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PERFORMANCE SPECIFICATION

DIGITAL REPRESENTATION FOR COMMUNICATION OF PRODUCT DATA: IGES APPLICATION SUBSETS AND IGES APPLICATION PROTOCOLS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 <u>Scope</u>. This specification identifies the requirements to be met when product definition data is delivered in the digital format of the Initial Graphics Exchange Specification (IGES, in accordance with the American National Standard (ANS) / United States Product Data Association (US PRO) standard. Discrete subsets and application protocols of the IGES entities are identified by class according to the application for which the digital data was prepared.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be used in improving this document should be addressed to: ATTN CALS Digital Standards Office, DISA Center for Information Technology Standards, Code JIEO/JEBEB, 10701 Parkridge Blvd, Reston VA 20191-4357, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A   AREA IPSC

<u>DISTRIBUTION STATEMENT A</u>. Approved for public release; distribution is unlimited.

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1.2 <u>Classification</u>. The digital representation of product definition data will be one or more of the following classes as specified in the contract or other form of agreement:

Class 1   –   Technical Illustration Subset
Class 2   –   Engineering Drawing Subset
Class 3   –   Electrical/Electronic Applications Subset (Withdrawn)
Class 4   –   Geometry for Numerical Control (NC) Manufacturing Subset
Class 5   –   3D Piping Application Protocol (AP)
Class 6   –   Layered Electrical Product (LEP) Application Protocol (AP)
Class 7   –   3D Geometry Subset

1.2.1 <u>Additional classes</u>. No new classes are anticipated.

1.3 <u>Year 2000 compliance</u>. This performance specification now meets DoD Year 2000 (Y2K) compliance requirements. The "Y2K" logo is a registered trademark of the United States Government. Details on U.S. Government Y2K requirements may be referenced at: http://www.y2k.gov

2. APPLICABLE DOCUMENTS

2.1 <u>General</u>. The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3 and 4 of this specification, whether or not they are listed in section 2

2.2 <u>Government documents</u>.

2.2.1 <u>Specifications, standards, and handbooks</u>. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

STANDARDS

MILITARY STANDARDS

MIL-STD-1840   –   Automated Interchange of Technical Information

(Copies of the referenced military specifications and standards are available from the Standardization Documents Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094 or http://www.dodssp.daps.mil/)

2.2.2 <u>Other Government documents, drawings, and publications</u>. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

UNITED STATES PRODUCT DATA ASSOCIATION (US PRO)

ANS US PRO/IPO-100-1993 –   IGES 5.2, Initial Graphics Exchange Specification

ANS US PRO/IPO-100-1996 –   IGES 5.3, Initial Graphics Exchange Specification

ANS US PRO/IPO-110-1994 –   3D Piping IGES Application Protocol

ANS US PRO/IPO-111-1997 –   IGES Layered Electrical Product Application Protocol (AP)

NISTIR 4379   –   IGES Technical Illustrations Application Guide, July 1991

NISTIR 4412   –   IGES V5.1 Initial Graphics Exchange Specification (IGES, Version 5.1, September 1991

NISTIR 4600   –   Recommended Practices Guide

(Application for copies of the above documents will be addressed to: US PRO, Trident Research Center, 5300 International Boulevard, Suite 204, North Charleston SC 29418 or https://www.uspro.org/)

2.3 <u>Non-Government publications</u>. This section is not applicable to this specification.

2.4 <u>Order of precedence</u>. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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3. REQUIREMENTS

3.1 <u>General requirements</u>. All digital product data files complying with this specification shall conform to the identified subset or application protocol class. The specific subset or application protocol class shall be identified by the use of global parameter #26.

3.1.1 <u>Restrictive nature of subsets</u>. A data file complying with this specification shall utilize only those specific entities identified in the referenced subset or application protocol class for representing the product definition. Additional volunteer entity types may be present as long as these entity types are:

      a.   Valid IGES entities (V5.3 or greater);

      b.   Not necessary to the product data representation; or

      c.   Solely for the purpose of regenerating the same development environment when the file is transferred back to the same Computer Aided Design (CAD) system which originally generated the file and may be ignored by other CAD systems.

3.1.1.1 <u>Additional limits</u>. These volunteer entities do not include geometry. Rather, they typically include IGES-defined properties, user-defined properties, and associative or color definition entities. A postprocessor (see 6.7.14) is not required to translate these volunteer entity types into the data base of its CAD/CAM system, but is required to continue processing the remainder of the data file.

3.1.2 <u>Limits on Parameter Data (PD)</u>. A data file complying with this specification shall not contain scalar values of PD outside the ranges specified by the identified subset or application protocol class.

3.1.3 <u>Physical file structure</u>. All digital product data files complying with this specification shall be written in the American Standard Code for Information Interchange (ASCII) form. The binary and compressed ASCII forms shall not be used.

3.1.4 <u>Physical media for delivery</u>. Unless otherwise specified in the solicitation all data files complying with this specification shall be delivered in accordance with MIL-STD-1840.

3.1.5 <u>Internet delivery</u>. Files may be transmitted over the internet using the guidelines established by MIL-STD-1840. When transmitting files the guidelines for Multipurpose Internet Mail Extensions (MIME) should be followed. The requirements for MIME file delivery are outlined within MIL-STD-1840.

3.2 <u>Specific requirements</u>. The following subsections define the requirements for each defined subset or application protocol class. A conforming data file shall use the most current IGES version entity types and form numbers for representation of data in the identified class subset. All references to entity types, form numbers, and data fields are references to IGES for class 1-4 and 7. Class 5, the 3D Piping AP, uses ANS US PRO/IPO-100-1993 (IGES 5.2) entities, see ANS US PRO/IPO-110-1994 (3D Piping IGES Application Protocol) for details. Class 6, LEP AP, uses ANS US PRO/IPO-100-1996 (IGES 5.3) entities, and ANS US PRO/IPO-111-1997 (Layered Electrical Product Application Protocol). All IGES references in this specification relate to the most current version of the IGES specification unless otherwise stated.

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3.2.1 Class 1 - technical illustration subset. The technical illustration subset of IGES addresses entities that support the exchange of figures and illustrations normally found in a technical publication. In this application, emphasis is on the visual clarity of figures and illustrations designed for human interpretation. NISTIR 4379 provides additional guidance on this usage of IGES.

3.2.1.1 File construction.

3.2.1.1.1 Start section. The following information shall be placed in the start section of the file:

a.   Statement of conformance to this application subset, the applicable revision level of this specification, and the release date of the latest amendment to this specification (or date of the latest revision if no amendment has been issued).

b.   Illustration number or identifier.

3.2.1.1.2 Global section. Fields in the global section shall be restricted to certain ranges. Defaulted values shall be interpreted as "unspecified" except as noted in table I for global parameters 1, 2, 12, 15, and 24.

TABLE I. Global section field ranges for Class 1 (Technical Illustration Subset)

Field	Value	Required	Defaults/Notes
1	,	N	Default to ,
2	;	N	Default to ;
3-6		Y	
7-11		N	
12		N	Default to field 3
13	1.0	Y	
14	1,2,4-11	Y	
15		N	Default to 1
16-17		Y	
18		Y	The year must be shown as YYYY
19		Y	
20		N	
21		N	
22		N	
23	11 or greater	Y	
24	0-7	N	Default to zero
25		N	If date is provided, the year must be shown as YYYY
26	23HMIL-PRF-28000B0,CLASS 1	Y	

3.2.1.1.3 Directory Entry (DE) section. See Notes in Table II for restrictions placed on the values in the DE section.

3.2.1.1.4 Parameter Data (PD) section. See Notes in Table II for restrictions placed on the parameters in the PD section.

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3.2.1.2 Information requirements and data functionality. Two-dimensional geometry and annotation entities form the majority of data items although some non-geometric information is required as well. Information requirements for this application subset include (but are not limited to):

   a.   Two dimensional geometry in the form of lines, circular arcs, conic arcs, and spline curves.

   b.   Non-geometric attributes of line weight and line font.

   c.   Annotation entities.

   d.   Data relationships, including the concept of subfigures.

3.2.1.3 Data accuracy requirements. All data transformations shall maintain an accuracy of at least 0.001 units on all parametric and coordinate values and all measurable dimensions. The generating system shall document the accuracy of the file in global section field 19.

3.2.1.4 Mapping of information content to IGES subset entities. Illustration geometry shall be mapped into two-dimensional IGES geometry entities and annotation entities. The composite curve, subfigure definition, and subfigure instance entities shall be used to organize the illustration information to preserve any required data relationships. Line weight and line style information shall be represented by the appropriate global and DE parameters. Several entity structures in this subset have been included to keep the file size to acceptable levels. For instance, the use of subfigures greatly reduces file size where illustration details are repeated. Similarly, the general note entity is a compact method of representing annotation entity as compared with the stroking of each character using line and arc geometry. However, there are instances where a system lacks the sophistication of subfigure entity constructs or it is desired to stroke the text for a special appearance not otherwise attainable. Lines, splines, linear curves, arcs, and conic arcs shall not have a zero arc length (zero length curves).

3.2.1.5 User conventions and data organization. A minimum complexity drawing/view entity combination, along with its drawing size property, shall be used to assure an illustration will be created on all receiving systems. The drawing shall be constructed in the positive quadrant. The origin point shall be located at the lower left corner of the illustration.

3.2.1.6 IGES entity subset specification. Table II lists the entities of this subset. Only IGES entities which are enumerated in this table shall be used for representing technical publication illustration product definition data. Other valid IGES entity types may be present in the file as described by 3.1.1. Additional requirements are placed on the global section of a file, and certain field value restrictions are also placed on the range of parameter values in both the Directory Entry (DE) and the PD sections of a valid IGES file.

TABLE II. IGES entity content for Class 1 (Technical Illustration Subset)

ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
0		Null		
100		Circular Arc	3	17
102		Composite Curve	1	4
104	1	Conic Arc	3	17, 20

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ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
104	2	Conic Arc	3	17, 20
104	3	Conic Arc	3	17, 20
106	11	2D Linear String	1	15
106	63	Simple Closed Planar Curve	1	21
110	0	Line	1	2
112		Parametric Spline Curve	1	2, 5
124	0	Transformation Matrix	6	7
126		Rational B-spline Curve	1	8
212		General Note	10	11, 18
230		Sectioned Area	1	17
308		Subfigure Definition	6	4
404	0	Drawing	9	9, 19
406	15	Name Property		16
406	16	Drawing Size Property		
406	17	Drawing Units Property		
* 406	18	Intercharacter Spacing Property	12	
408		Subfigure Instance	3	2
410	0	View	6	13
412		Rect Array Sub Instance	3	2, 14
414		Circ Array Sub Instance	3	2, 14

When the form column in table II is blank for an entity which has multiple form numbers, all forms of that entity are included in the subset.

*Denotes an IGES untested entity, capability.

Notes for table II:

1. DE field 4, line font pattern, shall be 1, 2, 3, 4, or 5.
    DE field 5, level, shall be 0.
    DE field 6, view pointer, shall be 0.
    DE field 7, transformation matrix pointer, shall be 0.
    DE field 8, label display pointer, shall be 0.

2. PD values for Z coordinates shall be 0.0.

3. DE field 4, line font pattern, shall be 1, 2, 3, 4, or 5.
    DE field 5, level, shall be 0.
    DE field 6, view pointer, shall be 0.
    DE field 8, label display pointer, shall be 0.

4. PD values shall point only to other entity types within this subset.

5. PD #3, NDIM, shall be 2 (planar).

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6. DE field 7, transformation matrix, shall be 0.

7. Translation and rotation are restricted to XY plane. PD #R13, #R23, #R31, #R32, and #T3 shall be 0.0, and #R33 shall be 1.0 or -1.0.

8. PD #3, PROP1, shall be 1 (planar), ZK shall be 0.0, XNORM and YNORM shall be 0.0, ZNORM shall be 1.0 or -1.0. Rational B-Splines are to be considered functionally and mathematically equivalent to NURBS (Non-Uniform Rational B-Spline) curves.

9. PD #1,   number of view pointers, shall be 1.
    PD #5,   number of annotation entities, shall be 0.
    PD #6,   number of associativity pointers, shall be 0,
    PD #7,   number of property pointers, shall be 1, 2 or 3.
    PD #8-#10, a DE pointer to a property (406, form 16) is required, a DE pointer to a property (406, form 15) is optional, and a DE pointer to a property (406, form 17) is optional.

10. DE field 5, level, shall be 0.
    DE field 6, view pointer, shall be 0.
    DE field 7, transformation matrix pointer, shall be 0.
    DE field 8, label display pointer, shall be 0.

11. PD #5, font code, shall be 1, 1001, 1002, 1003, or 3001, the Latin-1 character set. If a pointer to a property entity (406, form 18) is used to control intercharacter spacing, then any IGES font value may be used.

12. DE field 5, level, shall be 0.

13. PD #2, scale, shall be 1.0.
    PD #3-#8 shall be 0.

14. PD values shall not point to entity type 412, entity type 414, or an entity 308 which points to a 412 or 414, and shall only point to other entity types within this subset.

15. N (the number of points, PD #2) shall be 3 or more.

16. The name property entity shall take precedence over a name in DE field 18, entity label, for any entity which has a name property.

17. PD value for ZT coordinate shall be 0.0.

18. PD value for ZS(n) shall be 0.0, where n=1…N.

19. Drawing origin shall be the lower left-hand corner, no negative coordinates are allowed once all appropriate offsets and rotations are applied.

20. Conic coefficient B (PD #2) shall be zero (0.0). An associated matrix shall be used to rotate/translate the conic to its position in space.

21. PD #2, number of n-tuples, shall be greater than 2.

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3.2.2 Class 2 - engineering drawing subset. This engineering drawing subset of IGES shall be used to encode product data being acquired for delivery in digital form. Exchange emphasis is on completeness, visual equivalency for human interpretation, and functionality of the received drawing model, including the requirements of style and content for the document used to develop the drawing.

3.2.2.1 File construction.

3.2.2.1.1 Start section. The following information shall be given in the start section of the file:

a. Statement of conformance to this application subset, the applicable revision level of this specification, and the release date of the latest amendment to this specification (or date of the latest revision if no amendment has been issued).

b. Revision letters of most recent change to each drawing sheet in the file.

c. Performing organization, date of the IGES file preprocessing and contract number.

d. Intended drawing size letter and number of drawing sheets in this file.

e. Data organization method with contents of each level, for example:

Level	Description
1	model entities
201	dimension
202	crosshatching

3.2.2.1.2 Global section. Fields in the global section shall be restricted to certain ranges. Defaulted values shall be interpreted as "unspecified" except as noted in table III for global parameters 1, 2, 12, and 24.

TABLE III. Global section field ranges for Class 2 (Engineering Drawing Subset)

Field	Value	Required	Default/Notes
1	,	N	Default to ,
2	;	N	Default to ;
3-11		Y	
12		N	Default to field 3
13	1.0	Y	
14	1-11	Y	
15-17		Y	
18		Y	The year must be shown as YYYY
19		Y	
20		N	
21		Y	
22		Y	
23	11 or greater	Y	
24	0-7	N	Default to zero

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Field	Value	Required	Default/Notes
25		N	If date is provided, the year must be shown as YYYY
26	23HMIL-PRF-28000B0,CLASS 2	Y	

3.2.2.1.3 Directory Entry (DE) section. See notes for table IV for restrictions placed on the values in the DE section. In addition, the following capabilities shall be provided and shall be supported for all entities as required by IGES. IGES defines the actions of the preprocessors and postprocessors for the DE section values on an entity specific basis:

     a.   Line font pattern.

     b.   The level number field shall be zero or positive except where necessary to maintain the meaning of the referenced entity.

     c.   View pointer.

     d.   Translation matrix.

     e.   Blank status flag.

     f.   Subordinate entity switch.

     g.   Entity use flag.

     h.   Hierarchy status flag.

     i.   Line weight number.

     j.   Color number.

     k.   Form number.

3.2.2.1.4 Parameter Data (PD) section. See notes for table IV for restrictions placed on the parameters in the PD section.

3.2.2.2 Information requirements and data functionality. Currently, engineering drawings form the mainstay of product definition and form the accepted medium for viewing computer-generated data. Geometry and annotation entities form the majority of data items. Extensive use is made of dimensions, sectioned areas, text notes, and feature control symbols. Non-geometric information in the form of color, line weight, line font, and level is needed as well. Finally, relationships among the data help to structure the large quantities of data. Information requirements for this application subset include (but are not limited to):

     a.   Simple geometry in the form of points, lines, circular arcs, conic arcs, and spline curves.

     b.   Non-geometric attributes of color, line weight, and line font.

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c. Data relationships, including the concept of subfigures.

d. Data organization methods such as level.

e. Part name, drawing number, formal identification, and drawing revision.

f. Annotation entities represented by the corresponding IGES entity type thus retaining its intended functionality.

3.2.2.3 Data accuracy requirements. All data transformations shall maintain an accuracy of 1.0×10^{-6} units on all parametric and coordinate values and all measurable dimensions.

3.2.2.4 Mapping of information content to IGES subset entities. Engineering drawing geometry shall be mapped into IGES geometry entities and organized as necessary with the composite curve, subfigure definition, and subfigure instance entities. Text shall be represented by the general note entities and shall not be represented as geometry. Geometry that also happens to be text, such as a company's logo printed on a PC board, is not held to this restriction. Annotation entities shall not be represented as geometry. Use of IGES constructs such as the dotted line font (DE field 4-5) is encouraged to reduce file lengths (see 6.4).

3.2.2.5 User conventions and data organization. A minimum complexity drawing and view entity combination shall be used to assure a part model being created on all destination systems. A drawing size property shall be used to define drawing limits. As specified in the contract or other form of agreement, data shall be organized as one drawing per file with multiple sheets permitted, or shall be restricted to one sheet per file.

3.2.2.6 IGES entity subset specification. Table IV lists the entities of this subset. Only IGES entities which are enumerated in this table shall be used for representing engineering drawing product definition data. Other valid IGES entity types may be present in the file as described by 3.1.1. Additional requirements are placed on the global section of a file, and certain field value restrictions are placed on the range of parameter values in both the DE and the PD sections of a valid IGES file.

TABLE IV. IGES entity content for Class 2 (Engineering Drawing Subset)

ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
0		Null		
100		Circular Arc	1	
102		Composite Curve	1	2
104	1	Conic Arc	1	5
104	2	Conic Arc	1	5
104	3	Conic Arc	1	5
106	11	2D Linear String	1	6
106	12	3D Linear String	1	6
106	20	Centerline Through Points	1	
106	21	Centerline Through Circle Centers	1	
106	31	Section (parallel line segments)	1	
106	32	Section (parallel line segments in pairs)	1	

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ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
106	33	Section (alternating solid & dash segments)	1	
106	34	Section (parallel lines in quad.)	1	
106	35	Section (triples of parallel lines)	1	
106	36	Section (parallel sets of dash segments)	1	
106	37	Section (two perpendicular sets of parallel lines)	1	
106	38	Section (two perpendicular sets of parallel lines - principal solid & second dashed)	1	
106	40	Witness Line	1	11
106	63	Simple Closed Planar Curve	1	6
108	0	Unbounded Plane	1	7
108	1	Bounded Plane	1	14
110		Line	1	
112		Parametric Spline Curve	1	8, 16
114		Parametric Spline Surface	1	8, 16
116		Point	1	
118		Ruled Surface	1	2
120		Surface of Revolution	1	2
122		Tabulated Cylinder	1	2
124	0	Transformation Matrix	1	
124	1	Transformation Matrix	1	
126		Rational B-spline Curve	1	16
128		Rational B-spline Surface	1	16
130		Offset Curve	1	2
140		Offset Surface	1	2
141		Boundary		
142		Curve on a Parametric Surface	1	2
143		Bounded Surface		
144		Trimmed Parametric Surface	1	2
202		Angular Dimension	1	
206		Diameter Dimension	1	
210		General Label	1	
212		General Note	1	3
214		Leader Arrow	1	9
216		Linear Dimension	1	
218		Ordinate Dimension	1	
220		Point Dimension	1	12
222	0	Radius Dimension	1	
* 222	1	Radius Dimension	1	
228	0	General Symbol	1, 10	2
* 228	1	General Symbol	1, 10	2
* 228	2	General Symbol	1, 10	2
* 228	3	General Symbol	1, 10	2
230		Sectioned Area	1	2
304		Line Font Definition		
308		Subfigure Definition	1, 13	2

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ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
314		Color Definition		
402	3	Views Visible Associativity		
402	4	Views Visible, Color, Line Weight Associativity		
402	7	Group Without Back Pointers Associativity		
402	21	Dimensioned Geometry Associativity		
404		Drawing		4, 15
406	1	Definition Levels Property		
406	3	Level Function Property		
406	15	Name Property		
406	16	Drawing Size Property		
406	17	Drawing Units Property		
406	28	Dimension Units Property		
406	29	Dimension Tolerance Property		
406	30	Dimension Display Property		
406	31	Basic Dimension Property		
408		Subfigure Instance	1	
410		View		

When the form column in table IV is blank for an entity, which has multiple form numbers, all forms of that entity are included in the subset.

* Denotes an IGES untested entities capability.

Notes for table IV:
1. DE field 8, label display pointer, shall be 0.

2. PD pointer values shall point only to other entity types within this subset.

3. PD #5, font code, shall be 1, 1001, 1002, 1003, or 3001, the Latin-1 character set.

4. Drawing origin shall be the lower left-hand corner, no negative coordinates are allowed once all appropriate offsets and rotations are applied.

5. Conic coefficient B (PD #2) shall be zero (0.0). An associated matrix shall be used to rotate/translate the conic to its position in space.

6. N (the number of points, PD #2) shall be 3 or more.

7. Shall only appear in the file if it is used with an entity type 410 as a clipping plane.

8. CTYPE (PD #1) shall be 2 or 3.

9. Shall have at least one segment. Neither arrowhead height (PD #2) nor width (PD #3) shall be zero except for form 4 where both shall be zero and form 9 where the height can be zero.

10. May be used only for annotation entity.

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11. Shall contain at least two segments. Only first segment can be zero length.

12. Leader shall be form 4.

13. DE field 7 shall be 0.

14. Shall always point to a boundary curve. PD # 6-9 shall be ignored.

15. One or more drawing entities is required.

16. Due to computation stability, the use of the 126 and 128 entities is encouraged instead of the use of the 112 and 114 entities. Rational B-Splines are to be considered functionally and mathematically equivalent to NURBS (Non-Uniform Rational B-Spline) curves and surfaces.

3.2.2.7 Entity construction. The following entities (in entity number order) have particular meanings when used for engineering drawings. The requirements in this section shall be met in all conforming data files and by all translator implementations for IGES subset class 2.

102 Composite Curve. Composite curves are intended for showing connectivity and continuity among a number of component geometry entities. They shall contain a minimum of two entities one of which shall be a curve and only entities in this subset may be referenced.

124 Transformation Matrix. Defining matrices are used to position an entity into model space from its definition space. When entities share the same plane of definition, they shall use the same transformation matrix to avoid multiple identical matrices being included in the file. If an entity contains translation information in its PD section, a transformation matrix shall not be used to translate the entity.

126 Rational B-spline Curve. The rational B-spline curve is used to represent free-form edges of a part. It shall not be used to represent linear, circular, or conic edges of a part since more appropriate entities exist for these shapes.

202 Angular Dimension. This entity shall have two leaders, and a vertex point. The Z displacement of the vertex point can be obtained from any of the subordinates.

206 Diameter Dimension. This entity shall specify its arc center (may not be defaulted). The Z displacement of the arc center can be obtained from the subordinates. The arc center shall be valid. If multiple leaders occur, the first segment of each leader shall be collinear and opposite in direction.

212 General Note. General notes shall use a font code to minimize the number of text strings in the note. At least one string is required, but the number of different strings shall be minimized. Form numbers plus position information on each string shall be used. The rotation angle field shall contain the string angle. Transformation matrices shall not be used for string angles. Null strings are allowed and may be used to pattern a note into one of the standard forms.

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216 Linear Dimension. When there are two witness lines, they shall be parallel to each other.

218 Ordinate Dimension. This entity shall not be used in place of the general label. The leader shall contain only one segment.

222 Radius Dimension. This entity shall specify its arc center (may not be defaulted). Z displacement of the arc center can be obtained from any of its subordinates. Arc center shall be valid. If multiple leaders occur, the first segment of each shall be collinear. If two leaders are used, one and only one shall be of form 4.

228 General Symbol. This entity shall be used for annotation entity. Entity use flag in the subordinate entities (even geometry) shall be set to annotation entity. This entity shall not be used in place of a subfigure or group. All subordinate entities to the general symbol entity shall be coplanar.

230 Sectioned Area. This entity is used to provide for area fills. The normal distance between lines is constant and shall not be zero. Wider spaces between lines are to be considered blank lines with regard to normal distances. Boundary curve and islands are closed and not self-intersecting. Island interiors are mutually disjoint. Islands lie in the interior of the boundary curve. Boundary curve and islands can be logically dependent. Their entity use flag do not need to be set as annotation entities if they are not annotation entities.

404 Drawing. The drawing entity defines the basic engineering drawing format for each sheet. One drawing entity shall exist in the file for each sheet, or collection of sheets, of an engineering drawing. An example of a collection of sheets would be several B size sheets placed in an H size engineering drawing. All entities pointed to by the drawing entity shall be physically dependent and shall have its usage flagged as annotation.

406 Form 15 Name. This entity is used to convey the drawing name. A drawing name using entity 406, form 15 is required. If there is no name available in the architecture of the system, the preprocessor shall insert one, a reasonable value being global parameter 3 as the default for the PD attribute name.

406 Form 16 Drawing Size. A drawing size property shall be included for each drawing entity in the file. If drawing size is not in the architecture of the system, the preprocessor shall insert one and the drawing size for each sheet shall match the drawing size letter defined in the start section (see 3.2.2.1.1).

406 Form 17 Drawing Units. A drawing units property shall be included for each drawing entity in the file. If drawing units is not in the architecture of the system, the preprocessor shall use the defaults given in global parameters 14 and 15 as the defaults for the PD attributes units flag and units name, respectively.

3.2.2.7.1 Simplest entity. The simplest entity type shall be used to represent each piece of geometry, and zero size entities shall not be used. For instance, a B-spline curve shall not be used to represent a circular arc. A zero length line entity or a zero diameter circle shall not occur in the file.

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3.2.2.7.2 <u>200 series entities</u>. All 200 series entities shall be flagged as annotation entities and shall be parallel to the viewing plane, except for crosshatching. All dependent entities with parent 200 entities shall be flagged as annotation entities and shall be coplanar with their parent. The only exception is for geometry entities associated with the sectioned area (230 and 106 forms 31-38). Any annotation entity which points to multiple leaders and multiple witness lines shall order those leaders and witness lines so that leader-1 corresponds logically to witness-1 and leader-2 to witness-2.

3.2.3 <u>Class 3 - electrical/electronic applications subset</u>. The class 3 subset has been withdrawn in MIL-PRF-28000B, and replaced by class 6, LEP AP.

3.2.4 <u>Class 4 - geometry for Numerical Control (NC) manufacturing subset</u>. The NC machining subset of IGES is used to encode product data for the subsequent purposes of manufacturing. As such, it is designed to directly support the geometry data needs of process planning and NC cutter path generation. The data exchange shall preserve the precision and accuracy of all wire frames and surface geometry as well as the first order continuity between geometry entities. Exchange emphasis is on completeness and functionality of the received part model.

3.2.4.1 <u>File construction</u>.

3.2.4.1.1 <u>Start section</u>. The following information shall be given in the start section of the file:

a.   Statement of conformance to this application subset, the applicable revision level of this specification, and the release date of the latest amendment to this specification (or date of the latest revision if no amendment has been issued).

b.   Revision level of the file.

c.   Performing organization, date of the IGES file preprocessing, and contract number.

d.   Data organization method with contents of each level, for example:

Level	Description
1	model entities
201	dimension

3.2.4.1.2 <u>Global section</u>. Fields in the global section shall be restricted to certain ranges. Defaulted values shall be interpreted as "unspecified" except as noted in table V for global parameters 1, 2, 12, and 24.

TABLE V. <u>Global section field ranges for Class 4 (Numerical Control (NC) Manufacturing Subset)</u>

Field	Value	Required	Default/Notes
1	,	N	Default to ,
2	;	N	Default to ;
3-11		Y	
12		N	Default to field 3
13	1.0	Y	

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Field	Value	Required	Default/Notes
14	1-11	Y	
15-17		Y	
18		Y	The year must be shown as YYYY
19		Y	
20		N	
21		Y	
22		Y	
23	11 or greater	Y	
24	0-7	N	Default to zero
25		N	If date is provided, the year must be shown as YYYY
26	23HMIL-PRF-28000B0,CLASS 4	Y	

3.2.4.1.3 Directory Entry (DE) section. See notes for table VI for restrictions placed on the values in the DE section. In addition, the following capabilities shall be provided and shall be supported for all entities as required by IGES. IGES defines the actions of the preprocessors and postprocessors for the DE section values on an entity specific basis:

      a.   Line font pattern.

      b.   The level number field shall be zero or positive except where necessary to maintain the meaning of the referenced entity.

      c.   View pointer

      d.   Translation matrix.

      e.   Blank status flag.

      f.   Subordinate entity switch.

      g.   Entity use flag.

      h.   Hierarchy status flag.

      i.   Line weight number.

      j.   Color number.

      k.   Form number.

3.2.4.1.4 Parameter Data (PD) section. See notes for table VI for restrictions placed on the parameters in the PD section.

3.2.4.2 Information requirements and data functionality. Geometry and annotation entities form the majority of the data items. Geometry data are used to describe the nominal shape of the product either as a 2D wire frame

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or as a 3D wire frame model with surfaces. (Note: As used herein, nominal is defined as an attribute set which describes the size for specification or design purposes, but does not describe the actual or true size. The designation 2 x 4, as used in the lumber industry, is an example of such an attribute.) 2D descriptions are used to describe the profile of turned parts or of 2D parts such as found in sheet metal work. 3D descriptions are used for multi-axis machining.

3.2.4.2.1 Annotation entity. Nominal dimensions given in annotation entity shall agree with the corresponding values in the geometry data description. A major purpose of annotation entities shall be to represent tolerances on the geometry. Annotation entities are also used to describe material specifications and administrative data. Non-geometric information in the form of color, line weight, line font, and level is needed as well. Finally, relationships among the data are defined to help structure the large quantities of product data.

3.2.4.3 Data accuracy requirements. All data transformations shall maintain an accuracy of 1.0×10^{-6} units on all parametric and coordinate values and all measurable dimensions.

3.2.4.4 Mapping of information content to IGES subset entities. NC manufacturing geometry shall be mapped into IGES geometry entities and linked together as necessary with composite curve entities. Text shall be represented by the general note entities and shall not be represented as geometry. Annotation entities, including dimensions, labels, and centerlines shall be represented by their named IGES entity and shall not be represented as geometry. Line weight, color, and line font information shall be represented by the appropriate global and DE values. Level attributes shall be represented by the appropriate DE value.

3.2.4.5 User conventions and data organization. A minimum complexity drawing and view entity combination shall be used to assure a part model being created on all destination systems. A drawing size property shall be used to define drawing limits. As specified in the contract or other form of agreement, data shall be organized as one drawing per file with multiple sheets permitted, or shall be restricted to one sheet per file.

3.2.4.6 IGES entity subset specification. Table VI lists the entities of this subset. Only IGES entities which are enumerated in this table shall be used for representing geometry for NC manufacturing. Other valid IGES entity types may be present in the file as described by 3.1.1. Additional requirements are placed on the global section of a file, and certain field value restrictions are placed on the range of parameter values in both the DE and the PD sections of a valid IGES file.

TABLE VI. IGES entity content of geometry for Class 4 (NC Manufacturing Subset)

ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
0		Null		
100		Circular Arc	1	16
102		Composite Curve	1	16
104	1	Conic Arc	1	2, 16
104	2	Conic Arc	1	2, 16
104	3	Conic Arc	1	2, 16
106	1	Coordinate Pairs	15	3
106	2	Coordinate Triples	15	3, 11
106	11	2D Linear String	1	4

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ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
106	12	3D Linear String	1	4, 11
106	20	Centerline Through Points	1	
106	21	Centerline Through Circle Centers	1	
106	40	Witness Line	1	
106	63	Simple Closed Planar Curve	1	4
108	0	Plane - Unbounded	15	
108	-1, 1	Plane - Bounded	1	
110		Line	1	12
116		Point	1	5, 11
118	1	Ruled Surface	1	11
120		Surface of Revolution	1	
122		Tabulated Cylinder	1	11
124	0, 1	Transformation Matrix	6	
126		Rational B-spline Curve	1	18
128		Rational B-spline Surface	1	11, 18
130		Offset Curve	1	15
140		Offset Surface	1	15
141		Boundary		
142		Curve on a Parametric Surface	17	
143		Bounded Surface		
144		Trimmed Parametric Surface	17	
202		Angular Dimension	1	
206		Diameter Dimension	1	
210		General Label	1	7
212		General Note	1	8
214	1	Leader Arrow, Wedge	1, 9	10
214	2	Leader Arrow, Triangle	1, 9	10
214	3	Leader Arrow, Filled Triangle	1, 9	10
214	11	Leader Arrow, Open Triangle	1, 9	10
216		Linear Dimension	1	
218		Ordinate Dimension	1	
220		Point Dimension	1	
222	0	Radius Dimension	1	
* 222	1	Radius Dimension	1	
228	0	General Symbol	1	
* 228	1	General Symbol	1	
* 228	2	General Symbol	1	
* 228	3	General Symbol	1	
402	3	Views Visible Associativity		
402	4	Views Visible, Color, Line Weight Associativity		
402	7	Group Without Back Pointers Associativity	1	
402	21	Dimensioned Geometry Associativity		
404		Drawing		
406	15	Name Property		13
406	16	Drawing Size Property		

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ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
406	17	Drawing Units Property		
406	28	Dimension Units Property		
406	29	Dimension Tolerance Property		
406	30	Dimension Display Data Property		
406	31	Basic Dimension Property		
410		View		

When the form column in table VI is blank for an entity which has multiple form numbers, all forms of that entity are included in the subset.

*Denotes an IGES untested entities capability.

Notes for table VI:

1. DE field 4, line font pattern, shall be 1, 2, 3, 4, or 5.
    DE field 9c, entity use, shall be 00, 01, 02, 03, or 05.

2. Conic coefficient B (PD #2) shall be zero (0.0). An associated matrix shall be used to rotate/translate the conic to its position in space.

3. PD #2, number of n-tuples, shall be greater than 1.

4. PD #2, number of n-tuples, shall be greater than 2.

5. PD #4, PTR, shall be 0.

6. DE field 7, transformation matrix, shall be 0.

7. PD #2, number of leaders, shall be non-zero. All of the pointer fields, DENOTE and DE1 through DEN, are required to be present and shall point to valid entities.

8. PD #5, font code, shall be 1, 1001, 1002, or 1003.

9. DE field 9b, subordinate status, shall be 01.
    DE field 7, transformation matrix, shall be 0.

10. PD #4, ZT, shall be 0.0.

11. If 2D wireframe descriptions are used, Z-coordinates of this entity shall be 0.0.

12. If 2D wireframe descriptions are used, Z-coordinates of this entity shall be 0.0, unless this entity is being used as the axis of revolution for a surface of revolution entity.

13. The name property entity shall take precedence over a name in DE field 18, entity label, for any entity which has a name property.

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14. If 2D wireframe descriptions are used, PD #12, VZ, shall be 0.0.

15. DE field 9c, entity use, shall be 00, 01, 02, 03, or 05.

16. If 2D wire frame descriptions are used, ZT-coordinates shall be 0.0.

17. DE field 4, line font pattern, shall be 1, 2, 3, 4, or 5.

18. Rational B-Splines are to be considered functionally and mathematically equivalent to NURBS (Non-Uniform Rational B-Spline) curves and surfaces.

3.2.4.7 <u>Entity construction</u>. The following entities (in entity number order) have particular meanings when used for NC manufacturing. The requirements in this section shall be met in all conforming data files and by all translator implementations for IGES subset class 4.

100 Circular Arc. The circular arc is used to represent circular edges of a part. When using the circular arc to represent a complete circle, the start point and the terminate point shall be the same and shall be on the positive XT axis (PD #5 and #7 shall be identical, and PD #4 and #6 shall be identical).

102 Composite Curve. Composite curves are intended for showing connectivity and continuity among a number of component geometry entities. They shall contain a minimum of two entities one of which shall be a curve and only entities in this subset may be referenced.

104 Conic Arc. The conic arc is used to represent elliptical, hyperbolic, and parabolic edges of the part. When using the conic arc to represent a full ellipse, the start point and the terminate point shall be the same and shall be on the positive XT axis. (PD #9 and #11 shall be 0.0, and PD #8 and #10 shall be identical).

124 Transformation Matrix. Defining matrices are used to position an entity into model space from its definition space. When entities share the same plane of definition, they shall use the same transformation matrix to avoid multiple identical matrices being included in the file. If an entity contains translation information in its PD section, a transformation matrix shall not be used to translate the entity.

126 Rational B-spline Curve. The rational B-spline curve is used to represent free-form edges of a part. It shall not be used to represent linear, circular, or conic edges of a part since more appropriate entities exist for these shapes.

202 Angular Dimension. This entity shall have two leaders and a vertex point. The Z displacement of the vertex point can be obtained from any of the subordinates.

206 Diameter Dimension. This entity shall specify its arc center (may not be defaulted). The Z displacement of the arc center can be obtained from the subordinates. The arc center shall be valid. If multiple leaders occur, the first segment of each leader shall be collinear and opposite in direction.

212 General Note. General notes shall use a font code to minimize the number of text strings in the note. At least one string is required, but the number of different strings shall be minimized. Form

numbers plus position information on each string shall be used. The rotation angle field shall contain the string angle. Transformation matrices shall not be used for string angles. Null strings are allowed and may be used to pattern a note into one of the standard forms.

216 Linear Dimension. When there are two witness lines, they shall be parallel.

218 Ordinate Dimension. This entity shall not be used in place of the general label. The leader shall contain only one segment.

222 Radius Dimension. This entity shall specify its arc center (may not be defaulted). Z displacement of the arc center can be obtained from any of its subordinates. Arc center shall be valid. If multiple leaders occur, the first segment of each shall be collinear. If two leaders are used, one and only one shall be form 4.

404 Drawing. The drawing entity defines the basic engineering drawing format for each sheet. One drawing entity shall exist in the file for each sheet of an engineering drawing.

406 Form 15 Name. This entity is used to convey the drawing name. A drawing name using entity 406, form 15 is required. If there is no name available in the architecture of the system, the preprocessor shall insert one, a reasonable default being global parameter 3.

406 Form 16 Drawing Size. A drawing size property shall be included for each drawing entity in the file. If drawing size is not in the architecture of the system, the preprocessor shall insert one.

406 Form 17 Drawing Units. A drawing units property shall be included for each drawing entity in the file. If drawing units is not in the architecture of the system, the preprocessor shall use the defaults given in global parameters 14 and 15.

3.2.4.7.1 Simplest entity. In general, the simplest entity type shall be used to represent each piece of geometry, and zero size entities shall not be used. For instance, a B-spline curve shall not be used to represent a circular arc. A zero length line entity or a zero diameter circle shall not occur in the file.

3.2.4.7.2 200 series entities. All 200 series entities shall be flagged as annotation entity and shall be parallel to the viewing plane. All dependent entities with parent 200 entities shall be flagged as annotation entity and shall be coplanar with their parent. Any annotation entity which points to multiple leaders and multiple witness lines shall order those leaders and witness lines so that leader-1 corresponds logically to witness-1 and leader-2 to witness-2.

3.2.5 Class 5 - 3D piping Application Protocol (AP). The 3D Piping IGES AP addresses the representation of three-dimensional piping and related equipment models, and the exchange of these models from one piping modeling application to another. In this application, emphasis is on exchange requirements for the fabrication and assembly of piping systems. It should be noted that this protocol uses some entities from NISTIR 4412 (1991), which are not included in earlier versions of IGES. A class 5 file shall be created in accordance with ANS US PRO/IPO-110-1994 or subsequent version.

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3.2.5.1 File construction.

3.2.5.1.1 Start section. The following information shall be given in the start section of the file:

    a.   Statement of conformance to this application subset, the applicable revision level of this specification, and the release date of the latest amendment to this specification (or date of the latest revision if no amendment has been issued).

    b.   Revision level of the file.

    c.   Performing organization, date of the IGES file preprocessing, and contract number.

    d.   Data organization method with contents of each level, for example:

Level	Description
1	model entities
201	dimension

3.2.5.1.2 Global section. Fields in the global section shall be restricted to certain ranges. Defaulted values shall be interpreted as "unspecified" except as noted in table VII for global parameters 1, 2, 12, and 24.

TABLE VII. **Global section fields ranges for Class 5 (3D Piping AP)**

Field	Value	Required	Default/Notes
1	,	N	Default to ,
2	;	N	Default to ;
3-11		Y	
12		N	Default to field 3
13	1.0	Y	
14	1-11	Y	
15-17		Y	
18		Y	The year must be shown as YYYY
19		Y	
20		N	
21		Y	
22		Y	
23	11 or greater	Y	
24	0-7	N	Default to zero
25		N	If date is provided, the year must be shown as YYYY
26		See AP	For field #26 values refer to the latest version of the Class 5 3D Piping AP

3.2.5.1.3 Directory Entry (DE) section. In addition, the following capabilities shall be provided and shall be supported for all entities as required by IGES. IGES defines the actions of the preprocessors and postprocessors for the DE section values on an entity specific basis:

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a.   Line font pattern.

b.   The level number field shall be zero or positive except where necessary to maintain the meaning of the referenced entity.

c.   View pointer.

d.   Translation matrix.

e.   Blank status flag.

f.   Subordinate entity switch.

g.   Entity use flag.

h.   Hierarchy status flag.

i.   Line weight number.

j.   Color number.

k.   Form number.

3.2.6 Class 6 - Layered Electrical Product (LEP) Application Protocol (AP). The LEP AP class 6 replaces class 3, but maintains the key functionality of class 3. The LEP models electrical components to support the exchange of these models from one electrical modeling application to another. In this application, emphasis is on exchange requirements for the fabrication and assembly of electronic systems. A class 6 file shall be created in accordance with ANS US PRO/IPO-111-1997 or subsequent version.

3.2.6.1 File construction.

3.2.6.1.1 Start section. The following information shall be given in the start section of the file:

a.   Statement of conformance to this application subset, the applicable revision level of this specification, and the release date of the latest amendment to this specification (or date of the latest revision if no amendment has been issued).

b.   Revision level of the file.

c.   Performing organization, date of the IGES file preprocessing, and contract number.

d.   Data organization method with contents of each level, for example:

Level	Description
1	model entities
201	dimension

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3.2.6.1.2 Global section. Fields in the global section shall be restricted to certain ranges. Defaulted values shall be interpreted as "unspecified" except as noted in table VIII for global parameters 1, 2, 12, and 24.

TABLE VIII. Global section fields ranges for Class 6 (Layered Electrical Product (LEP) AP)

Field	Value	Required	Default/Notes
1	,	N	Default to ,
2	;	N	Default to ;
3-11		Y	
12		N	Default to field 3
13	1.0	Y	
14	1-11	Y	
15-17		Y	
18		Y	The year must be shown as YYYY
19		Y	
20		N	
21		Y	
22		Y	
23	11 or greater	Y	
24	0-7	N	Default to zero
25		N	If date is provided, the year must be shown as YYYY
26		See AP	For field #26 values refer to the latest version of the Class 6 LEP AP

3.2.6.1.3 Directory Entry (DE) section. In addition, the following capabilities shall be provided and shall be supported for all entities as required by IGES. IGES defines the actions of the preprocessors and postprocessors for the DE section values on an entity specific basis:

    a.   Line font pattern.

    b.   The level number field shall be zero or positive except where necessary to maintain the meaning of the referenced entity.

    c.   View pointer.

    d.   Translation matrix.

    e.   Blank status flag.

    f.   Subordinate entity switch.

    g.   Entity use flag.

    h.   Hierarchy status flag.

    i.   Line weight number.

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j.   Color number.

k.   Form number

3.2.7 Class 7 - 3D geometry subset. This 3D geometry subset of IGES shall be used to encode product data for the subsequent purposes of manufacturing by NC and other 3D model applications. As such, it is designed to directly support the geometry data needs of process planning and NC cutter path generation. The data exchange shall preserve the precision and accuracy of all wire frame and surface geometry as well as the first order continuity between geometry entities. Exchange emphasis is on completeness and functionality of the received part model.

3.2.7.1 File construction.

3.2.7.1.1 Start section. The following information shall be given in the start section of the file:

a. Statement of conformance to this application subset, the applicable revision level of this specification, and the release date of the latest amendment to this specification (or date of the latest revision if no amendment has been issued).

b.   Revision level of the file.

c.   Performing organization, date of the IGES file preprocessing, and contract number.

d.   Data organization method with contents of each level, for example:

Level   Description
1   model entities

3.2.7.1.2 Global section. Fields in the global section shall be restricted to certain ranges. Defaulted values shall be interpreted as "unspecified" except as noted in table IX for global parameters 1, 2, 12, and 24.

TABLE IX. Global section field ranges for Class 7 (3D Geometry Subset)

Field	Value	Required	Default/Notes
1	,	N	Default to ,
2	;	N	Default to ;
3-11		Y	
12		N	Default to field 3
13	1.0	Y	
14	1-11	Y	
15-17		Y	
18		Y	The year must be shown as YYYY
19		Y	
20		N	
21		Y	
22		Y	

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Field	Value	Required	Default/Notes
23	11 or greater	Y	
24	0-7	N	Default to zero
25		N	If date is provided, the year must be shown as YYYY
26	23HMIL-PRF-28000B0,CLASS 7	Y	

3.2.7.1.3 Directory Entry (DE) section. See notes for table X for restrictions placed on the parameters in the DE section. In addition, the following capabilities shall be provided and shall be supported for all entities as required by IGES. IGES defines the actions of the preprocessors and postprocessors for the DE section values on an entity specific basis:

    a.   Line font pattern.

    b.   The level number field shall be zero or positive except where necessary to maintain the meaning of the referenced entity.

    c.   View pointer.

    d.   Translation matrix.

    e.   Blank status flag.

    f.   Subordinate entity switch.

    g.   Entity use flag.

    h.   Hierarchy status flag.

    i.   Line weight number.

    j.   Color number.

    k.   Form number.

3.2.7.1.4 Parameter Data (PD) section. See notes for table X for restrictions placed on the parameters in the PD section.

3.2.7.2 Information requirements and data functionality. Geometry forms all of the data items. Geometry data is used to describe the nominal shape of the product either as a 3D wireframe or as a 3D wireframe model with surfaces. (Note: As used herein, nominal is defined as an attribute set which describes the size for specification or design purposes, but does not describe the actual or true size. The designation, "2 x 4", as used in the lumber industry, is an example of such an attribute.) 3D descriptions are used to describe the profile of turned parts or of 3D parts such as found in sheet metal work. 3D descriptions are used for multi-axis machining.

3.2.7.3 Data accuracy requirements. All data transformations shall maintain an accuracy of 1.0×10^{-6} units on all parametric and coordinate values and all measurable dimensions.

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3.2.7.4 Mapping of information content to IGES subset entities. 3D geometry shall be mapped into IGES geometry entities and linked together as necessary with composite curve entities. Level attributes shall be represented by the appropriate DE parameter.

3.2.7.5 User conventions and data organization. A minimum complexity drawing and view entity combination shall be used to assure a part model being created on all destination systems. A drawing size property shall be used to define drawing limits. As specified in the contract or other form of agreement, data shall be organized as one drawing per file with multiple sheets permitted, or shall be restricted to one sheet per file.

3.2.7.6 IGES entity subset specification. Table X lists the entities of this subset. Only IGES entities, which are enumerated in this table, shall be used for representing geometry for 3D geometry. Other valid IGES entity types may be present in the file as described in 3.1.1. Additional requirements are placed on the global section of a file, and certain field value restrictions are placed on the range of parameter values in both the DE and the PD sections of a valid IGES file.

TABLE X. IGES entity content for Class 7 (3D Geometry Subset)

ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
0		Null		
100		Circular Arc	1	
102		Composite Curve	1	
104	1	Conic Arc	1	2
104	2	Conic Arc	1	2
104	3	Conic Arc	1	2
106	1	Coordinate Pairs		3
106	2	Coordinate Triples		3
106	11	2D Linear String	1	4
106	12	3D Linear String	1	4
106	63	Simple Closed Planar Curve	1	4
108	0	Plane - Unbounded		
108	-1, 1	Plane - Bounded	1	
110		Line	1	
116		Point	1	5
118	1	Ruled Surface	1	
120		Surface of Revolution	1	
122		Tabulated Cylinder	1	
124	0, 1	Transformation Matrix	6	
126		Rational B-spline Curve	1	9
128		Rational B-spline Surface	1	9
130		Offset Curve	1	
140		Offset Surface	1	
141		Boundary		
142		Curve on a Parametric Surface		
143		Bounded Surface		
144		Trimmed Parametric Surface		
308		Subfigure Definition	8	

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ENTITY	FORM	ENTITY NAME	DE NOTES	PD NOTES
402	7	Group Without Back Pointers Associativity		
406	15	Name Property	7	
408		Singular Subfigure Instance	8	

When the form column in table X is blank for an entity which has multiple form numbers, all forms of that entity are included in the subset.

*Denotes an IGES untested entities, capability.

Notes for table X:

1. DE field 4, line font pattern, shall be 1, 2, 3, 4, or 5.
    DE field 9c, entity use, shall be 00, 02, 03, or 05. (01 Usage Annotation is not allowed)

2. Conic coefficient B (PD #2) shall be zero (0.0). An associated matrix shall be used to rotate/translate the conic to its position in space.

3. PD #2, number of n-tuples, shall be greater than 1.

4. PD #2, number of n-tuples, shall be greater than 2.

5. PD #4, PTR, shall be 0.

6. DE field 7, transformation matrix, shall be 0.

7. The name property entity shall take precedence over a name in DE field 18, entity label, for any entity which has a name property.

8. When the Hierarchy is set to Global Defer (01), all the following are ignored and may be defaulted: Line Font Pattern, Line Weight, Color Number, Level, View, and Blank Status.

9. Rational B-Splines are to be considered functionally and mathematically equivalent to NURBS (Non-Uniform Rational B-Spline) curves and surfaces.

3.2.7.7 Entity construction. The following entities (in entity number order) have particular meanings when used for 3D geometry. The requirements in this section shall be met in all conforming data files and by all translator implementations for IGES subset class 7.

100 Circular Arc. The circular arc is used to represent circular edges of a part. When using the circular arc to represent a complete circle, the start point and the terminate point shall be the same and shall be on the positive XT axis (PD #5 and #7 shall be identical, and PD #4 and #6 shall be identical).

102 Composite Curve. Composite curves are intended for showing connectivity and continuity among a number of component geometry entities. They shall contain a minimum of two entities one of which shall be a curve and only entities in this subset may be referenced.

104 Conic Arc. The conic arc is used to represent elliptical, hyperbolic, and parabolic edges of the part. When using the conic arc to represent a full ellipse, the start point and the terminate point shall be the same and shall be on the positive XT axis. (PD #9 and #11 shall be 0.0, and PD #8 and #10 shall be identical).

124 Transformation Matrix. Defining matrices are used to position an entity into model space from its definition space. When entities share the same plane of definition, they shall use the same transformation matrix to avoid multiple identical matrices being included in the file. If an entity contains translation information in its PD section, a transformation matrix shall not be used to translate the entity.

126 Rational B-spline Curve. The rational B-spline curve is used to represent free-form edges of a part. It shall not be used to represent linear, circular, or conic edges of a part since more appropriate entities exist for these shapes.

308 This entity supports multiple instantiation of a defined collection of entities.

406 Form 15 Names. This entity is used to convey a name.

408 This entity defines the occurrence of a single instance of the defined subfigure (Type 308).

3.2.7.7.1 <u>Simplest entity</u>. In general, the simplest entity type shall be used to represent each piece of geometry, and zero size entities shall not be used. For instance, a B-spline curve shall not be used to represent a circular arc. A zero length line entity or a zero diameter circle shall not occur in the file.

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4. VERIFICATION

4.1 <u>Classification of inspections</u>. The inspection requirements specified herein are classified as follows:

a.   First article inspection (see 4.2).

b.   Conformance inspection (see 4.3).

4.2 <u>First article inspection</u>. This section is not applicable to this specification.

4.3 <u>Conformance inspection</u>. Conformance inspection is described in detail for each class.

4.3.1 <u>Class 1 - technical illustration subset</u>. Start, global, DE, PD, and terminate sections shall each be analyzed for conformance to the specified IGES version with an appropriate software utility. The start section shall be displayed and checked visually with requirements of 3.2.1.1.1. The global section shall be displayed and compared against the requirements of 3.2.1.1.2. Entities in the DE section shall be checked against table II by an appropriate software utility. Ranges of parameter values shall be compared against requirements of table II. A conforming MIL-PRF-28000 class 1 preprocessor shall translate native CAD file constructs into the appropriate class 1 entities. A conforming MIL-PRF-28000 class 1 postprocessor shall translate all MIL-PRF-28000 class 1 entities into the appropriate native CAD file constructs. For example, translating a circle into many straight-line segments would not be acceptable.

4.3.2 <u>Class 2 - engineering drawing subset</u>. Start, global, DE, PD, and terminate sections shall each be analyzed for conformance to the specified IGES version with an appropriate software utility. The start section shall be displayed and checked visually with requirements of 3.2.2.1.1. The global section shall be compared against the requirements of 3.2.2.1.2. Entities in the DE section shall be checked against table IV by an appropriate software utility. Ranges of parameter values shall be compared against requirements of table IV. A conforming MIL-PRF-28000 class 2 preprocessor shall translate native CAD file constructs into the appropriate class 2 entities. A conforming MIL-PRF-28000 class 2 postprocessor shall translate all MIL-PRF-28000 class 2 entities into the appropriate native CAD file constructs. For example, translating a circle into many straight-line segments would not be acceptable.

4.3.3 <u>Class 3 - electrical/electronic applications subset</u>. Not supported in this release of the specification.

4.3.4 <u>Class 4 - geometry for Numerical Control (NC) manufacturing subset</u>. Start, global, DE, PD, and terminate sections shall each be analyzed for conformance to the specified IGES version with an appropriate software utility. The start section shall be displayed and checked visually with requirements of 3.2.2.1.1. The global section shall be compared against the requirements of 3.2.4.1.2. Entities in the DE section shall be checked against table VI by an appropriate software utility. Ranges of parameter values shall be compared against requirements of table VI. A conforming MIL-PRF-28000 class 4 preprocessor shall translate native CAD file constructs into the appropriate class 4 entities. A conforming MIL-PRF-28000 class 4 postprocessor shall translate all MIL-PRF-28000 class 4 entities into the appropriate native CAD file constructs. For example, translating a circle into many straight-line segments would not be acceptable.

4.3.5 <u>Class 5 - 3D piping Application Protocol (AP)</u>. Start, global, DE, PD, and terminate sections shall each be analyzed for conformance to the requirements of ANS US PRO/IPO-110-1994 or subsequent version. Processors must completely support the functionality defined in ANS US PRO/IPO-110-1994 to claim conformance to this AP. An AP compliant preprocessor must convert each piping construct of the Application Reference Model (ARM) into the specified IGES constructs of the Application Interpreted Model (AIM), with the required attributes and values. An AP compliant postprocessor must convert each IGES construct of the AIM into native constructs which match the geometry, attributes, and relationships of the piping constructs specified in the ARM. The functionality of the piping constructs shall be preserved. (See the Implementation and Conformance Testing Guidelines section of ANS US PRO/IPO-110-1994.)

4.3.6 <u>Class 6 - Layered Electrical Product (LEP) Application Protocol (AP)</u>. Start, global, DE, PD, and terminate sections shall each be analyzed for conformance to the requirements of ANS US PRO/IPO-100-1996 or subsequent version. Processors must completely support the functionality defined in ANS US PRO/IPO-100-1996 to claim conformance to this AP. An AP compliant preprocessor must convert each electrical construct of the ARM into the specified IGES constructs of the AIM, with the required attributes and values. An AP compliant postprocessor must convert each IGES construct of the AIM into native constructs, which match the geometry, attributes, and relationships of the electrical constructs specified in the ARM. The functionality of the electrical constructs shall be preserved. (See the Implementation and Conformance Testing Guidelines section of ANS US PRO/IPO-111-1997.)

4.3.7 <u>Class 7 - 3D geometry subset</u>. Start, global, DE, PD, and terminate sections shall each be analyzed for conformance to the specified IGES version with an appropriate software utility. The start section shall be displayed and checked visually with requirements of 3.2.7.1.1. The global section shall be compared against the requirements of 3.2.7.1.2. Entities in the DE section shall be checked against table X by an appropriate software utility. Ranges of parameter values shall be compared against requirements of table X. A conforming MIL-PRF-28000 class 7 preprocessor shall translate native CAD file constructs into the appropriate class 7 entities. A conforming MIL-PRF-28000 class 7 postprocessor shall translate all MIL-PRF-28000 class 7 entities into the appropriate native CAD file constructs. For example, translating a circle into many straight-line segments would not be acceptable.

4.4 <u>Responsibility for inspection</u>. Unless otherwise specified in the contract or other form of agreement, the contractor is responsible for the performance of all inspection requirements (examinations and tests) in accordance with this specification. Except as otherwise specified in the contract or other form of agreement, the contractor may use his own or any other facilities appropriate for the performance of the inspection requirements herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.5 <u>Responsibility for compliance</u>. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling in quality conformance does not authorize submission of known

defective material, either indicated or actual, nor does it commit the Government to acceptance of defective material.

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5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When actual packaging of material is to be performed by DoD personnel, these personnel need to contact the responsible packaging activity to ascertain requisite packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activity within the Military Department or Defense Agency, or within the Military Department's System Command. Packaging data retrieval is available from the managing Military Department or Defense Agency's automated packaging files, CD-ROM products, or by contacting responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 <u>Intended use</u>. This specification is designed to be incorporated into a contract to define the technical requirements to be met when it is desired to purchase product definition data or product data in digital form. IGES is a specification for representing digital product definition data in a neutral, public domain format. IGES provides a neutral format for the representation and transfer of vector graphics data used for illustration purposes between CAD systems and application programs. Information is transferred by entities that represent geometry, annotation entity, attribute, and logical relationships of the product model. IGES files are composed of five sections: start, global, DE, PD, and terminate.

6.1.1 <u>Application subsets</u>. This specification defines the technical requirements for the exchange of digital product data in specific application subsets of IGES. The essential content and general requirements of application subsets are given by this specification and specific application subsets are identified. The definition of the class 5 3D Piping and class 6 LEP APs are identified by this specification. In particular the definition and use of the following specific application areas are defined:

      a.   Class 1 - technical illustration subset

      b.   Class 2 - engineering drawing subset

      c.   Class 3 - electrical/electronic applications subset (Withdrawn)

      d.   Class 4 - geometry for NC manufacturing subset

      e.   Class 5 - 3D piping application protocol (AP)

      f.   Class 6 – Layered Electrical Product (LEP) Application Protocol (AP

      g.   Class 7 - 3D geometry subset

6.1.2 <u>Application subsets or protocols in development</u>. No new IGES APs are planned. All future IGES APs will be continued in STEP.

6.1.3 <u>Application Protocol (AP)</u>. Assuring completeness of information exchange with the subset concept relies on a careful encoding of the information into the IGES entities. This specification used the subset concept as a first attempt at this encoding. A more rigorous method has been developed called an application protocol. It involves a formal information model with the rigorous mapping to the IGES entities; see ANS US PRO/IPO for further details.

6.2 <u>Acquisition requirements</u>. Acquisition documents must specify the following:

      a.   Title, number, and date of this specification.

b.   Issue of the DoDISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2).

c.   Packaging requirements (see 5.1).

d.   The type of product data being procured as class 1, class 2, class 4, class 5, class 6, or class 7 (see 1.2).

e.   The physical media to be used if not magnetic tape (see 3.1.4).

f.   For class 2, engineering drawings, specify:

   1.   One drawing per file with multiple sheets per file permitted (see 3.2.2.5).

   2.   One sheet per file (see 3.2.2.5).

6.3 Associated documents. Not applicable

6.4 File size and efficiency considerations. IGES files are often quite large, and implementers are urged to make use of the most efficient entity constructs.

6.4.1 Entity constructs. Several of the entity constructs included in the subset classes of this specification were selected to keep the file sizes to acceptable levels. For instance, the use of subfigures greatly reduces file size where details are repeated; however, more verbose entity constructs may be essential, such as stroking text characters to obtain special appearance like proportional spacing or using multiple line segments to provide a dotted line font.

6.4.2 Efficient constructs. Use of more efficient constructs like the dotted line font (classes 2, 3, and 4) or the intercharacter spacing property (class 1) for proportional text spacing is encouraged to reduce file sizes.

6.5 Summary of start section requirements. The start section of an IGES data file is used to contain human-readable notes to aid in interpreting the data in the file. This specification makes use of such capability, and requirements are stated in appropriate places in the class subset descriptions. Specifically, the following paragraphs reference notes to be placed in the start section:

   3.1
   3.2.1.1.1
   3.2.2.1.1
   3.2.4.1.1
   3.2.5.1.1
   3.2.6.1.1
   3.2.7.1.1

6.5.1 Format or appearance of notes. The format or appearance of the notes is not specified. However, for explanation a sample start section is shown in figure 1.

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	S 1
CONFORMANCE:	S 2
This IGES file conforms to the MIL-PRF-28000B	S 3
01 JAN 1998 Class 2 (Engineering Drawing)	S 4
	S 5
CREATED BY:	S 6
AJAX Inc.	S 7
100 Doe Street	S 8
San Diego CA 92110	S 9
	S 10
DATE: 01 JAN 1998	S 11
	S 12
CONTRACT NUMBER: None	S 13
	S 14
PART NAME: LBRACKET	S 15
	S 16
DRAWING NAME: LBRACKET	S 17
	S 18
DESCRIPTION:	S 19
Reference drawing name L-bracket which is comprised of all the IGES	S 20
structure entities (304-410) specified in MIL-PRF-28000 class 2.	S 21
	S 22
REVISION: C	S 23
	S 24
DRAWING SIZE and NUMBER: One C-size	S 25
	S 26
PART LEVEL SCHEME:	S 27
	S 28

LEVEL	ENTITY DESCRIPTION	MODE	
			S 29
			S 30
Default	definition entities	model	S 31
1	geometric entities	model	S 32
2	dimension entities	draw	S 33
3	other detailing	draw	S 34
4	subfigure entities	draw	S 35

FIGURE 1. Example of a start section.

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6.6 Additional processing conditions. Certain additional IGES file processing practices are preferred, but are not mandatory. Implementers should be aware of the following Recommended Practices (RP), from NISTIR 4600, IGES 5.0 Recommended Practices Guide, which further specify preferred processing algorithms. These include:

RP 2:	Witness Line Suppression
RP 4:	Transformation Matrix Processing
RP 7:	Maximum Coordinate Value
RP 8:	Independent Witness Lines
RP 15:	Zero Radius Arcs
RP 16:	Translation Vector
RP 17:	Model Space Scale
RP 19:	Independent and Dependent Processing
RP 21:	Comments in PD Records
RP 24:	Representation of Linear Strings
RP 26:	Arrowhead and Leader Line Data
RP 29:	Spline Curves and Surfaces
RP 32:	Arrow and Witness Pointers
RP 40:	Scale in Matrix
RP 43:	Closed Areas
RP 46:	Drafting Symbols
RP 52:	Drawing Entities That Contain No Views

6.7 Definitions.

6.7.1 Acronyms. Acronyms used in this specification are defined as follows:

a.	AIM	–	Application Interpreted Model
b.	AP	–	Application Protocol
c.	ARM	–	Application Reference Model
d.	ASCII	–	American Standard Code for Information Interchange
e.	ASME	–	American Society of Mechanical Engineers
f.	CAD	–	Computer Aided Design
g.	CALS	–	Continuous Acquisition and Life-Cycle Support
h.	CAM	–	Computer Aided Manufacturing
i.	DE	–	Directory Entry

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j.	DISA	–	Defense Information Systems Agency
k.	DoDISS	–	Department of Defense Index of Specifications and Standards
l.	FIPS	–	Federal Information Processing Standards
m.	IGES	–	Initial Graphics Exchange Specification
n.	IPO	–	IGES/PDES Organization
o.	LEP	–	Layered Electrical Product
p.	NC	–	Numerical Control
q.	NIST	–	National Institute of Standards and Technology
r.	NISTIR	–	NIST Internal Report
s.	PD	–	Parameter Data
t.	RP	–	Recommended Practices
u.	STEP	–	Standard for the Exchange of Product Model Data
v.	US PRO	–	United States Product Data Association

6.7.2 Annotation. Text or symbols, not part of the geometric model, which provide information.

6.7.3 Application Interpreted Model (AIM). An information model that describes the logical information structures required for accomplishing a physical implementation of an associated ARM. The AIM is prepared at a level of abstraction that is sufficient for selecting the necessary IGES entities for an application protocol.

6.7.4 Application Protocol (AP). Defines the context for the use of product data and specifies the use of the specification in that context to satisfy an industrial need.

6.7.5 Application Reference Model (ARM). An information model that describes the information structures and constraints for an application area. The information model uses application specific terminology and rules familiar to an expert from the application area.

6.7.6 Application subset. A set of specific IGES entities which are used to completely and unambiguously represent the information requirements of a product for a specified application.

6.7.7 Associativity. A structure entity which defines a logical link between different entities.

6.7.8 Attribute. Information which serves to qualify entity definition.

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6.7.9 <u>Directory Entry (DE) section</u>. A section of an IGES file consisting of fixed field data items for an index and attribute list of all entities in a file.

6.7.10 <u>Entity</u>. The basic unit of information in an IGES file. The term applies to single items which may be individual elements of geometry, collections of annotation entity to form dimensions, or collections of entities to form structured entities.

6.7.11 <u>Form number</u>. An integer which is used to further define a specific entity.

6.7.12 <u>Layered electrical product</u>. A generic term intended to include a variety of electrical products which are fabricated usually using alternate layers of conductive and non-conductive materials.

6.7.12 <u>Minimum complexity drawing</u>. A class 1 technical illustration.

6.7.13 <u>Parameter Data (PD) section</u>. A section of an IGES file consisting of specific geometric or annotative information about the entities or pointers to related entities.

6.7.14 <u>Postprocessor</u>. A program which translates a file of product definition data from the IGES format into the data base of a specific CAD/CAM system.

6.7.15 <u>Preprocessor</u>. A program which translates a file of product definition data from the data base of a specific CAD/CAM system into the IGES format.

6.7.16 <u>Product data</u>. All data elements necessary to define the geometry, the function, and the behavior of a piece part or an assembly of parts over its entire life span. The term includes all product definition data elements as well as additional logistics elements for reliability and maintainability.

6.7.17 <u>Product definition data</u>. Denotes the totality of data elements required to completely define a product. Product definition data includes geometry, topology, relationship, tolerances, attributes, and features necessary to completely define a component part or an assembly of parts for the purpose of design, analysis, manufacture, test, and inspection.

6.7.18 <u>Property entity</u>. A structure entity which allows numeric or text information to be related to other entities.

6.7.19 <u>Start section</u>. The section of an IGES file containing the human-readable file prologue.

6.7.20 <u>Wireframe</u>. A type of modeling that represents an object by its edges, forming an outline of the object in curve segments.

6.8 <u>Note on specification fonts</u>. As part of the CALS initiative to introduce the use of digital technology into the process of reviewing and coordinating specifications, this revision of the specification has been reformatted for improved readability as both a paper and an electronic document. The body text of this specification uses the same font as the previous revision, but slightly enlarged to give an improved on-screen appearance when displayed by a computer. The tables and figures now use a sans-serif font for a cleaner appearance and to be

distinguished easily from the body text. Computer code entries, values, and listings are shown in a font type so that they may be identified easily and with minimal confusion.

6.9 <u>Subject term (keyword) listing</u>.

     3D piping
     3D geometry
     Engineering drawings
     Electrical application
     IPO-100-1996
     Layered electrical product (LEP)
     Numerical control (NC)
     Piping
     Technical illustration
     Year 2000 compliance

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CONCLUDING MATERIAL

Custodians: Preparing Activity:
    Army – CR   DISA – DC3
    Navy – OM   (Project IPSC 0268)
    Air Force – 16

Review activities:
    OSD – DO, IR
    Army – AC, AC1, AL, AT, MI, PT, TM, TM1
    Navy – AS, CG, CH, EC, MC, ND, TD
    Air Force – 02, 11, 13, 19, 33, 93
    DLA – DH
    DIA – DI
    DISA – DC1, DC4
    NSA – NS
    NORAD & USSPACECOM – US
    Others – DOE, GPO, NCS, OST

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I RECOMMEND A CHANGE:	**1. DOCUMENT NUMBER** MIL-PRF-28000B	**2. DOCUMENT DATE** (YYYYMMDD) 19990930

3. DOCUMENT TITLE Digital Representation for Communication of Product Data: IGES Application Subsets and IGES Application Protocols

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON *(If applicable)*	**7. DATE SUBMITTED** (YYYYMMDD)

8. PREPARING ACTIVITY

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