborative Design Evaluation

- Description of Activity: Load design, interrogate, annotate, propose changes, and finalize design among engineers and decision makers both located locally or remotely.
- Requirements:
  - Geometry – high accuracy
  - 3D annotations
  - GD&T
  - Mechanical properties
  - Sender/Receiver information, revision version, purpose of activity – review/ finalize design

Usage: Visualization formats only

- Process:
  - Sender exports native file into viz. format and sends out to reviewer
  - Reviewer inspects with viz. format reader, make annotations, and sends it back to sender
  - Sender makes appropriate changes to native file according the annotations on viz. file.
- Success Factors:
  - Ability to communicate on design via annotations without a CAD system on the receiver end

Usage: STEP only

- Process:
  - Sender exports native file into STEP format and sends out to reviewer
  - Reviewer inspects with any STEP-supported CAD software, make annotations, exports as STEP, and send back to sender.
  - Sender either imports STEP as native file replacement or makes appropriate changes to native file according the annotations on the STEP file.
- Success Factors:
  - Ability to communicate on design via annotations with CAD system of choice on the receiver end

Usage: STEP + Visualization formats

- Process:
  - Sender exports native file into both STEP and viz. format and sends out to CAD and non-CAD reviewers
  - Reviewer inspects with either STEP-supported CAD software, or viz. format viewer. Reviewer make annotations, exports as STEP or save changes in viz. formats, and send back to sender.
  - Sender either imports STEP as native file replacement or makes appropriate changes to native file according the annotations on STEP or viz. file.
- Success Factors:
  - Ability to communicate on design via annotations with both CAD (any STEP-CAD system) and non-CAD users

Use Case: Request for Quote/bid

- Description of Activity: present design to bidder for review while maintaining intellectual property rights.
- Requirements:
  - Geometry – low accuracy
  - 3D annotations
  - Sender/Receiver information, purpose of activity – review/ bid design

Usage: Visualization formats only

- Process:
  - Sender exports native file into viz. format and sends out to reviewer
  - Reviewer inspects with viz. format reader
- Success Factors:
  - Ability to present design without a CAD system while maintaining intellectual property rights

Usage: STEP only

- Process:
  - Sender exports native file into STEP format and sends out to reviewer
  - Reviewer inspects with STEP-supported CAD software
- Success Factors:
  - Ability to present design with CAD system of choice on the receiver end while maintaining intellectual property rights

Usage: STEP + Visualization formats

- Process:
  - Sender exports native file into both STEP and viz. format and sends out to CAD and non-CAD reviewers
  - Reviewer inspects with either STEP-supported CAD software, or viz. format viewer.
- Success Factors:
  - Ability to present design with both CAD (any STEP-CAD system) and non-CAD users while maintaining intellectual property rights

Use Case: Design to Manufacturing

- Description of Activity: communicate finalized design to manufacturer to be produced either for a prototype or large-scale manufacturing. Manufacturer could be in-house or out-sourced.
- Requirements:
  - Geometry – high accuracy for manufacturing analysis
  - GD&T
  - 3D annotations
  - Mechanical properties
  - Sender/ Receiver information, revision version

Usage: Visualization formats only

- Process:
  - Sender exports native file into viz. file and sends to manufacturer
  - Manufacturer inspects geometry and PMI with viz. format reader
- Success Factors:
  - Ability to communicate design with comprehensive manufacturing details without a CAD system

Usage: STEP only

- Process:
  - Sender exports native file into STEP and sends to manufacturer
  - Manufacturer inspects with any STEP-supported CAD system of choice, and possibly perform manufacturing analysis with their CAD system
- Success Factors:
  - Ability to communicate design with comprehensive manufacturing details on any STEP-supported CAD system on the receiver end
  - Ability to perform additional manufacturing analysis with STEP supported CAD system

Usage: STEP + Visualization formats

- Process:
  - Sender exports native file into STEP for manufacturing manager for review and analysis
  - Sender exports native file into viz. format for shop-floor worker for inspection
  - Manufacturing manager inspects with any STEP-supported CAD system of choice, perform manufacturing analysis with their CAD system, and exports into viz. format for shop-floor workers
  - Shop-floor worker inspects geometry and PMI with viz. format reader possibly from original sender or manufacturing manager
- Success Factors:
  - Ability to communicate design with comprehensive manufacturing details both CAD (any STEP-CAD system) and non-CAD users
  - Ability to perform additional manufacturing analysis with STEP supported CAD system

Use Case: Engineering Change Order

- Description of Activity: Order of change in design/ configuration sent out by manager, engineer, or customer. This could occur during design or manufacturing.
- Requirements:
  - Geometry – low accuracy
  - GD & T
  - 3D annotations
  - Construction history (optional - to show changes)
  - Sender/ Receiver information, revision version, Information regarding affected process/ components

Usage: Visualization formats only

- Process:
  - Sender exports data with annotations into viz. format from native file, STEP file, or viz. format. Data is then sent to corresponding receivers.
  - Receiver inspects viz. file with reader, possibly make appropriate changes to design with CAD system.
- Success Factors:
  - Ability to communicate change order without CAD system on receiver end.

Usage: STEP only

- Process:
  - Sender exports data with annotations into STEP format from native file, STEP file, or viz. format. Data is then sent to corresponding receivers.
  - Receiver inspects STEP file with STEP-supported CAD system, possibly make appropriate changes to design directly onto STEP file.
- Success Factors:
  - Ability to communicate change order and make design changes directly with STEP-supported CAD system of choice on receiver end.

Usage: STEP + Visualization formats

- Process:
  - Sender exports data with annotations into STEP and viz. format from native file, STEP file, or viz. format. Data could be sent to both CAD and non-CAD receivers.
  - CAD-receiver inspects STEP file with STEP-supported CAD system, possibly make appropriate changes to design directly onto STEP file.
  - Non-CAD-receiver inspects viz. file with reader, make appropriate changes to corresponding process.
- Success Factors:
  - Ability to communicate change order and make design changes directly with STEP-supported CAD system of choice on receiver end.
  - Ability to communicate change order to non-CAD users on receiver end.

Use Case: Design to Analysis

- Description of Activity: Design is being sent out for analysis-structural, thermal, manufacturability, etc.
- Requirements:
    - Geometry – high accuracy
    - GD & T
    - Mechanical properties
    - Revision version, results of analysis, proposed changes

Usage: Visualization formats only

- Process:
    - Designer exports file into viz. format with high geometry accuracy and sends it to analyst.
    - Analyst performs analysis with viz. format using analysis software that possibly supports the corresponding viz. format
    - Analyst might have to extend analysis software to read viz. format if not supported directly.
    - Results of analysis could be annotated and resend back to designer via viz. format.
- Success Factors:
    - Highly accurate geometry data that could be used by receiving analysis software.
    - Ability to communicate results of analysis conveniently without CAD software.

Usage: STEP only

- Process:
    - Designer exports file into STEP format and sends it to analyst.
    - Analyst performs analysis using STEP-supported analysis software.
    - Results of analysis could be annotated and resend back to designer with STEP.

- Success Factors:
    - Highly accurate geometry data that could be used by receiving analysis software.
    - Ability to communicate results of analysis with any STEP-supported CAD software.

Usage: STEP + Visualization formats

- Process:
    - Designer exports file into STEP format with high geometry accuracy and sends it to analyst.
    - Analyst performs analysis using STEP-supported analysis software.
    - Results of analysis could be annotated and resend back to designer with viz. format.
- Success Factors:
    - Highly accurate geometry data that could be used by receiving analysis software.
    - Ability to communicate results of analysis conveniently without CAD software.

Appendix C: Task 3 Survey for Use Cases for Lightweight Formats

Lightweight 3DVisualization Formats Use Case Survey

Introduction:

Thank you for participating in our research study. The survey has three (3) parts, each one consisting of eight (8) questions. Your answers to these questions will not be shared with anyone in a way that would personally identify you. When reporting results from this survey, they will be reported in aggregate form only. You may choose to withdraw from this study at any time without repercussions, and you may choose to not answer a question at any time. Your responses will be collected in a database, and the results will be analyzed by the research team. The survey results and accompanying database will remain in Professor Hartman's possession in a secure location. Relative to the final questions regarding job title and industry segment, your answers to these questions will not be used to personally identify you. **We are most interested in responses from people who are in companies where a product is designed and/or manufactured. E.g., design engineers, manufacturing engineers, project managers, engineering resource managers, IT supports.** If you have questions regarding this study, please contact:

Professor Nathan Hartman
Purdue University
Department of Computer Graphics Technology
401 N. Grant St.
West Lafayette, IN 47907
(765) 496-6104
nhartman@purdue.edu

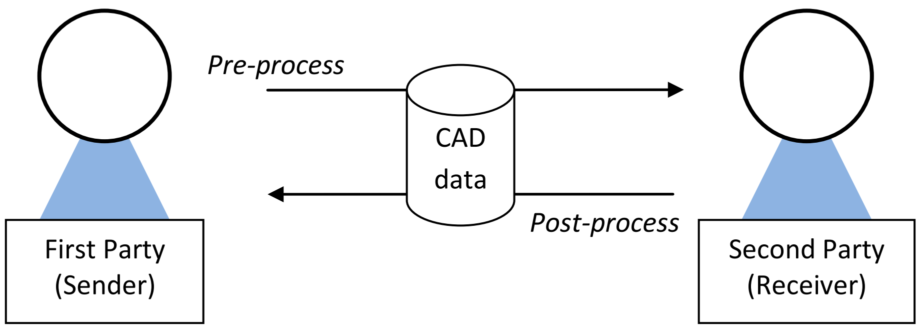
1. Are you involved in and/or familiar with your company's collaborative processes during the design and evaluation of your product?
   ☐ Yes
   ☐ No

   If you answered Yes, continue to the next question. If No, skip to Question 10 on page 59.

Use Case 1

Please read the following scenario on **Collaborative Design Evaluation** and answer the following questions:

In a **collaborative design evaluation** scenario, the designers present their CAD design to other engineers, company decision makers, or perhaps customers. This could take place within a company, or between companies. The original designers could either send out their native CAD file or the appropriate exported formats to the receiver end. The receivers would load the file, interrogate, annotate, propose changes, and eventually finalize the design for manufacturing.



2. In a typical **collaborative design evaluation** process at YOUR Company, check the following individuals who are involved.

	First Party	Second Party	Third Party (if Applicable)
Design Engineer	☐	☐	☐
Simulation Engineer	☐	☐	☐
Manager	☐	☐	☐
Manufacturer	☐	☐	☐
Customer	☐	☐	☐
Supplier	☐	☐	☐

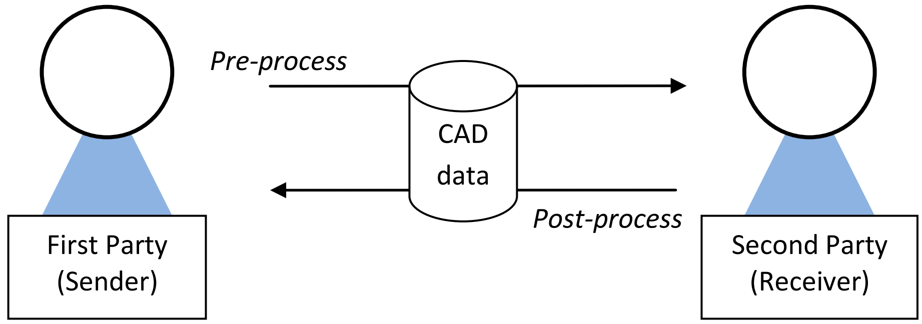
Use Case 1

3. Specify all CAD tools and formats used in a **Collaborative Design Evaluation** at your Company, and by whom:

	First Party	Second Party	Third Party (if Applicable)
CATIA	☐	☐	☐
NX	☐	☐	☐
Pro E	☐	☐	☐
STEP AP203 ed2	☐	☐	☐
IGES	☐	☐	☐
3DXML	☐	☐	☐
JT	☐	☐	☐
PDF-U3D	☐	☐	☐
PDF-PRC	☐	☐	☐

4. Please specify OTHER software or formats used not listed in the previous question:

Use Case 1



5. Check on the specific **Collaborative Design Evaluation** processes involved in your Company:

Pre-process

- ☐ Native CAD files are sent out
- ☐ Native CAD files are exported into a neutral format to be sent out
- ☐ Native CAD files are exported into a lightweight format to be sent out
- ☐ 2D Drawing files or prints are sent out

Process

- ☐ Proposed changes or comments are done on native CAD file as annotations
- ☐ Proposed changes or comments are done on neutral CAD file as annotations
- ☐ Proposed changes or comments are done on lightweight CAD file as annotations
- ☐ Changes are made directly on the distributed native CAD file
- ☐ Changes are made directly on the distributed neutral CAD file
- ☐ Distributed CAD file is used for analysis

Post-process

- ☐ Revised native CAD files are sent back as new revision
- ☐ Annotated neutral files are sent back and used as reference to change original CAD files
- ☐ Annotated lightweight files are sent back and used as reference to change original CAD files
- ☐ Proposed changes or comments done on other documents (please specify):
- ☐ Annotated neutral files are sent back, translated, and combined with original CAD files using (please specify):
- ☐ Annotated lightweight files are sent back, translated, and combined with original CAD files using (please specify):
- ☐ Other documents are generated as reference to change original CAD files (please specify):
- ☐ Other Processes (please specify):

Use Case 1

6. List specific CAD data requirements involved in a **Collaborative Design Evaluation** process:

- ☐ Assembly structure
- ☐ Geometry
- ☐ 3D annotations
- ☐ GD&T
- ☐ Material properties
- ☐ Mechanical properties

Additional PMI

- ☐ Sender/Receiver information
- ☐ Revision version
- ☐ Purpose of activity
- ☐ Digital Rights Management
- ☐ Others (please specify):

7. Have there been any major problems in this **Collaborative Design Evaluation** process currently or in the past:

Information loss over translation

- ☐ Assembly structure
- ☐ Geometry accuracy
- ☐ 3D annotations
- ☐ GD&T
- ☐ Material properties
- ☐ Mechanical properties
- ☐ Additional PMI

Other issues

- ☐ Software compatibility issues
- ☐ Breach of intellectual property
- ☐ Unsupported files (please specify):
- ☐ Incompatible file format version (please specify):
- ☐ Additional Issues (please specify):

Use Case 1

8. In your opinion, what are the current important success factors in the use of lightweight formats for the purpose of **collaborative design evaluation** in your company? (Check all the applies)

Successful CAD data translation…

- ☐ among different CAD systems
- ☐ among CAD systems and viewers

Ease of CAD data translation…

- ☐ among different CAD systems
- ☐ among CAD systems and viewers

Others:

- ☐ Successful CAD data sharing without a full CAD system on 2nd party
- ☐ Ease of CAD data sharing without a full CAD system on 2nd party
- ☐ Successful collaboration among parties via annotations on CAD model
- ☐ Intellectual property protection while sharing
- ☐ Additional Factors (please specify):

9. In your opinion, what are the current important success factors in the use of neutral formats for the purpose of **collaborative design evaluation** in your company? (Check all the applies)

Successful CAD data translation…

- ☐ among different CAD systems
- ☐ among CAD systems and viewers

Ease of CAD data translation…

- ☐ among different CAD systems
- ☐ among CAD systems and viewers

Others:

- ☐ Successful CAD data sharing without a full CAD system on 2nd party
- ☐ Ease of CAD data sharing without a full CAD system on 2nd party
- ☐ Successful collaboration among parties via annotations on CAD model
- ☐ Intellectual property protection while sharing
- ☐ Additional Factors (please specify):

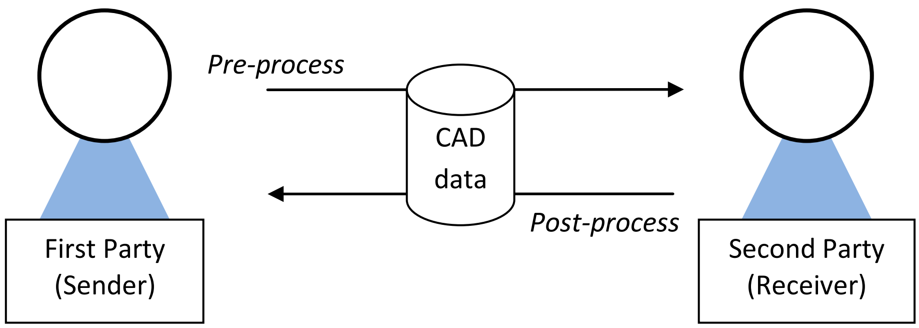
10. Are you involved or familiar with your company's Request for Quote process?
☐ Yes
☐ No

If you answered Yes, continue onto the next question. If No, skip to Question 19 on page 64.

Use Case 2

Please read the following scenario on **request for quote** and answer the following questions:

In a **request for quote** process, a company invites several suppliers to present and bid on their design based on the company's requirements. The company will then select the best design at the best price. In other cases, the company provides their own design to the best manufacturer. Several important factors during the transactions of CAD data in this bidding process are the protection of intellectual property of the supplier's or the company's; and design review capabilities such as the ones for a collaborative design evaluation process.



11. In a typical **request for quote** process at YOUR Company, check the following individuals who are involved.

	First Party	Second Party	Third Party (if Applicable)
Design Engineer	☐	☐	☐
Simulation Engineer	☐	☐	☐
Manager	☐	☐	☐
Manufacturer	☐	☐	☐
Customer	☐	☐	☐
Supplier	☐	☐	☐

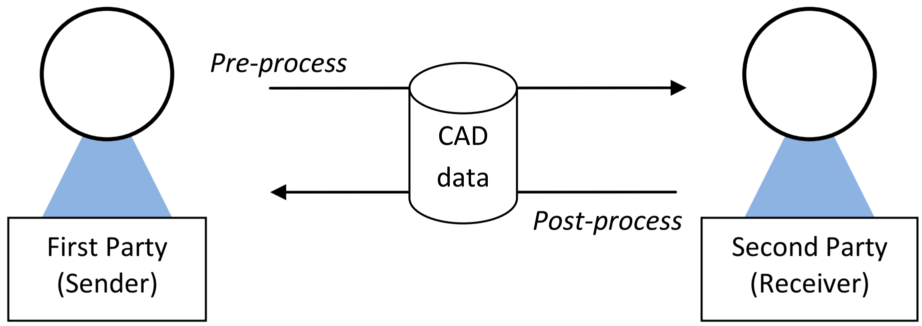
Use Case 2

12. Specify all CAD tools and formats used in a **request for quote** at your Company, and by whom:

	First Party	Second Party	Third Party (if Applicable)
CATIA	☐	☐	☐
NX	☐	☐	☐
Pro E	☐	☐	☐
STEP AP203 ed2	☐	☐	☐
IGES	☐	☐	☐
3DXML	☐	☐	☐
JT	☐	☐	☐
PDF-U3D	☐	☐	☐
PDF-PRC	☐	☐	☐

13. Please specify OTHER software or formats used not listed in the previous question:

Use Case 2



14. Check on the specific **Request for Quote** processes involved in your Company:

Pre-process

- ☐ Native CAD files are sent out
- ☐ Native CAD files are exported into a neutral format to be sent out
- ☐ Native CAD files are exported into a lightweight format to be sent out
- ☐ 2D Drawing files or prints are sent out

Process

- ☐ Proposed changes or comments are done on native CAD file as annotations
- ☐ Proposed changes or comments are done on neutral CAD file as annotations
- ☐ Proposed changes or comments are done on lightweight CAD file as annotations
- ☐ Changes are made directly on the distributed native CAD file
- ☐ Changes are made directly on the distributed neutral CAD file
- ☐ Distributed CAD file is used for analysis

Post-process

- ☐ Revised native CAD files are sent back as new revision
- ☐ Annotated neutral files are sent back and used as reference to change original CAD files
- ☐ Annotated lightweight files are sent back and used as reference to change original CAD files
- ☐ Proposed changes or comments done on other documents (please specify):
- ☐ Annotated neutral files are sent back, translated, and combined with original CAD files using (please specify):
- ☐ Annotated lightweight files are sent back, translated, and combined with original CAD files using (please specify):
- ☐ Other documents are generated as reference to change original CAD files (please specify):
- ☐ Other Processes (please specify):

Use Case 2

15. List specific CAD data requirements involved in a **request for quote** process:

- ☐ Assembly structure
- ☐ Geometry
- ☐ 3D annotations
- ☐ GD&T
- ☐ Material properties
- ☐ Mechanical properties

Additional PMI

- ☐ Sender/Receiver information
- ☐ Revision version
- ☐ Purpose of activity
- ☐ Digital Rights Management
- ☐ Others (please specify):

16. Have there been any major problems in this **request for quote** process currently or in the past:

Information loss over translation

- ☐ Assembly structure
- ☐ Geometry accuracy
- ☐ 3D annotations
- ☐ GD&T
- ☐ Material properties
- ☐ Mechanical properties
- ☐ Additional PMI

Other issues

- ☐ Software compatibility issues
- ☐ Breach of intellectual property
- ☐ Unsupported files (please specify):
- ☐ Incompatible file format version (please specify):
- ☐ Additional Issues (please specify):

Use Case 2

17. In your opinion, what are the current important success factors in the use of lightweight formats for the purpose of **request for quote** in your company? (Check all the applies)

Successful CAD data translation…

- ☐ among different CAD systems
- ☐ among CAD systems and viewers

Ease of CAD data translation…

- ☐ among different CAD systems
- ☐ among CAD systems and viewers

Others:

- ☐ Successful CAD data sharing without a full CAD system on 2nd party
- ☐ Ease of CAD data sharing without a full CAD system on 2nd party
- ☐ Successful collaboration among parties via annotations on CAD model
- ☐ Intellectual property protection while sharing
- ☐ Additional Factors (please specify):

18. In your opinion, what are the current important success factors in the use of neutral formats for the purpose of **request for quote** in your company? (Check all the applies)

Successful CAD data translation…

- ☐ among different CAD systems
- ☐ among CAD systems and viewers

Ease of CAD data translation…

- ☐ among different CAD systems
- ☐ among CAD systems and viewers

Others:

- ☐ Successful CAD data sharing without a full CAD system on 2nd party
- ☐ Ease of CAD data sharing without a full CAD system on 2nd party
- ☐ Successful collaboration among parties via annotations on CAD model
- ☐ Intellectual property protection while sharing
- ☐ Additional Factors (please specify):

19. Are you familiar with and/or involved in your company's collaborative process between design and manufacturing?

☐ Yes

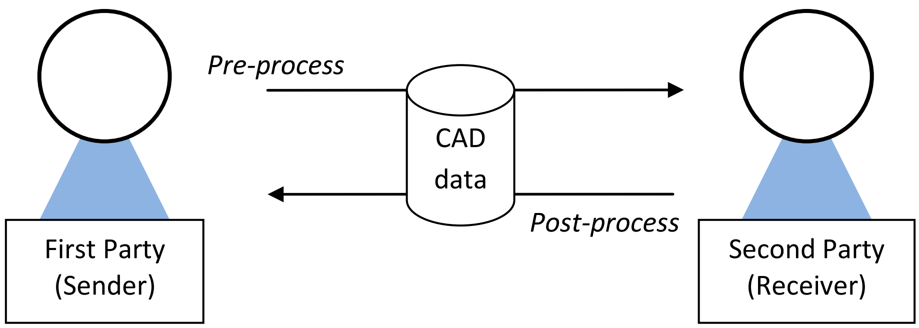
☐ No

If you answered Yes, continue onto the next question. If No, skip to Question 28 on page 69.

Use Case 3

Please read the following scenario on **Design to Manufacturing** and answer the following questions:

In the process of **design to manufacturing**, design engineers communicate their design to the manufacturers for prototyping or large-scale manufacturing. The manufacturer in this case could be in-house or out-sourced to another party. The designers present their CAD data in the appropriate format that contains manufacturing information such as material properties, mechanical properties, geometric dimensioning and tolerance, and important annotations. In some cases, a highly accurate geometry data is also provided for the manufacturer to perform a manufacturing analysis.



20. In a typical **design to manufacturing** process at YOUR Company, check the following individuals who are involved.

	First Party	Second Party	Third Party (if Applicable)
Design Engineer	☐	☐	☐
Simulation Engineer	☐	☐	☐
Manager	☐	☐	☐
Manufacturer	☐	☐	☐
Customer	☐	☐	☐
Supplier	☐	☐	☐

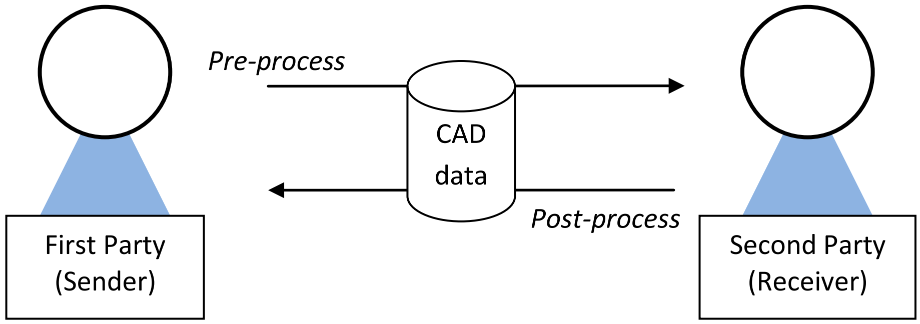
Use Case 3

21. Specify all CAD tools and formats used in a **design to manufacturing** at your Company, and by whom:

	First Party	Second Party	Third Party (if Applicable)
CATIA	☐	☐	☐
NX	☐	☐	☐
Pro E	☐	☐	☐
STEP AP203 ed2	☐	☐	☐
IGES	☐	☐	☐
3DXML	☐	☐	☐
JT	☐	☐	☐
PDF-U3D	☐	☐	☐
PDF-PRC	☐	☐	☐

22. Please specify OTHER software or formats used not listed in the previous question:

Use Case 3



23. Check on the specific **Design to Manufacturing** processes involved in your Company:

Pre-process

- ☐ Native CAD files are sent out
- ☐ Native CAD files are exported into a neutral format to be sent out
- ☐ Native CAD files are exported into a lightweight format to be sent out
- ☐ 2D Drawing files or prints are sent out

Process

- ☐ Proposed changes or comments are done on native CAD file as annotations
- ☐ Proposed changes or comments are done on neutral CAD file as annotations
- ☐ Proposed changes or comments are done on lightweight CAD file as annotations
- ☐ Changes are made directly on the distributed native CAD file
- ☐ Changes are made directly on the distributed neutral CAD file
- ☐ Distributed CAD file is used for analysis

Post-process

- ☐ Revised native CAD files are sent back as new revision
- ☐ Annotated neutral files are sent back and used as reference to change original CAD files
- ☐ Annotated lightweight files are sent back and used as reference to change original CAD files
- ☐ Proposed changes or comments done on other documents (please specify):
- ☐ Annotated neutral files are sent back, translated, and combined with original CAD files using (please specify):
- ☐ Annotated lightweight files are sent back, translated, and combined with original CAD files using (please specify):
- ☐ Other documents are generated as reference to change original CAD files (please specify):
- ☐ Other Processes (please specify):

Use Case 3

24. List specific CAD data requirements involved in a **design to manufacturing** process:

- ☐ Assembly structure
- ☐ Geometry
- ☐ 3D annotations
- ☐ GD&T
- ☐ Material properties
- ☐ Mechanical properties

Additional PMI

- ☐ Sender/Receiver information
- ☐ Revision version
- ☐ Purpose of activity
- ☐ Digital Rights Management
- ☐ Others (please specify):

25. Have there been any major problems in this **design to manufacturing** process currently or in the past:

Information loss over translation

- ☐ Assembly structure
- ☐ Geometry accuracy
- ☐ 3D annotations
- ☐ GD&T
- ☐ Material properties
- ☐ Mechanical properties
- ☐ Additional PMI

Other issues

- ☐ Software compatibility issues
- ☐ Breach of intellectual property
- ☐ Unsupported files (please specify):
- ☐ Incompatible file format version (please specify):
- ☐ Additional Issues (please specify):

Use Case 3

26. In your opinion, what are the current important success factors in the use of lightweight formats for the purpose of **design to manufacturing** in your company? (Check all the applies)

Successful CAD data translation…

☐ among different CAD systems

☐ among CAD systems and viewers

Ease of CAD data translation…

☐ among different CAD systems

☐ among CAD systems and viewers

Others:

☐ Successful CAD data sharing without a full CAD system on 2nd party

☐ Ease of CAD data sharing without a full CAD system on 2nd party

☐ Successful collaboration among parties via annotations on CAD model

☐ Intellectual property protection while sharing

☐ Additional Factors (please specify):

27. In your opinion, what are the current important success factors in the use of neutral formats for the purpose of **design to manufacturing** in your company? (Check all the applies)

Successful CAD data translation…

☐ among different CAD systems

☐ among CAD systems and viewers

Ease of CAD data translation…

☐ among different CAD systems

☐ among CAD systems and viewers

Others:

☐ Successful CAD data sharing without a full CAD system on 2nd party

☐ Ease of CAD data sharing without a full CAD system on 2nd party

☐ Successful collaboration among parties via annotations on CAD model

☐ Intellectual property protection while sharing

☐ Additional Factors (please specify):

Demographics Information

28. Select the choice that best represents your company or the company division in which you work:

- [ ] Automotive OEM
- [ ] Automotive supply chain
- [ ] Aerospace OEM
- [ ] Aerospace supply chain
- [ ] Consumer products
- [ ] Heavy equipment
- [ ] Pharmaceuticals
- [ ] Energy
- [ ] Government
- [ ] Education
- [ ] Other (please specify):

29. Select the choice that best represents your primary job role:

- [ ] Concept Design
- [ ] Design Engineering
- [ ] Analysis
- [ ] Manufacturing Engineering
- [ ] Manufacturing Planning
- [ ] Supply chain/logistics
- [ ] Customer support
- [ ] Legacy programs/maintenance

Thank you for taking our survey. Your response is very important to us. If you have further questions regarding this study, please contact:

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