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Product Data Exchange Specification
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CLASSIFICATION METHODS

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TITLE: Classification Methods

ABSTRACT:

This document presents two methods for classifying a STEP implementation; an implementation architecture view and an applications view. It incorporates material on implementation architectures (levels) and on application protocols.

KEY WORDS:

Application Protocols, Classification, Implementation Levels

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The technology embodied in this standard can be seen from two distinctly different viewpoints, from that of a user interested in a specific application use and from an implementer who is reducing the technology to software code to deal with exchange files or to implement a database. Each viewpoint has its own dimension, independent of the other, and is further segregated into finer categories. It is an enumeration of these viewpoint dimensions and categories that provides a taxonomy useful in understanding the planned utility of this standard.

Application Protocols

A basic objective of this standard is to achieve the successful transfer of the information required for a given application area. Information, be it in the form of a sentence or in the form of a digital product model, consists of syntax and semantics. The standard alone only defines the basic syntax and core semantics of the representation format.

In order to ensure complete and reliable information exchange, the application specific semantics and required functionality must also be documented and controlled. Application protocols are a formalized methodology for defining and controlling this semantic content.

The standard is designed to support a broad range of applications and information, and it is recognized that few software products will support all of the standard. Application protocols allow the definition of logical subsets of the standard and their usage, as well as providing necessary benchmarks for validating implementations. The exchange of information using an application protocol ensures that participating organizations agree on the types of information to be exchanged and employ corresponding information control procedures.

A protocol is a set of conventions or rules that govern the operation of functional units to achieve communication.[1] The key concept of application protocols is to explicitly link the application area's information content to the entities and data structures to be exchanged. The procedure for developing application protocols involves identifying the information requirements of an application area and documenting them in an information model. This application information model is then used to select the corresponding subschema of the standard for representing the required information.

An application protocol defines the information content of a specific application area, specifies the mapping of the application information into data constructs, and describes the restrictions and conventions required in implementing these constructs. The key components of an application protocol are:

1. An application reference model
2. The selected subschema of the standard
3. The mappings between the model and the subschema
4. An application protocol format specification with a protocol usage guide
5. A well defined testing methodology with a set of application protocol format test cases.

Implementation Architectures

In the current world of product data exchange, a variety of systems are able to communicate their data only through standards whose implementation is seen through some type of standard exchange format file. Naturally, each system is implemented in a fashion that is suitable for its computer environment and although there are a wide variety of computer environments, common architectural components are found. Significant benefits in the data exchange process can be realized if common implementation components, which were developed because of common computer environments, are recognized and exploited.

Therefore, the purpose of distinguishing levels is to improve data exchange by understanding various computer system architectures. Architectures can be understood by virtue of being compared against a common architecture. Once it is available, this information is meant to be used by system developers who are responsible for designing data exchange/sharing architectures. Those system developers can use that information to recognize "connect points" between different architectures which can then be bridged for more efficient and effective data exchange. In order to bridge those "connect points", standards must be established at those interfaces.

A first assumption is that a variety of implementations are derivable from the same conceptual schema. In this case, all implementations must be derived from the integrated product data model (IPDM) conceptual schema defined in Clause 4. A second assumption is that the implementation levels must not be mutually exclusive. That is, a level 1 implementation must have a well defined mapping into a level 2, 3, or 4 implementation. It would be unacceptable for a level (i) implementation to be isolated and unable to communicate with a level (i+1) implementation.

Current Approach

At this time, three standard interfaces are being investigated. They are:

Exchange Format File (included in this document)
Access Software (a standard software binding)
Query Language (a standard definition/manipulation language)

Eleven criteria have been proposed to be used in the refinement of each interface. They are listed below.

1. Can the implementation read / write to the standard exchange format file ?

2. Can the system generate / access the standard working form ?

3. What is the granularity of the accessable data in this implementation ?

    Can query on a single entity attribute
    Can query on multiple entity attributes
    Can query on a single entity
    Can query on multiple entities
    Can query on a single model
    Can query on multiple models

4. What standard forms of a data query are supported for this implementation ?

   No standard query form supported
   Standard function calls only
   Standard interactive DML only
   Standard batch DML only
   All standard forms of query

5. What standard forms of data query response are supported for this application ?

   No standard forms of data query response are supported
   Standard function's output parameters only
   Standard reply to a file
   Standard reply to an output device
   All standard forms of reply

6. What physical locations for the data can the implementation support ?

   In local computer memory
   On local computer disk
   On local and/or remote computers

7. What are the logical navigational capabilities of the implementation against the integrated product data model ?

   Hierarchical queries supported
   Network queries supported
   Relational queries supported
   Other ___________

8. What are the constraint checking capabilities of the implementation ?

   IF IT IS PERFORMED
      No constraint checking
      Some constraint checking
      All constraint checking
   WHAT
      Simple constraint checking
      Complex constraint checking
   HOW
      Performed by hard-coded function calls
      Performed by executing external directives
      Performed by other means
   WHEN
      Performed once when data is loaded into system
      Performed each time data is updated
      Performed each time data is used

9. What is the automation level of the data sharing process ?

   Not automated (i.e. manual only)
   Partially automated (e.g. automatic notification, some manual steps)
   Fully automated (updates occur automatically, always current data)

10. Can the implementation accept/use User-Defined data ?

    Cannot accept User-Defined data
    Can accept, store and retrieve for downstream processes but cannot use
    Can accept and use User-Defined data

11. What configuration control capabilities are supported ?

    No configuration controls provided
    Limited configuration controls available, if so, what kinds ?

The Current Working Definitions

Although not fully comprehensive, the following implementation level definitions are useful in classifying implementations of this standard.

LEVEL 1 FILE EXCHANGE

Product data is translated into or out of the standard exchange format file using non-standard software. The data in the exchange file is derived from the IPDM. The granularity of the data in the exchange file will range from the multi-model level to the entity level. No standard forms of query are defined for the product data when in this form. No standard navigational capabilities are defined for the product data when in this form. No standard validity constraint checks are defined for the product data when in this form. The automation level of the data sharing process is not defined when the product data is in this form.

LEVEL 2 WORKING FORM EXCHANGE

Product data is translated into or out of the standard working form. The product data in the working form is derived from the IPDM. The granularity of the data in the working form will range from the model level to the entity level. There must be a standard mapping of product data from the exchange format file form. Product data in the working form is accessed via standard access software function calls. The access software must support relational, network, or hierarchical types of queries against the product data. The access software has no database capabilities beyond data manipulation and navigational capabilities. The access software does not enforce validity constraints. The automation level of the data sharing process is not defined when the product data is in this form.

LEVEL 3 DATABASE EXCHANGE

Product data is translated into or out of a Database Management System (DBMS). The product data in the DBMS is derived from the IPDM. The granularity of the data in the DBMS will range from the multi-model level to the entity level. The DBMS must be accessable by standard exchange format files, standard access software function calls, or standard Data Manipulation Language statements. The DBMS must support relational, network, or hierarchical types of queries against the product data. The DBMS will not enforce validity constraints. The data sharing process is fully automated when the product data is in this form.

LEVEL 4 KNOWLEDGEBASE EXCHANGE

Product data is translated into or out of a Knowledgebase Management System (KBMS). The product data in the KBMS is derived from the IPDM. The granularity of the data in the KBMS will range from the multi-model level to the entity level. The KBMS must be accessable by standard exchange format files, standard access software function calls, or standard Data Manipulation Language statements. The KBMS must support relational, network, or hierarchical types of queries against the product data. The KBMS will enforce all of the validity constraints specified in the standard. The data sharing process is fully automated when the product data is in this form.

References

1. "ANSI/IEEE Standard 729-1983, Glossary of Software Engineering Terminology," Software Engineering Standards: The Institute of Electrical and Electronic Engineers, Inc., 1984.

INFORMATION MODELING LANGUAGE EXPRESS

DOCUMENT NUMBER: ANNEX A **VERSION:**

TITLE: Information Modeling Language EXPRESS

ABSTRACT:

This document has the same technical content as WG1 N268 but has been reprinted in LaTeX. The preface to N268 has been removed, page headings have been changed and minor changes to paragraph numbering have been made to conform to ISO document style.

KEY WORDS:

Data Definition Language, Grammar, Information Models, Language, Syntax, Universe of Discourse

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Annex A The Express Language

A.1 Introduction to Express

This section introduces the major concepts on which the *Express* language is based and explains the objectives and requirements established for an information modeling language.

A.1.1 Purpose

The goal of an information modeling endeavor is to precisely describe some subset of the world we know.

Express is a language that allows us to formulate a precise information specification in terms that people can understand, and that computers can directly employ.

A.1.2 Formal Languages

A language such as English is a means of communicating ideas. English can be written, spoken, or signed. Meaning is largely independent of the method of articulation, although some communication methods are more robust and precise than others.

Express is a specialized language used to communicate about a subset the knowledge we have about the world around us. This language allows us to say what we know about information that may be used by an information system.

Express provides the words, syntax, and grammar needed to describe a Universe of Discourse in a uniform, precise, and compact manner. English could be used for this purpose, but English (or any natural language) is anything but uniform, precise, or compact. A formal structured language is needed to restrict meanings in order that a high degree of common understanding can be achieved.

Express is not itself a methodology. A methodology is an orderly process that helps to accomplish some end objective. But *Express* is a formal language that could be used as part of a methodology aimed at creating an information model.

A.1.3 Objectives

The design of *Express* was guided by three basic objectives:

- to provide a lot of expressive power,
- to enable the separation of abstract and concrete ideas, and.
- to treat information units as general information resources.

A.1.4 Expressive Power

Producing an information model of a complex subject area like Product Data demands a lot of expressive power. The first objective of *Express* is to allow knowledgeable people to formally document their knowledge. That formal expression can then be used by a variety of people. The people that will read *Express* are likely to have varying degrees of understanding about the subject.

A.1.5 Separation of Abstract and Concrete Ideas

Every user will not have the same need for detail. Experts in a subject area will demand a greater degree of detail than those casually interested the subject. The separation of abstract from concrete views helps to tailor the specification to the needs of the user.

The separation of abstract and concrete concepts requires a different vocabulary. The vocabulary used to express abstract ideas is, by intention, vague. The vocabulary used to express concrete ideas is, by necessity, exact. For example, during the abstract stage we might say that the X component of a point is simply a number. The concrete view might be that X must be an integer number with nine digits of precision, or that it must be a real (floating point) number of some kind.

A.1.6 General Information Resource

An entity represents some idea that is important to the UoD being described. The context in which an entity is used should not alter its meaning, nor should the evolution of the information model over time.

The idea that an information object has to be a stable resource is of paramount importance to the orderly growth of this standard.

A.1.7 Requirements

Express is designed to satisfy the four basic requirements described below. Other requirements such as ease of use are addressed also, but are not discussed in detail in this document.

The four basic requirements are:

- modeling the things of interest,
- defining the constraints that are to be imposed upon those things,
- defining the operations in which those things participate, and
- modeling in a computer sensible manner.

A.1.8 Modeling of Things

An entity is something of interest. An entity represents an idea and is defined in terms of a set of attributes by which the idea is realized. The set of attributes that make up an entity often do not have a one to one correspondence to the physical record structures found in a database.

Abstraction separates the idea an entity represents from the set of attributes chosen to represent it. For example, point is an idea, and X, Y, Z are the names of the attributes commonly used to realize that idea. It is important to be able to deal with either the idea or the details that make up the idea separately and selectively. The term abstract is used for the idea that the entity represents. The term concrete is used for the details of which the entity is composed.

The abstract component provides a high level view of the schema. The most important information is raised to a level where it may be seen easily. The details of how those things are defined are hidden. At the abstract level the idea of a geometric line is important, not the particulars of how the line is defined. At the abstract level it is not even important that the line has a concrete definition.

The concrete component reveals the ingredients that make up the definition of an entity. At the concrete stage of the development of a schema it becomes important to fix on a set of attributes that define an entity.

Each attribute is made up of two components: a type and a name that describes the role that the type plays in the definition of an entity. For example, a number plays the role of the *X* component of a *Point* entity. A type is a realization of the role. At the abstract level these types have little or no meaning. However, at the concrete level, types are necessary to shape the choices made about how a particular entity is viewed by the enterprise. For example, at the abstract level, "circle" is self-evident. A circle is a plane curve everywhere equidistant from a given fixed point, its center. However, this definition is not very useful when the circle is processed by a computer. Choices must be made about the set of attributes necessary to realize this concept. Therefore, we might elect to use attributes named *Center*, *Axis*, and *Radius*, where *Center* is a point (type), *Axis* is a vector, and *Radius* is a floating point number.

A well chosen role name has an abstractive quality. The role name *Radius* is abstract. The fact that *Radius* is to be represented as a floating point number is concrete. At some stage in the development of a schema, a specific type must be associated with each attribute.

A.1.9 Modeling of Rules

A rule (constraint) stipulates a condition which must be true within a UoD. That is, it establishes a fact. A database is in a valid state when every rule is true.

Rules can be written to stipulate a variety of conditions:

- discrete values; e.g., radius cannot be less than zero.
- combinations of discrete values; e.g., June has no more than 30 days.

- uniqueness; e.g., every employee identification in a database must be different; no point can be the same as any other point in the definition of a spline.
- cardinality; e.g., for each spline there must be at least two, but not more than 30 control points; no edge can exist unless it is used in the definition of exactly two loops.
- a variety of different global constraints; e.g., the sum of the debits must equal the sum of the credits; there must be one registered nurse on duty for every eight occupied beds; the machine tool spindle direction must agree with the handedness of the cutter; etc.

A rule written as part of an entity declaration is called a local rule. Local rules apply only to the values of those attributes that exist within an entity instance or to values accessed through a defining relationship. Local rules can deal with single attributes or combinations of attributes.

A rule written as part of a schema is called a global rule. Global rules potentially deal with every instance of every type of entity to which the rule applies. For example, a global rule might say that at least one point must exist at the origin. An examination of the set of point instances might find an origin point right away, but it could be that every point in the set has to be examined to determine whether the rule is satisfied or not.

The rules described in an *Express* schema define a valid end state. The state of an Information System during a transition from one state to another is not addressed. Furthermore, a rule does not address the problem of recovering from a rule violation.

A.1.10 Modeling of Operations

An operation establishes how an entity may be employed within the Universe of Discourse (UoD). Operations on numbers such as addition, subtraction, multiplication, and division are universal. The set of operations that apply to numbers provide a framework for all who wish to employ mathematics. The same reasoning applies to geometric elements, bills of material, and other product data. Once a set of operations is defined for an entity, that knowledge becomes a valuable resource to those who wish to deal with product definition data in a uniform manner.

An operation often has a symbolic representation. Addition is usually written in infix notation as in:

```
number + number
```

The two numbers are the operands and the + symbol is the operator.

In computer programming languages, operations not accounted for symbolically are written as functions. For example, a square root operation is often implemented as a function. Functions are sometimes used instead of operations because keyboards do not have appropriate symbols.

Various programming languages implement the same operation in different ways. Pascal implements the modulo operation as the compound symbol MOD (X MOD Y) while PL/I implements the same operation as the built-in function MOD(X,Y). In either case, the built-in operations almost always permit generic inputs, i.e., either SQRT(10) or SQRT(10.0) or SQRT(1.E1) is permitted. The compiler recognizes the input type and invokes the appropriate algorithm.

Express allows operations to be written as functions. Generic types can be used to avoid the problem of developing a specific function for each permissible input type.

A.1.11 Computer Processable

The problem of constructing an information model of Product Data is too large to manage without computer assist. For this reason, the modeling language must be processable by a computer while still being usable by people. The effect of this requirement is that *Express* must be a structured language; computers cannot deal effectively with unstructured input such as natural language or graphics. Alternate forms of *Express* may be generated as a by-product of computer processing to aid human understanding. Some of these alternate forms of output could be syntactic and semantic analysis, graphics, a table of contents or index, an implementation data structure, or even a form of natural language.

A.1.12 Overview of the Elements of Express

The main descriptive elements of *Express* are:

```
Schema
   Type
   Entity
   Algorithm
      Function
      Procedure
   Rule
```

The schema is a description of a UoD and is composed of declarations of types, entities, functions and the like. The schema is roughly similar to a description of a database.

A type describes the characteristics of the data that is used to represent entities.

The entity describes the things of interest to a UoD. These elements are roughly similar to records that occur in a database.

Rules define the constraints on entities and attributes that must be enforced by the information system.

Functions, procedures, and rules are used to describe the behavior of things.

A.1.13 The Schema

A schema is a description of all of the things of interest to a UoD. The entities declared in a schema will later appear as record occurrences in a database (although not necessarily on a one-to-one basis). Rules and operations will exist as part of application programs or database management system

A.1.14 Types

A type is a representation of data. *Express* provides a number of built-in types as well as a facility for defining extensions to the built-in type set. These built-in types are grouped into the following categories: base types, aggregation types, entity types, function types, and enumeration types.

- base types are the stuff of which databases are built: real and integer numbers, logical (truth values), and (character) strings.
- aggregation types define collections of like things. They are the array type, list type, and set type.
- entity may be used as a data type.
- function may be used as a type to show how attributes may be derived from other attributes.
- enumeration type specifies, in order, all of its possible values of something by name.

A.1.15 Entity

An entity is an object, concept, or idea that has meaning to the UoD. It represents an information unit, which may be exchanged between users.

The name given to an entity should describe the role it plays within the UoD. An entity is defined by a set of attributes. The behavior of an entity is defined by a set of rules. Its purpose is defined by the operations performed on it.

An attribute is either a fact about an entity or the data from which facts may be derived. Each attributes has a name that is unique within the scope of an entity. The name (of the attribute) should describe the role the it plays in the definition of an entity. An attribute is defined in terms of a type. The type defines how the role is realized. The behavior of an attribute is defined by the characteristics of its type and any additional rules used to further constrain its behavior.

A.1.16 Algorithms - Function and Procedure

Algorithms are an integral part of a schema and are used to define the constraints that govern entities and attributes. The liberal use of algorithms in a schema contribute to the understanding of entities and their behavior.

An algorithm is a sequence of operations on data that produces an end state. The end state depends on whether the algorithm is a function, procedure, or rule.

- the function yields a type as a result,
- the procedure may operate on data in a variety of ways.
- the rule operates on the model as a whole, and signals any global inconsistencies in it.

A.1.17 Reference Manual

The Reference Manual explains how the elements of *Express* are used. Each element is presented in its own context with examples. Simple elements of *Express* are introduced first, and more complex ideas are presented in an incremental manner.

1. Character Set
2. Operators
3. Keywords
4. Identifiers
5. Literals
6. Directives
7. Types
8. Built-in Constants
9. Built-in Functions
10. Built-in Procedures
11. Statements and Blocks
12. Expressions

Note - See Part iii (the Syntax Specification) for a description of the notation used for the syntax examples in this section.

A.2 Character Set

The *Express* language is written as a string of characters which conform to certain rules. These characters, except for whitespace, are combined to form tokens. Tokens are called symbols, keywords, identifiers, or literals. The base character set used to write *Express* is:

A.2.1 Digits

The Arabic digits:

```
0 1 2 3 4 5 6 7 8 9
```

A.2.2 Letters

The lower and upper case letters of the English alphabet:

```
a b c d e f g h i j k l m n o p q r s t u v w x y z
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
```

A.2.3 Underscore

The underscore character can be used as a letter when forming identifiers, except the underscore cannot be used as the first character.

```
_
```

A.2.4 Special Characters

```
# ( ) * + , - . / : ; < = > [ ] _ { } |
```

A.2.5 Whitespace

Whitespace can be used to separate tokens and is often used to improve the structure and readability of the written language, i.e., to indent sections or leave blank lines. The liberal use of whitespace is encouraged.

A.2.5.1 Space Character

One or more blank spaces can appear between two tokens.

A.2.5.2 Tab Character

The tab character is treated as a space.

A.2.5.3 Newline

The newline marks the physical end of a source line. If the record is variable length, the newline is a sequence of non-printable characters. For fixed length records the newline is the physical end of the record. In either case, newline is treated as a space. Newline is significant only when it terminates a tail remark or abnormally terminates a string literal.

A.2.5.4 Remark

A remark is treated as whitespace. There are two forms of a remark. The embedded remark can be placed between any two tokens. The tail remark must be at the end of a line. In either case, a remark is treated as documentation and is not processed as part of the language.

A.2.5.4.1 Embedded Remark

The character pair '(*' denotes the start of an embedded remark and the character pair '*)' denotes its end. An embedded remark can appear between any two tokens.

Any character can be written between the start and end of a remark. Embedded remarks can span several physical lines.

Embedded remarks can be nested. For example, the following remark would be handled successfully.

```
(* The (* symbol starts a remark, and *) ends it *)
```

Example:

```
(* anything can go here *)
```

A.2.5.4.2 Tail Remark

The tail remark must be written at the end of a physical line. The '--' character pair starts the tail remark and a newline terminates it.
Example:

```
-- this is a remark that ends with a newline
```

A.3 Operators

Operators denote some action that is performed on an operand or a pair of operands.

*	multiplication
**	exponentiation
+	addition
-	subtraction, unary negation
/	division, real
<	less than
=	equal
>	greater than
<=	less than or equal
<>	not equal
>=	greater than or equal
:=	assignment
:=:	instance identity
:<>:	instance not identity
||	string concatenation
and	boolean and
div	division, integer
in	membership
like	string wildcard
mod	modulo (remainder after integer division)
not	logical negation
or	inclusive or
xor	exclusive or

The relationship *cardinality* operator produces a logical result given objects that participate in a relationship. It is not written as a single token.

Note – Some operators such as + are overloaded; i.e., the meaning of the operator depends on the operands and the operator. The + operator means addition when used with number operands, but it means inclusion when used with sets and set elements. The exact usage of operators is explained for each type.

A.4 Reserved Words

The reserved words of *Express* are either keywords or the names of built-in constants, functions, or procedures. None of the reserved words can be used as an identifier. The reserved words of *Express* are shown below. A reserved word can be written using any combination of upper and lower case letters.

Reserved Words

AGGREGATE	AND	ARRAY	AS
ASSUME	BEGIN	BY	CASE
DEFINE	DERIVE	DIV	DYNAMIC
ELSE	END	END_CASE	END_ENTITY
END_FUNCTION	END_IF	END_LOCAL	END_MAP
END_PROCEDURE	END_REPEAT	END_RULE	END_SCHEMA
END_TYPE	ENTITY	ENUMERATION	ESCAPE

EVERYTHING	EXCEPT	EXPORT	EXTERNAL
FOR	FROM	FUNCTION	GENERIC
IF	IN	INCLUDE	INTEGER
INTERNAL	LIKE	LIST	LOCAL
LOGICAL	MAP	MOD	NOT
NULL	NUMBER	OF	OPTIONAL
OR	OTHERWISE	PROCEDURE	REAL
REPEAT	RETURN	RETYPE	RULE
SCHEMA	SELECT	SET	SKIP
STRING	SUBTYPE	SUPERTYPE	THEN
TO	TYPE	UNIQUE	UNTIL
USES	VAR	VARYING	WHERE
WHILE	WITH	XOR	

Built-in Functions

ABS	ACOS	ASIN	ATAN
COS	EXISTS	EXP	HIBOUND
LOBOUND	LOG	LOG10	LOG2
ODD	SIN	SIZEOF	SQRT
TAN	TYPEOF	VALUE	

Built-in Procedures

INSERT	NULLIFY	VIOLATION	

Built-in Constants

#	FALSE	PI	TRUE
UNKNOWN			

Note – The "pound sign" character represents the notion of an indeterminate bound in an aggregate type.

A.5 Identifiers

Identifiers are names given to the elements being defined in a schema. An identifier must not be the same as an *Express* reserved word.

The first character of an identifier must be a letter. The remaining characters, if any, can be any combination of letters, digits, or the underscore character. Letters are not case sensitive as upper and lower case letters are treated as equal.

Identifiers have scope. An identifier can be declared only once within the same scope.

Sometimes it is necessary to "qualify" an identifier. This occurs when addressing an attribute of an entity or when specifying a particular array or list elements. The dot character is used to qualify attribute names. Array, List, and Set elements are specified by enclosing a numeric expression within square brackets.

Syntax

```
148 ID = ID-SIMPLE | ID-QUALIFIED .
152 ID-SIMPLE = LETTER { ID-CHAR } .
149 ID-CHAR = LETTER | DIGIT | UNDERSCORE .
151 ID-QUALIFIED = ID-INDEXED { DOT ID-INDEXED } .
150 ID-INDEXED = ID { SUBSCRIPT } .
```

Example:

Valid Identifiers

```
POINT     line      Circle     Rational_B_Spline
item406
```

Valid Qualified Identifiers

```
Point.x   Z[i*2]
```

Invalid Identifiers

```
_POINT              underscore can't be first character
line?               ? can't be part of identifier
3dcircle            digit can't be first character
schema              schema is an Express keyword
```

A.5.1 Simple Identifiers

A simple identifier is any identifier that has no qualification.

A.5.2 Qualified Identifiers

Qualified identifiers must be used when it is impossible to determine the scope of a simple identifier or when an element is subscripted as in an array.

Example:

```
x = x + y.c[37];    -- y.c[37] is a qualified identifier.
```

Note - See the Function Call, which can also be qualified.

A.5.3 Scope of Identifiers

A particular kind of object is created by a declaration of an identifier at some place in a schema. When that identifier is used again, it must be within the scope of its declaration.

The scope of an identifier is that part of the schema in which a reference to an identifier refers to the same object the declaration created. A scope encompasses its declaration to the end of the current block, including all blocks declared within the current block.

The blocks that establish a scope in this manner are:

1. Schema
2. Entity
3. Map
4. Function
5. Procedure
6. Rule

An identifier can be redeclared in another block. That is, the same name can be used in another context. In such a case, the identifier represents some entirely different thing and it should not be confused with any other like identifier. A given identifier cannot be redeclared within the same block however. For example, if there is an entity called *e1* in schema *s1*, the name *e1* cannot be redeclared in *s1* for any purpose.

An identifier cannot normally be seen outside its scope. The **Assume** directive can be used to overcome this restriction.

Example:

```
+- Universe - - - - - - - - - - - - - +
   Built-in Constants
|  Built-in Functions                 |
   Built-in Procedures
```

```
|  Built-in Types                   |
   +- Schema S1 -----------------+
|  |                             |  |
   |  +- Schema S2------------+  |
|  |  |                       |  |  |
   |  |  +- Entity E1 -----+  |  |
|  |  |  |                 |  |  |  |
   |  |  +-----------------+  |  |
|  |  |                       |  |  |
   |  +-----------------------+  |
|  |                             |  |
   |  +- Schema S3 -----------+  |
|  |  |                       |  |  |
   |  |  +- Entity E2 -----+  |  |
|  |  |  |  A2 : E1 ;      |  |  |  |  E1 cannot be seen from the
   |  |  +-----------------+  |  |     scope established by schema S3.
|  |  |                       |  |  |  Thus, this reference is illegal.
   |  +-----------------------+  |
|  |                             |  |
   +-----------------------------+
|                                   |
+- - - - - - - - - - - - - - - - - -+
```

The outermost schema (*S1*) exists within the "universe", which can be immagined as a schema that encloses every other schema. All of the built-in constants, types, functions, and procedures can be thought of as having been declared within the universe. As a consequence, those built-in elements can be referenced from anywhere.

Entity *e1* is declared in the scope established by Schema *s2* and entity *e2* is declared in the scope established by Schema *s3*. The attribute named *a2* in entity *e2* attempts to use *e1* as its type. That is illegal since *e1* is not in the scope of *s3*.

The **Assume** directive can be used to cross normal scope boundaries. Had Schema S3 contained the directive "Assume (S2);" the declarations in the scope of S2 could have been seen within S3.

A.6 Literals

A literal is a self defining constant value. The type of a literal depends on how characters are composed to form a token. The literals are integer, real, string, or logical.

A.6.1 Integer Literal

An integer literal is composed entirely of digits. It defines an integer (whole) number.

Syntax

```
155 INTEGER-LITERAL = DIGIT { DIGIT } .
```

Example:

```
4016
38
```

A.6.2 Real Literal

A real literal is composed of a mantissa and an optional exponent. It defines a fractional number.
Syntax

```
169 REAL-LITERAL = INTEGER-LITERAL DOT [ INTEGER-LITERAL ] [ 'E' [ SIGN ]
    INTEGER-LITERAL ] .
```

Example:

```
1.e6
3.5e-5
359.62
```

Illegal Real Literal

```
.001    At least one digit must precede the decimal point
1e10    A decimal point must be part of the literal
```

A.6.3 String Literal

A string literal is a sequence of characters enclosed by quote marks (apostrophes). If a quote mark is itself part of the string, two consecutive quote marks must be written. A string literal cannot span a physical line.
Syntax

```
176 STRING-LITERAL = \Q { \A | ( \Q \Q ) } \Q .
```

Note – \a represents any character except a newline; \q represents a quote mark.
Example:

```
'Baby needs a new pair of shoes!'
  Reads ... Baby needs a new pair of shoes!

'Ed''s Computer Store'
  Reads ... Ed's Computer Store
```

Illegal String Literal

```
'Ed's Computer Store'
  There must always be an even number of quote marks.
```

A.6.4 Logical Literal

A logical literal is any of the words 'True', 'False', or 'Unknown'.
Syntax

```
160 LOGICAL-LITERAL = TRUE | FALSE | UNKNOWN .
```

Example:

```
x := true;
y := false;
z := unknown;
```

A.7 Directives

The compiler directives allow the schema writer to control the behavior of the compiler that processes an *Express* source file. The **Assume** directive is used to override normal scoping rules. **Define** directives allow identifiers to stand for a substitution string. The **Export** directive allows a schema to control what may or may not be seen outside its scope. **Include** directives allow separate source to be combined into a single logical file. The **Uses** directive allows individual declarations in some other schema to be used as if they are part of another schema.

A.7.1 Assume Directive

Description:

The **Assume** directive is used to gain access to declarations that are not normally known via ordinary scoping rules. The directive specifies one or more schema names. When an identifier reference is unresolved, an attempt will be made to resolve that identifier in the schemas mentioned by the Assume directive.

Note that the author of a schema can use the **Export** directive to prevent other schemas from using an identifier, even when the other schema uses the **Assume** directive.
Syntax

```
184 ASSUME-DIRECTIVE = ASSUME LEFT-PAREN SCHEMA-ID { COMMA SCHEMA-ID }
    RIGHT-PAREN SEMICOLON .
```

Example:

See the example given in 6.3. (Export Directive).

Restrictions:

- The ASSUME directive must appear before any identifier references that require the assumed schemas to resolve those identifiers.

A.7.2 Define Directive

Description:

A lexical constant is created by the Define directive. It equates an identifier to a sequence of characters which must be enclosed by quotes. Whenever this lexical constant identifier is encountered, the sequence of characters equated to it are substituted in its place. The substitution can consist of zero or more characters.
Syntax

```
193 DEFINE-DIRECTIVE = DEFINE DEFINED-TYPE-ID STRING-LITERAL SEMICOLON .
```

Example:

```
DEFINE muchprecision 'REAL(30)';
```

Whenever the identifier muchprecision is seen in the source file the character string REAL(30) is substituted for it. The enclosing quotes are not part of the substitution and the substitution can consist of zero or more characters. Thus if the following line appeared in the schema:

```
x : muchprecision ;
```

the line would be interpreted as:

```
x :  REAL(30) ;
```

A substitution string can contain other defined lexical constants as in:

```
DEFINE a '30';
DEFINE b 'real(a)';
```

then

```
x : b;
```

yields:

```
x : real(30);
```

Restrictions:

- A Define directive must appear before a reference to a reference to the identifier.
- Circular defines are prohibited. If substitution string A references identifier B, then substitution string B cannot reference identifier A either directly or indirectly.

A.7.3 Export Directive

Description:

The Export directive is used to allow access to objects declared within a schema. If a schema does not supply an Export directive, nothing can be exported; i.e., seen outside its scope.

Syntax

```
46 EXPORT = 'EXPORT' .
```

Restrictions:

1. Indirect declarations cannot be exported. For example, a function declared within a function cannot be exported in this manner.

Example:

The following example shows how the Export and Assume directives work together. The schema called main encompasses two inner schemas: inside1 and inside2. Some of the declarations in inside1 are private and others are public (exported). Declarations in inside2 reference entities declared in inside1.

```
SCHEMA MAIN;
  ENTITY X;        <------------------------+
  END_ENTITY;                               |
  SCHEMA INSIDE1;                           |
    EXPORT (I11, I12);                      |
    ENTITY I11; <---------------+           |
    END_ENTITY.                 |           |
    ENTITY I12;                 |           |
    END_ENTITY.                 |           |
    ENTITY I13; <--------+      |           |
    END_ENTITY.          |      |           |
  END_SCHEMA;            |      |           |
    SCHEMA INSIDE2;          |         |        |
      ASSUME (INSIDE1);      |         |        |
      ENTITY I21;            |         |        |
        A : X;    (1)-------------------------+
      END_ENTITY;            |         |
      ENTITY I22;            |         |
        A : I13;  (2)-----+            |
      END_ENTITY;                      |
      ENTITY I23;                      |
        A : I11;  (3)------------------+
      END_ENTITY;
    END_SCHEMA;
  END_SCHEMA;
```

- The reference to (entity) X is resolved according to normal scoping rules.
- The reference to (entity) I13 is ILLEGAL! Even though I13 is declared within INSIDE1, which is assumed, I13 was not marked as exportable; i.e., it is private.
- The reference to (entity) I11 is resolved correctly. INSIDE1 is assumed and I13 was marked as exported.

A.7.4 Include Directive

Description:

A schema can be made up of several separate source files. These files can be composed into a single logical source file by the use of the **Include** directive. Whenever the **Include** directive is encountered, the file specified is processed just as if it were physically present in the file in which the **Include** appears. **Includes** can be nested to the depth permitted by the operating system environment. The form of the file name specification is also dependent on the operating system.

Syntax

```
216 INCLUDE-DIRECTIVE = INCLUDE STRING-LITERAL SEMICOLON .
```

Example:

```
SCHEMA abc;
  INCLUDE 'part1.dat';
  INCLUDE 'part2.dat';
END_SCHEMA;
```

The schema named abc is composed of three separate files: the schema itself and the files named part1.dat and part2.dat.

Restrictions:

- Circular includes are prohibited. If file A includes file B, then file B must not include file A either directly or indirectly.
- The file name is operating system dependent.

A.7.5 Uses Directive

Description:

The Uses directive creates an exact logical copy of the objects listed. In effect, those objects become part of the current schema. The main use of the Uses directive is to define *application subset* schemas.

Syntax

```
265 USES-DIRECTIVE = USES NESTED-ID-LIST SEMICOLON .
```

Restrictions:

- A schema cannot appear as an identifier in a Uses directive.

Example:

An application subset schema defines several entities unique to it, and also brings in several other entities declared elsewhere. The Uses directive is required since none of the declarations within the application subset reference those entities either directly or indirectly.

```
SCHEMA MAIN;
  -- A THRU G ARE DECLARED HERE.
  SCHEMA APPLICATION_SUBSET;
    USES (A, B, C, D, E, F, G);
    ENTITY H;
    END_ENTITY;
    ENTITY J;
    END_ENTITY;
    ...
  END_SCHEMA;
END_SCHEMA;
```

The schema named application_subset declares the entities H and J. It also needs to treat entities A through G as if they were part of the schema. When an implementation of the application_subset is developed, it needs only to account for the entities defined in the application subset schema, and entities defined elsewhere but referenced from it. The Uses directive creates a logical declaration of entities of interest.

A.8 Types

Types are used to associate a data representation with an attribute, local variable, or formal parameter.

Syntax

```
type
  = base-type
  | aggregation-type
  | entity-type
  | defined-type
  | number-type
  | enumeration-type
  | select-type
  | generic-type
  .
```

A.8.1 Base Types

Description

The base types represent the data values that can be held in an information system of some kind. Tracing a path through the schema will eventually end with one of these base types. The base types are Real Integer String and Logical.

Syntax

```
186 BASE-TYPE = INTEGER-TYPE | LOGICAL-TYPE | NUMBER-TYPE | REAL-TYPE
    | STRING-TYPE .
220 INTEGER-TYPE = INTEGER [ PRECISION-SPEC ] .
233 PRECISION-SPEC = LEFT-PAREN EXPRESSION RIGHT-PAREN .
227 LOGICAL-TYPE = LOGICAL .
231 NUMBER-TYPE = NUMBER .
237 REAL-TYPE = REAL [ PRECISION-SPEC ] .
252 STRING-TYPE = STRING [ PRECISION-SPEC ] [ VARYING ] .
```

A.8.1.1 Integer Type

Description

An Integer type represents a whole number. You can optionally specify the maximum number of decimal digits. If the number of decimal digits is given, there is an implicit constraint on the value. For example, the specification "INTEGER(3)" would constrain a value to -999...999 inclusive. The value of the integer number is unconstrained if no precision specification is given.

The number of decimal digits specified suggests the storage allocation needed to hold a value of that type; e.g., if a signed binary two's complement internal representation is used, the formula *b=(precision/0.30103)* yields the approximate number of bits needed.

Syntax

```
220 INTEGER-TYPE = INTEGER [ PRECISION-SPEC ] .
233 PRECISION-SPEC = LEFT-PAREN EXPRESSION RIGHT-PAREN .
```

Rules and Restrictions:

- *expression* must yield a numeric result that is non-zero and non-negative.
- A real result is truncated to an integer.

Example:

This example associates an integer type with the attribute named AGE_IN_YEARS. The value of the integer is totally unconstrained.

```
ENTITY PERSON;
  AGE_IN_YEARS : INTEGER;
  ...
END_ENTITY;
```

Operations on Integer Types:

form	op	description
unary	+	no effect
unary	-	negates the operand
binary	+	forms the sum of the operands
binary	-	forms the difference of the operands
binary	*	forms the product of the operands
binary	/	converts operands to real and forms real quotient
binary	div	forms integer quotient
binary	mod	forms integer modulus
binary	**	raises op1 to the power op2
binary	=	compares for equality
binary	<>	compares for inequality
binary	<	compares for less than
binary	<=	compares for less than or equal
binary	>	compares for greater than
binary	>=	compares for greater than or equal

A.8.1.2 Real Type

Description

A **Real** type represents a normalized fractional number. A real is sometimes called a float, a floating point number, or scientific notation. It has an inexact resolution. The number of significant decimal digits can optionally be specified. The precision of the real number is unconstrained if no precision specification is given.

The number of decimal digits specified suggests the storage allocation needed to hold a value of that type; e.g., if a signed binary two's complement internal representation is used, the formula *b=(precision/0.30103)* yields the approximate number of bits needed for the mantissa. It also suggests the maximum number of digits that are transmitted in the physical file.

Syntax

```
237 REAL-TYPE = REAL [ PRECISION-SPEC ] .
233 PRECISION-SPEC = LEFT-PAREN EXPRESSION RIGHT-PAREN .
```

Rules and Restrictions:

- *expression* must yield a numeric result that is non-zero and non-negative.
- A real result is truncated to an integer.

Example:

This example shows the effect of defining the number of decimal digits in the fraction part of a real number; i.e, it's precision.

```
LOCAL
  DISTANCE   : REAL(6);
  X1, Y1, Z1 : REAL;
  X2, Y2, Z2 : REAL;
END_LOCAL;
  ...
  X1 := 0; Y1 := 0; Z1 := 0;
  X2 := 10; Y2 := 11; Z2 := 12;
  ...
  DISTANCE := SQRT((X2-X1)**2 + (Y2-Y1)**2 + (Z2-Z1)**2);
```

DISTANCE is computed to a value of 1.9104973...e+1 but has an actual value of 1.91050e+1 since the specification calls for six digits of precision; thus, only six normalized digits of precision are retained.

Rounding is performed as follows: given *p* which is the precision, the digit at *p+1* is examined. If that digit is five or more, one is added to the digit *p*.

When two real numbers are compared, the one with the smaller precision is zero extended to match the longer specification. For example, given:

```
    A : REAL(3) := 1.23E0;
    B : REAL(5) := 1.2300E0;
the expression {\tt (a=b)} will be true.
```

Operations on Real Types:

form	op	description
unary	+	no effect
unary	-	negates the operand
binary	+	forms the sum of the operands
binary	-	forms the difference of the operands
binary	*	forms the product of the operands
binary	/	forms real quotient
binary	div	converts operands to integer and forms integer quotient
binary	mod	converts operands to integer and forms integer modulus
binary	**	raises op1 to the power op2
binary	=	compares for equality
binary	<>	compares for inequality
binary	<	compares for less than
binary	<=	compares for less than or equal
binary	>	compares for greater than
binary	>=	compares for greater than or equal

Normalization

A non-zero real number is normalized in the following manner. Reading from left to right, find the first significant (i.e., non-zero) digit. Then adjust the decimal point so that it lies just to the right of the significant digit. Count the number of places the decimal point moved and the direction it moved. If it moved to the right, subtract one from the exponent for each position; if it moved to the left, add to the exponent.

Example:

0.0	0.0
0.000001e11	1.0e5
00017800000.e0	1.78e+7

A.8.1.3 Logical Type

Description

A Logical type represents a True/False value. Unknown is a third logic state which can be used when the state of a logical value is neither True nor False.
The following conditions hold for logical types:

```
False <  Unknown < True
```

Syntax

```
227 LOGICAL-TYPE = LOGICAL .
```

Example:

This example associates a logical type with an attribute named FLAG. FLAG can only hold the values True and False.

```
ENTITY SOMETHING;
  FLAG : LOGICAL;
  ...
END_ENTITY;
```

Operations on Logical Types:

form	op	description
unary	not	reverses the state of the operand
binary	and	returns true if both operands are true
binary	or	returns true if either operand is true
binary	xor	returns true if one of the operand is true
binary	=	compares for equality
binary	<>	compares for inequality
binary	<	compares for less than
binary	<=	compares for less than or equal
binary	>	compares for greater than
binary	>=	compares for greater than or equal

Truth Tables

AND	T	?	F
T	T	?	F

OR	T	?	F
T	T	T	T

NOT	
T	F

```
   +---+---+---+     +---+---+---+    +---+---+
 ? | ? | ? | F |   ? | T | ? | ? |    | ? | ? |
   +---+---+---+     +---+---+---+    +---+---+
 F | F | F | F |   F | T | ? | F |    | F | T |
   +---+---+---+     +---+---+---+    +---+---+
```

A.8.1.4 String Type

Description

A String type represents a sequence of zero or more characters. The character set and collating sequence is defined by ISO 6937/2.

Characters and symbols not defined by that standard can be represented as an "escape" sequence. The escape sequence is defined in normative Annex B, the Physical File Structure Language. An example of an escape sequence is given below.

The maximum number of characters in a string can be specified. If no such specification is given, the maximum length of the string is unlimited.

The **varying** property indicates that the string is allowed to grow and shrink in apparent size. The absence of the **varying** property indicates that the string is always exactly the specified size.

Syntax

```
252 STRING-TYPE = STRING [ PRECISION-SPEC ] [ VARYING ] .
233 PRECISION-SPEC = LEFT-PAREN EXPRESSION RIGHT-PAREN .
```

Rules and Restrictions:

- *expression* must yield a numeric result that is non-zero and non-negative.
- A real result is truncated to an integer.

Example:

The following four examples show the effect of the different specification elements of a string.

```
STRING1 : STRING;
```

This defines an abstract string. It cannot be implemented without making assumptions about its maximum length.

```
STRING2 : STRING(10);
```

This defines a string that is always ten characters in length; i.e., all ten positions are assumed to hold a character of some kind.

```
STRING3 : STRING VARYING;
```

This defines an abstract string. It cannot be implemented without making assumptions about its maximum length.

```
STRING4 : STRING(10) VARYING;
```

This defines a string that can hold zero to ten characters.

Escape Sequence Example:

```
letters := '|greek:01, 02, 03|ABC|math5:01, 02, 03|';
```

The string in this example has nine characters and uses characters from three character sets. The first three come from the Greek character set, the next three come from the (default) ISO 6937/2 set, and the last three come from a math character set. The numbers (01, 02, etc.) refer to a specific character in the designated character set.

Operations on String Types:

form	op	description
binary	||	concatenates the operands
binary	=	compares for equality
binary	<>	compares for inequality
binary	<	compares for less than
binary	<=	compares for less than or equal
binary	>	compares for greater than
binary	>=	compares for greater than or equal
binary	like	returns true if the left operand matches the template, which is the right operand

Components of a string variable can be addressed by a subscript. For example, the seventh character of a string called "name" could be examined by

```
IF NAME[7]='S' THEN
  ...
```

String comparison

To compare two strings, compare the first (leftmost) pair of characters, then the pair at the second position, etc. until an unequal pair is found, or until all character pairs have been examined. If an unequal pair is found, the string containing the lesser character (as defined by the ISO 6937/2 collating sequence) is considered less than the other string. When all pairs are equal, the two strings are equal.

When two strings are not the same length, the shorter string is blank extended until the lengths of the two strings are the same.

Implementations that do not use the ISO 6937/2 collating sequence must yield a string comparison result that is the same as an implementation that does.

A.8.2 Aggregation Types

Description

Aggregation types are used to represent ordered or unordered collections of like things. These collections can have fixed or varying sizes. Aggregation types are called **Aggregate, Array List and Set.**

Syntax

```
181 AGGREGATION-TYPE = AGGREGATE-TYPE | ARRAY-TYPE | LIST-TYPE | SET-TYPE .
180 AGGREGATE-TYPE = AGGREGATE LIMIT-SPEC OF [ UNIQUE ] ATTRIBUTE-CAN-BE .
222 LIMIT-SPEC = LEFT-BRACKET EXPRESSION COLON ( EXPRESSION | INFINITY )
    RIGHT-BRACKET .
182 ARRAY-TYPE = ARRAY INDEX-SPEC OF [ OPTIONAL ] [ UNIQUE ]
    ATTRIBUTE-CAN-BE .
218 INDEX-SPEC = LEFT-BRACKET EXPRESSION COLON EXPRESSION RIGHT-BRACKET .
223 LIST-TYPE = LIST LIMIT-SPEC OF [ UNIQUE ] ATTRIBUTE-CAN-BE .
247 SET-TYPE = SET [ LIMIT-SPEC ] OF ATTRIBUTE-CAN-BE .
```

A.8.2.1 Aggregate Type

Description

An Aggregate type is a generalization of any aggregation type; i.e., an Array, List, or Set. An aggregate type can be used only as a formal parameter of a function or procedure, or as the result of a function.

When a procedure or function is invoked, an actual parameter is passed. That actual parameter must be either an Array, List, or Set. The operations that can be performed then depend on the type of the actual parameter.

Syntax

```
180 AGGREGATE-TYPE = AGGREGATE LIMIT-SPEC OF [ UNIQUE ] ATTRIBUTE-CAN-BE .
222 LIMIT-SPEC = LEFT-BRACKET EXPRESSION COLON ( EXPRESSION | INFINITY )
    RIGHT-BRACKET .
```

Rules and Restrictions:

- Both expressions must yield a number result.

- A real result is truncated to an integer.
- Expression1 is the lower bound of the array.
- Expression2 is the upper bound of the array.
- The lower bound must be less than or equal to the upper bound.
- The Optional specification indicates that the array instance can be sparse; i.e., all of the elements are not always populated.
- The Unique specification indicates that each populated element of an array must be different than all other populated elements.

Example:

This example shows how a multi-dimensioned array is declared.

```
sectors : ARRAY [ 1 : 10 ] OF ARRAY [ 11 : 14 ] OF e;
```

The first array has 10 elements of type ARRAY[11:14] OF e. There are 40 elements total in the attribute named sectors. There is no restriction on the number of dimensions of an array.

Operations on Array Types:

form	op	description
binary	=	compares for equality
binary	<>	compares for inequality

A.8.2.2 List Type

Description

A **List** type represents an ordered collection of like elements. The number of elements of a list can vary from one occurrence to another. A list specifies the minimum number of elements that must be present and the maximum number of elements that can be present. The minimum bound of a list must never be less than zero and the maximum bound can be either exact or indefinite. The number of elements in a list can vary between the minimum and maximum bounds (inclusive).

The **SizeOf** built-in function can be used to determine the number of elements in a list.

Syntax

```
223 LIST-TYPE = LIST LIMIT-SPEC OF [ UNIQUE ] ATTRIBUTE-CAN-BE .
222 LIMIT-SPEC = LEFT-BRACKET EXPRESSION COLON ( EXPRESSION | INFINITY )
    RIGHT-BRACKET .
```

Rules and Restrictions:

1. Both expressions must yield a number result.
2. A real result is truncated to an integer.
3. Expression1 is the minimum number of elements that must be in a list.
4. Expression2 is the maximum number of elements that can be in a list. The alternate # specification states that the size of the list is unconstrained.
5. The lower bound must be less than or equal to the upper bound and it must be non-negative.
6. The Unique specification indicates that each element of a list must be different than all other elements. The effect of using unique in the declaration of a list is to define an ordered set.

Example:

This example defines a list of arrays. The list can contain zero to ten arrays. Each array must be different from all other arrays in the list.

```
ComplexList : LIST[0:10] OF UNIQUE ARRAY[1:10] OF INTEGER;
```

There are zero, 10, 20, ..., 100 integer values associated with the attribute named ComplexList depending on the number of list elements. Each array must be different than every other array as specified by the Unique qualifier.

Operations on List Types:

form	op	description
binary	=	compares for equality
binary	<>	compares for inequality
binary	in	returns true if the first operand (an element of the list) is in the list
binary	+	L+E adds E to end of list E+L adds E to front of list L+L combines the two lists (concatenation)

L represents a list; E represents an element of that list.

The INSERT built-in procedure is used to insert elements into a list.

A.8.2.3 Set Type

Description

A Set type represents an unordered collection of like elements. The number of elements in a set can be constrained, but that is not necessary; it can be empty or contain any number of elements. No two elements of a set can have the same value however.

Syntax

```
 247 SET-TYPE = SET [ LIMIT-SPEC ] OF ATTRIBUTE-CAN-BE .
 222 LIMIT-SPEC = LEFT-BRACKET EXPRESSION COLON ( EXPRESSION | INFINITY ) RIGHT-BRA
.
```

Rules and Restrictions:

- Both expressions must yield a number result.
- A real result is truncated to an integer.
- Expression1 is the minimum number of elements that must be in a set.
- Expression2 is the maximum number of elements that can be in a set. The alternate # specification states that the size of the set is unconstrained.
- The lower bound must be less than or equal to the upper bound and it must be non-negative.

Example:

This example defines an attribute as a set of points (an entity type).

```
ABunchOfPoints : Set Of Point;
```

The attribute named ABunchOfPoints can contain zero or more points. Each point instance (in the set instance) must be different than every other point in the set.

If a set requires at least one (or more) element, the specification can provide a lower bound.

```
ABunchOfPoints : Set [1:#] Of Point;
```

The attribute named ABunchOfPoints now must contain at least one point. Each point instance (in the set instance) must be different than every other point in the set.

Operations on Set Types:

form	op	description

binary	=	compares for equality
binary	<>	compares for inequality
binary	in	returns true if the first operand (an element of the set) is in the set (E in S)
binary	+	S+S is union
binary	+	S+E adds E to S
binary	-	S-S is difference
binary	-	S-E removes E from S
binary	*	S*S is intersection
binary	<=	returns true when S1 is a subset of S2
binary	>=	returns true when S2 is a subset of S1

S represents a set; E represents an element of that set.

A.8.3 Entity Type

Description

Any Entity declared in a schema can be used as the type of an attribute, local variable, or parameter.

Syntax

```
200 ENTITY-TYPE = ENTITY-ID .
```

Rules and Restrictions:

1. An entity type cannot be used in a defined type.

Example:

This example uses a Point entity as the type of an attribute.

```
ENTITY POINT;
  X, Y, Z : REAL;
END_ENTITY;

ENTITY LINE;
  P0, P1 : POINT;
END_ENTITY;
```

The line entity has two attributes named P0 and P1. The type of each of those attributes is [entity] Point. In this case the value of each Point is mandatory. Thus, a line cannot exist without those two points.

Relationships in Express

Every attribute establishes a relationship between an entity and some object. That object can be a terminal or a non-terminal object. A terminal object is anything such as an integer number that we think of as irreducible. The base types of *Express* are terminal objects. An entity is a non-terminal object. The nature of the relationship does not depend on whether the object is terminal or non-terminal.

Given an entity *E* an attribute *A* and the type of the attribute *T* a relationship can be diagrammed as:

```
E.A ---[m:n]-------[p:q]---> T
```

The relationship can be explained in English as: " *T* plays the role of *A* in the definition of *E* ". For example, for *E=Line A=Start* and *T=Point* the interpretation is: " *Point* plays the role of *Start* in the definition of *Line* ".

m and *n* define the number of *T's* needed for each *E.A* ; *p* and *q* define the number of *E's* needed for each *T* .

The value of *m* and *n* is specified by array, list, or set or the absence of one of those aggregates. A specification such as

```
A : B;
```

means that *m=n=1* while the specification

```
A : ARRAY[1:90] OF B;
```

translates to *m=1:n=90.*

The value of *p* and *q* depends on whether the relationship is internal or external. An internal relationship always yields *p=q=1*; i.e., for every *T* there must be exactly one *E*. An external relationship always yields *p=0:q=#*; i.e., for every *T* there can be zero or more *E's*. Since dynamic means either internal or external, the values of *p* and *q* depend on whether *T* is actually internal or external in an entity instance.

In a system of instances (as in a database) we may find that a constraint has to be put on *p* and *q*. In other words, *p=0:q=#* is unacceptable. The cardinality relational operator can be used to state that constraint. The cardinality relational operator looks like

```
T {\em [ p' : q' ]} E.A
```

which means that the actual number of *E.A 's* for a given *T* (*k*) must satisfy

```
{ p' <= k <= q' } .
```

We have not redefined p and q, but have constrained k in some context of use.

Operations on Entity Types:

form	op	description
binary	=	compares for equality
binary	<>	compares for inequality
binary	:=:	compares for instance equality
binary	:<>:	compares for instance inequality

A.8.4 Defined Type

Description

A Defined type is a user extension to the set of built-in types. Defined types must be declared in a Type block. Once declared, a defined type can be used as any other type.

Enumeration and Select types can be defined only as a defined type.

Syntax

```
194 DEFINED-TYPE = DEFINED-TYPE-ID .
```

Rules and Restrictions:

1. A defined type must be declared in a **Type...End_Type** block.
2. An **Entity** type can not be used as a defined type.

Example:

Several types are defined below to indicate the units of measure associated with certain kinds of attributes.

```
TYPE
  AREA          = REAL;
  MAGNITUDE     = REAL;
  VOLUME        = REAL;
  MASS          = REAL;
  ...
END_TYPE;
  ...
ENTITY PART;
  ...
  WEIGHT : MASS;
END_ENTITY;
```

The WEIGHT attribute is represented as a real number, but the use of the defined type, MASS, helps to clarify the meaning and context of the real number; it means mass, not volume or area for instance.

Operations on Defined Types:

The operations applicable to defined types depends on the base type; e.g., if the base type is real, only the operation set for real types can be used. Note however that assignment of dissimilar user defined types is restricted; e.g., if *VA* is a variable of type *A* and *VB* is a variable of type *B* then the statement *VA := VB;* is illegal.

A.8.5 Number Type

Description

A Number is an abstraction of Real or Integer types. Generally speaking, a number type is used in an "abstract" sense when an exact representation does not matter, or as the specification of a generic number parameter of a function or procedure.

Syntax

```
231 NUMBER-TYPE = NUMBER .
```

Example:

The following example shows a generic numeric addition function that accepts any number as actual parameters and returns the appropriate kind of numeric result. An integer is returned if both inputs are integers; a real result is returned for mixed arithmetic. This function does no error checking.

```
FUNCTION ADD(A,B:NUMBER):NUMBER;
  LOCAL
    RI : INTEGER; -- INTEGER RESULT
    RR : REAL;    -- REAL RESULT
  END_LOCAL;
  CASE TYPEOF(A) OF
    INTEGER : CASE TYPEOF(B) OF
                INTEGER : BEGIN; RI := A+B; RETURN(RI); END;
                REAL    : BEGIN; RR := A+B; RETURN(RR); END;
              END_CASE;
    REAL    : CASE TYPEOF(B) OF
                INTEGER : BEGIN; RR := A+B; RETURN(RR); END;
                REAL    : BEGIN; RR := A+B; RETURN(RR); END;
              END_CASE;
  END_CASE;
END_FUNCTION;
```

Operations on Number Types:

form	op	description
unary	+	no effect
unary	-	negates the operand
binary	+	forms the sum of the operands
binary	-	forms the difference of the operands
binary	*	forms the product of the operands

binary	/	forms real quotient
binary	div	converts operands to integer and forms integer quotient
binary	mod	converts operands to integer and forms integer modulus
binary	**	raises op1 to the power op2
binary	=	compares for equality
binary	<>	compares for inequality
binary	<	compares for less than
binary	<=	compares for less than or equal
binary	>	compares for greater than
binary	>=	compares for greater than or equal

A.8.6 Enumeration Type

Description

An **Enumeration** is an ordered set of values represented by names. Note that the enumeration type can only be used as a defined type.

Each enumeration item exists at the same scope as the type of the enumeration itself. Thus, given the example below, the identifiers colors, red, blue, and green all exist at the same lexical scope.

Syntax

```
201 ENUMERATION-TYPE = ENUMERATION OF NESTED-ID-LIST .
```

Rules and Restrictions:

1. Each identifier declared as an enumerated item becomes a unique identifier in the current scope.
2. Each enumerated item has a value that is dependent on its position in the list. The value of the first item is less than the second; the second is less than the third, etc. The specific value is not relevant.

Example:

This example shows an enumeration of colors.

```
COLORS = ENUMERATION OF (RED, BLUE, GREEN);

(* RED < BLUE, BLUE < GREEN *)
```

Operations on Enumeration Types

form	op	description
binary	=	compares for equality
binary	<>	compares for inequality
binary	<	compares for less than
binary	<=	compares for less than or equal
binary	>	compares for greater than
binary	>=	compares for greater than or equal

A.8.7 Select

Type
Description

A Select type is used when a choice must be made among a number of possible entity types.

Syntax

```
245 SELECT-TYPE = SELECT NESTED-ID-LIST .
```

Rules and Restrictions

1. Each identifier in the selection list must be an entity identifier or a select type.

Example

A choice must be made among several dissimilar things in a given context.

```
TYPE
  ArbitraryChoice = SELECT(NAIL, SCREW, GLUE);
END_TYPE
  ...
  AttachmentMethod : ArbitraryChoice;
```

An AttachmentMethod can be any of the entities named NAIL, SCREW, or GLUE.
Operations on Select Types

No operations are defined for the select type.

A.8.8 Generic Type

Description

A Generic type is used to represent any type. The purpose of the generic type is to enable the writing of generic functions and procedures.

Syntax

```
213 GENERIC-TYPE = GENERIC }\\
```

Rules and Restrictions

1. A generic type can only be used as a parameter type in a function or procedure formal parameter list or as the result type of a function.

Example:

This example shows a generic function that adds numbers or vectors. It is an elaboration of the example given above in 7.1.1.

```
FUNCTION ADD(A,B:GENERIC):GENERIC;
  LOCAL
    RI : INTEGER; -- INTEGER RESULT
    RR : REAL;    -- REAL RESULT
    RV : VECTOR;  -- VECTOR RESULT
  END_LOCAL;
  CASE TYPEOF(A) OF
    INTEGER : CASE TYPEOF(B) OF
                INTEGER : BEGIN; RI := A+B; RETURN(RI); END;
                REAL    : BEGIN; RR := A+B; RETURN(RR); END;
              END_CASE;
    REAL    : CASE TYPEOF(B) OF
                INTEGER : BEGIN; RR := A+B; RETURN(RR); END;
                REAL    : BEGIN; RR := A+B; RETURN(RR); END;
             END_CASE;
    VECTOR  : IF TYPEOF(B)=VECTOR THEN
                RV.I := A.I+B.I;
                RV.J := A.J+B.J;
                RV.K := A.K+B.K;
                RETURN(RV);
              END_IF;
  END_CASE;
END_FUNCTION;
```

Operations on Generic Types:

No operations are defined for generic types. You must first determine the actual type (by the TypeOf built-in function) and then use the appropriate operation set for that type.

A.9 Built-in Constants

The built-in constants are assumed to have *exact* values, even though an exact value may not exist in the real world; e.g., *pi* is assumed to be exact.

A.9.1 Infinity

The infinity symbol (#) stands for an indeterminate upper bound of a LIST or SET.

A.9.2 False

False is the opposite of True; see below.

A.9.3 Pi

Pi is the number 3.14159.... It is assumed that this number is exact.

A.9.4 True

True False and Unknown together make up a ternary logic system in which False is NOT True and Unknown is neither True nor False.

A.9.5 Unknown

Unknown is a logic state which indicates that the value is neither True nor False.

A.9.6 Built-in Functions

All functions (and mathematical operations in general) are assumed to yield exact results. Functions that operate on angles express angular measurement in terms of radians.

A.9.7 Abs - Arithmetic Function

```
FUNCTION ABS ( V:NUMBER ) : NUMBER;
```

The Abs function finds the absolute value of *V* and returns the result (integer or real depending on the type of the input) to the point of invocation.

Example:

```
ABS ( -10 )  --> 10
```

A.9.8 ACos - Arithmetic Function

```
FUNCTION ACOS ( V:NUMBER ) : REAL;
```

The ACos function finds the arc-cosine of *V* and returns a real in radians to the point of invocation.

Example:

```
ACOS ( 0.3 )  --> 1.266103...
```

A.9.9 ASin - Arithmetic Function

```
FUNCTION ASIN ( V:NUMBER ) : REAL;
```

The ASin function finds the arc-sine of *V* and returns a real result in radians to the point of invocation.
Example:

```
ASIN ( 0.3 )  --> 3.04692...e-1
```

A.9.10 ATan - Arithmetic Function

```
FUNCTION ATAN ( V1:NUMBER [ ; V2:NUMBER ] ) : REAL;
```

The ATan function finds the arctangent of *V* and returns a real result in radians to the point of invocation.

```
ATAN ( v1 [, v2] )
```

The argument *v1* must always be specified; the argument *v2* is optional. If *v2* is omitted, *v1* represents the value whose arctangent is to be found. If *v2* is specified, the value whose arctangent is to be found is taken to be the expression *v1/v2* and in the case where *v2* is zero the result is *pi/2* or *-pi/2* depending on the sign of *v1*.
Example:

```
ATAN ( 0 )           -->  0.0
ATAN ( x, y )
ATAN ( -5.5, 3.0 )  --> -1.071449...
```

A.9.11 Cos - Arithmetic Function

```
FUNCTION COS ( V:NUMBER ) : REAL;
```

The Cos function finds the cosine of *V* expressed in radians and returns a real result to the point of invocation.
Example:

```
COS ( 0.5 )  --> 8.77582...E-1
```

A.9.12 Exists - General Function

```
FUNCTION EXISTS ( V ) : LOGICAL;
```

The Exists function accepts any variable and returns True if a value exists for that parameter, or False when no value exists for it. Note that only attributes declared with the Optional keyword can ever have a missing value.
Example:

```
if EXISTS ( a )  then
   ...
```

A.9.13 Exp - Arithmetic Function

```
FUNCTION EXP ( V:NUMBER ) : REAL;
```

The **Exp** function raises e (the base of the natural logarithm system) to the power *V* and returns a real to the point of invocation.
Example:

```
EXP ( 10 )  --> 2.202646...E+4
```

A.9.14 HiBound - Arithmetic Function

```
FUNCTION HIBOUND ( V ) : INTEGER;
```

The **HiBound** function returns the actual upper bound of an Array, List, or Set. The result depends on the type of the actual parameter *V*. If the actual parameter is:

Actual Parameter Type	Result
Array	the declared upper bound of the array
List	the number of elements actually in the list.
Set	the number of elements actually in the set.
any non-aggregate	1 (one).

Example:

```
LOCAL
  A : ARRAY[-3:19] OF SET OF LIST[0:#] OF INTEGER;
  H1, H2, H3 : INTEGER;
END_LOCAL;

  A[-3][1][1] := 2;
  H1 := HIBOUND(A);          -- =19 (UPPER BOUND OF ARRAY)
  H2 := HIBOUND(A[-3]);      -- =1 (SIZE OF SET)
  H3 := HIBOUND(A[-3][1]);   -- =1 (SIZE OF LIST)
```

A.9.15 LoBound - Arithmetic Function

```
FUNCTION LOBOUND ( V ) : INTEGER;
```

The **LoBound** function returns the actual lower bound of an Array, List, or Set. The result depends on the type of the actual parameter *V*. If the actual parameter is:

Actual Parameter Type	Result
Array	the declared lower bound of the array
List	0 (zero) if the list is empty; otherwise 1 (one).
Set	0 (zero) if the set is empty; otherwise 1 (one).
any non-aggregate	1 (one).

Example:

```
LOCAL
  A : ARRAY[-3:19] OF SET OF LIST[0:#] OF INTEGER;
  H1, H2, H3 : INTEGER;
END_LOCAL;

  H1 := LOBOUND(A);          -- =-3 (LOWER BOUND OF ARRAY)
  H2 := LOBOUND(A[-3]);      -- =0 (SIZE OF SET)
  H3 := LOBOUND(A[-3][1]);   -- =0 (SIZE OF LIST)
```

A.9.16 Log - Arithmetic Function

```
FUNCTION LOG ( V:NUMBER ) : REAL;
```

The **Log** function finds the natural logarithm of *V* and returns a real result to the point of invocation.

Example:

```
LOG ( 4.5 )  --> 1.504077...E0
```

A.9.17 Log2 - Arithmetic Function

```
FUNCTION LOG2 ( V:NUMBER ) : REAL;
```

The **Log2** function finds the base 2 logarithm of *V* and returns a real result to the point of invocation.

Example:

```
Log2 ( 8 )  --> 3
```

A.9.18 Log10 - Arithmetic Function

```
FUNCTION LOG10 ( V:NUMBER ) : REAL;
```

The **Log10** function finds the base ten logarithm of *V* and returns a real to the point of invocation.

Example:

```
LOG10 ( 10 )  --> 1.00...E0
```

A.9.19 Odd - Arithmetic Function

```
FUNCTION ODD ( V:INTEGER ) : LOGICAL;
```

The **Odd** function accepts any integer value *V* and returns **True** if the number is odd; i.e., -3, -1, 1, 3, 5 ...
Example:

```
ODD ( 121 )  --> TRUE
```

A.9.20 Sin - Arithmetic Function

```
FUNCTION SIN ( V:NUMBER ) : REAL;
```

The **Sin** function finds the sine of *V* expressed in radians and returns a real result to the point of invocation.
Example:

```
SIN ( pi )  --> 0.0
```

A.9.21 SizeOf - Aggregate Function

```
FUNCTION SIZEOF ( V:AGGREGATE ) : INTEGER;
```

The SizeOf function accepts any aggregate type and returns the number of elements in it.

The returned value for an **Array** will be its declared number of elements.

The returned value for a **List** will be the number of occupied elements.

The returned value for a Set will be the number of actual elements.
Example:

```
LOCAL
  N : NUMBER;
  X : LIST[1:#] OF Y;
  ...
  N = SIZEOF ( X ) ;
```

A.9.22 Sqrt - Arithmetic Function

```
FUNCTION SQRT ( V:NUMBER ) : REAL;
```

The Sqrt function finds the square root of the non-negative numeric value *V* and returns a real result to the point of invocation.
Example:

```
SQRT ( 121 )  --> 11
```

A.9.23 Tan - Arithmetic Function

```
FUNCTION TAN ( V:NUMBER ) : REAL;
```

The Tan function finds the tangent of *V* and returns a real to the point of invocation.
Example:

```
TAN ( 0.0 )  --> 0.0
```

A.9.24 TypeOf - General Function

```
FUNCTION TYPEOF ( V ) : SET OF TYPE;
```

The TypeOf function accepts any variable *V* and returns a set containing its type. When *V* is an entity subtype the set contains the type of the entity itself and each of its supertype entity types, etc. until there are no more supertype entity types.
Example:

```
if TYPEOF ( a ) =point THEN
  ...
```

A.9.25 Value - Arithmetic Function

```
FUNCTION VALUE ( V:STRING ) : NUMBER;
```

The Value function converts a string variable or string literal to its numeric equivalent and returns the result to the point of invocation. The type of the result matches the type of the input string. If the string cannot be converted to a number, the returned value is zero.
Example:

```
VALUE ( '1.234' )   --> 1.234       (REAL)
VALUE ( '20' )      --> 20          (INTEGER)
```

A.10 Built-in Procedures

A.10.1 Insert - List Procedure

```
PROCEDURE INSERT ( VAR L:LIST; E; P:NUMBER ) ;
```

The Insert procedure is used to insert an element compatible with a list variable into that list variable. *L* is a list, *E* is an element compatible with the type of *L* and *P* is a number indicating where *E* is inserted into the list. The value of *P* must satisfy:

```
{ 0 <= P <= SizeOf(L) }
```

E is inserted after the list element indicated by *P*. For example, when *P=0 E* becomes the first element in the list.

A.10.2 Nullify - General Procedure

```
PROCEDURE NULLIFY ( VAR V ) ;
```

The **Nullify** procedure accepts a variable of any type and nullifies its value. Nullification means causing a value associated with an attribute to cease to exist. That is, the attribute no longer has a value after nullification. Attempts to nullify an attribute not declared as optional has no effect on its value.

A.10.3 Violation - General Procedure

```
PROCEDURE VIOLATION ;
```

The **Violation** procedure raises an exception. This procedure can be invoked inside a rule to indicate that some global constraint has been violated. Other than having the ability to indicate that an exceptional condition exists, *Express* provides no mechanism for recovering from it.

A.11 Statements and Blocks

A statement is a sequence of tokens that conform to the grammar of *Express*. Most statements are terminated by the semicolon character. There are a few exceptions to this rule. For example, the **TYPE** statement which starts a type definition block is not terminated with a semicolon.

Certain sequences of statements are called blocks. All of the statements that make up a block are treated logically as a single statement. There are two kinds of blocks: declaration blocks and execution blocks. The declaration blocks are the **Schema Entity Map Type** and **Local** blocks. **Functions procedures,** and **rules** are called execution blocks.

The outermost block must be a **Schema** block. A schema contains all declarations including possibly other schemas.

Some blocks establish a scope over which identifiers must be unique. Every identifier declaration within those blocks must be unique. The type block is a pseudo-block; it does not spawn a new identifier scope. For example, the names of the attributes of an entity are unique to the entity block in which they are declared. The same attribute identifier could be used in another entity since each entity establishes its own scope.

Examples

```
SCHEMA example; -------------------------+
                                         |
  ENTITY entity1; ----+                  |  this is a block
    a : integer;      | this is a block  |
    b : integer;      | inside a block   |
  END_ENTITY; --------+                  |
                                         |
  ENTITY entity2; ----+                  |
    a : entity1;      | this is a block  |
    b : integer;      | inside a block   |
  END_ENTITY; --------+                  |
                                         |
END_SCHEMA; -----------------------------+
```

A.11.1 Schema

Description

A **Schema** contains all of the declarations needed to describe some problem area. A schema can declare types, rules, entities, functions, procedures, and even other schemas. It can also contain directives and remarks as needed.

In general, a declaration does not have to precede references to it. Position is important for two directives. A **Define** directive must appear before a reference to the replacement symbol it declares. Likewise, an **Assume** directive must be given prior to any references that would be resolved in one of the assumed schemas.

Syntax

```
244 SCHEMA-DECL = SCHEMA SCHEMA-ID SEMICOLON { BLOCK-MEMBER }
    END-SCHEMA SEMICOLON .
187 BLOCK-MEMBER = ENTITY-DECL | MAP-DECL | FUNCTION-DECL | PROCEDURE-DECL
    | RULE-DECL | SCHEMA-DECL | TYPE-DECL | DIRECTIVE .
197 DIRECTIVE = ASSUME-DIRECTIVE | DEFINE-DIRECTIVE | EXPORT-DIRECTIVE
    | INCLUDE-DIRECTIVE | USES-DIRECTIVE .
184 ASSUME-DIRECTIVE = ASSUME LEFT-PAREN SCHEMA-ID { COMMA SCHEMA-ID }
    RIGHT-PAREN SEMICOLON .
193 DEFINE-DIRECTIVE = DEFINE DEFINED-TYPE-ID STRING-LITERAL SEMICOLON .
205 EXPORT-DIRECTIVE = EXPORT ( NESTED-ID-LIST | EVERYTHING
    | EVERYTHING EXCEPT NESTED-ID-LIST ) SEMICOLON .
216 INCLUDE-DIRECTIVE = INCLUDE STRING-LITERAL SEMICOLON .
265 USES-DIRECTIVE = USES NESTED-ID-LIST SEMICOLON .
```

A.11.2 Type Declarations

Description

Any user defined types must be declared in a Type block. Each defined type is a unique type that is not assignment compatible with other built-in or user defined types. This is true even if the underlying types are the same.

Syntax

```
261 TYPE-DECL = TYPE TYPE-ITEM { TYPE-ITEM } END-TYPE SEMICOLON .
```

Examples

```
TYPE
  MASS   = REAL ;
  VOLUME = REAL ;
END_TYPE ;
```

Whenever MASS or VOLUME is used as a data type, a REAL is used to store the value of a variable. MASS and VOLUME are incompatible types however. That is, it is illegal to assign a variable of type MASS to a variable of type VOLUME.

A.11.3 Entity

Description

A **Entity** declaration creates an entity type. The entity type represents some thing, concept, event, etc. that is important to a schema. An entity instance is an occurrence of an entity type as in a database. The word entity used alone means *entity type*. Whenever an entity occurrence is intended the words *entity instance* will be used.

An entity is defined in terms of a set of attributes. Explicit attributes represent the data one would expect to find in a database. Derived attributes represent information that can be computed as needed from other attributes. Derived attributes are declared following the *Derive* keyword.

Uniqueness constraints are specified following the *Unique* keyword. Uniqueness can be specified for individual attributes or combinations of attributes.

It is often necessary to define a number of constraints that apply to the explicit attributes, either individually or in combination with one another. These constraints are defined following the *Where* keyword.

The combination of explicit attributes, derived attributes, and constraints is often sufficient to fully define the intended characteristics of an entity. On occasion however, a more complex constraint is needed to fully define the behavior of an entity. See the section titled *Rule* for more information on this subject.

Syntax

```
199 ENTITY-DECL = ENTITY ENTITY-ID [ SUBSUPER-DECL ] SEMICOLON
    [ EXPLICIT-ATTRIBUTE-DECL ] [ DERIVED-ATTRIBUTE-DECL ]
    [ UNIQUE-RULE ] [ WHERE-RULE ] END-ENTITY SEMICOLON .
204 EXPLICIT-ATTRIBUTE-DECL = EXPLICIT-ATTRIBUTE { EXPLICIT-ATTRIBUTE } .
203 EXPLICIT-ATTRIBUTE = ID-LIST COLON [ OPTIONAL ] [ EXTERNAL | INTERNAL
    | DYNAMIC ] ATTRIBUTE-CAN-BE SEMICOLON .
196 DERIVED-ATTRIBUTE-DECL = DERIVE DERIVED-ATTRIBUTE { DERIVED-ATTRIBUTE } .
195 DERIVED-ATTRIBUTE = ATTRIBUTE-ID COLON RESULT-CAN-BE INITIALIZER
    SEMICOLON .
219 INITIALIZER = ASSIGNMENT-OPERATOR EXPRESSION .
263 UNIQUE-RULE = UNIQUE { ID-LIST SEMICOLON } .
266 WHERE-RULE = WHERE { EXPRESSION SEMICOLON } .
```

A.11.3.1 Supertypes and Subtypes

Description

An Entity SubType is a kind or variety of the entity that is its supertype. All of the subtype entities that share the same supertype have certain characteristics in common. These common characteristics may be material; i.e., the attributes of the supertype entity are implicitly part of each subtype entity. In some cases entities that share a common supertype may share no attributes, but are still constructed as subtypes because they are widely understood to be related entities.

Syntax

```
 254 SUBSUPER-DECL = SUBTYPE-DECL [ SUPERTYPE-DECL ] | SUPERTYPE-DECL
     [ SUBTYPE-DECL ] .
```

An **Entity SuperType** must mention those entities that are its subtypes. Likewise, an entity that is a subtype must mention each of its supertypes. The relationship between a supertype entity and its subtypes can be inclusion (*and*) or exclusion (*or* or *xor*) . If a subtype entity has more than one supertype entity, the relationship is always inclusion (this means that the existence of a subtype depends on the existence of all of its supertypes).

Examples

Assume entities named *A*, *B*, *C*, *D*, *E*, and *F*. Entities *B*, *C*, and *D* are subtypes of entity *A*. Entities *D* and *F* are subtypes of entity *E*. If we assume exclusion in all cases, the entity headers for each entity would look like:

```
ENTITY A SUPERTYPE OF (B xor C xor D);
ENTITY B SUBTYPE   OF (A);
ENTITY C SUBTYPE   OF (A);
ENTITY D SUBTYPE   OF (A, E);
ENTITY E SUPERTYPE OF (D xor F);
ENTITY F SUBTYPE   OF (E);
```

```
        A        E
      / | \    /   \
    /   |   \ /      \
B       C    D         F
```

The dependency relationships that can exist for this configuration are:

Given an instance of:	There must also exist:
A	B xor C xor D
B	A
C	A
D	A and E
E	D xor F
F	E

An instance of a subtype entity demands the existence of each of its supertypes.

If a supertype entity has an attribute, that attribute is implicitly known to each of its subtypes. Thus, if the entity *A* above had an attribute called *a*, the entities *B*, *C*, and *D* also have the very same *a* attribute. This means that entity *E* cannot also have an attribute called *a* since entity *D* would have no way of distinguishing between the two attributes.

The form of the supertype declaration can specify both inclusion and exclusion. For example, the entity header:

```
ENTITY X SUPERTYPE OF ((P xor Q) and R);
```

says that entity X is at the same time a supertype of either entities P and R, or Q and R.

You can also indicate that a supertype entity might have no subtype as in:

```
ENTITY X SUPERTYPE OF (A xor B xor NULL);
```

Meaning that entity *X* is a supertype of *A* or *B* or nothing at all. Note that the *and* operator cannot be used with *NULL*.

A.11.3.2 Attribute

An entity is defined in terms of a set of attributes, which are the entity's essential traits, qualities, or properties. Attributes can be explicit data or the value can be derived.

A.11.3.2.1 Explicit Attribute

Description

An explicit attribute represents actual data that one might expect to find in a database implementation.

Syntax

```
204 EXPLICIT-ATTRIBUTE-DECL = EXPLICIT-ATTRIBUTE { EXPLICIT-ATTRIBUTE } .
203 EXPLICIT-ATTRIBUTE = ID-LIST COLON [ OPTIONAL ] [ EXTERNAL
    | INTERNAL | DYNAMIC ] ATTRIBUTE-CAN-BE SEMICOLON .
```

Several attributes that are alike in all respects can be declared together as in:

```
ENTITY point ;
  x, y, z : real ;
END_ENTITY ;
```

which is equivalent to:

```
ENTITY point ;
  x : real ;
  y : real ;
  z : real ;
END_ENTITY ;
```

Optional indicates that an attribute does not have to have a value.

An explicit attribute can be both **Optional** and **Unique** at the same time (see "Uniqueness Rule" below). When an attribute is declared as both **Optional** and **Unique** and the value in an instance is missing, that value is exempt from the uniqueness test. If neither of these keywords are given, the attribute value is mandatory (not optional) and not unique.

External Internal and **Dynamic** can be used alone or in combination with the **Optional** or **Unique** keywords. These keywords specify the kind of ownership the entity has over attribute values. If none of these keywords are used, **Dynamic** is assumed.

External says that the attribute value exists outside the scope of the entity, and potentially can be shared by several entities.

Internal says that the attribute value exists within the scope of the entity, and cannot be shared by any other entity.

Dynamic says that the attribute can exist within an entity instance sometimes and outside it at other times.

A.11.3.2.2 Derived Attribute

Description

A derived attribute represents information that is computed in some manner. Derived attributes must be declared following the **Derive** keyword. Each derived attribute must be specified individually. The type of the attribute follows the colon as in an explicit attribute declaration; then the derivation is given as an expression. All of the parameters used in the expression must be literals or explicit or derived attributes of the entity being declared.

Syntax

```
196 DERIVED-ATTRIBUTE-DECL = DERIVE DERIVED-ATTRIBUTE { DERIVED-ATTRIBUTE } .
195 DERIVED-ATTRIBUTE = ATTRIBUTE-ID COLON RESULT-CAN-BE INITIALIZER
    SEMICOLON .
219 INITIALIZER = ASSIGNMENT-OPERATOR EXPRESSION .
```

Examples

In the following example a circle is defined by three points through which it passes. These three points represent the data by which the circle is defined. In addition to these data there is a need to account for important traits such as the radius, or the axis. This is accomplished by defining them as derived attributes, giving the value as an expression.

```
FUNCTION f1(p1,p2,p3:point):real ;
  (* Compute RADIUS of circle given three points on circumference *)
```

```
END_FUNCTION

FUNCTION f2(p1,p2,p3:point):vector ;
  (* Compute AXIS of circle given three points on circumference *)
END_FUNCTION ;

ENTITY circle ;
  p1, p2, p3 : point ;
DERIVE
  radius : real   := f1(p1,p2,p3) ;
  axis   : vector := f2(p1,p2,p3) ;
  area   : real   := pi*radius**2 ;
END_ENTITY ;
```

The three defining points (P1, P2, and P3) are explicit attributes. *Radius*, *Axis*, and *Area* are derived information. The values of these derived attributes are computed by the expression following the assignment operator. The values of *Radius* and *Axis* are obtained by means of a function call; the value of *Area* is computed in-line. Note that the type given after the colon must be assignment compatible with the result produced by the expression.

A.11.3.3 Uniqueness Rule

Description

A uniqueness constraint can be given for individual explicit attributes or combinations of them by means of a **Unique** rule. The uniqueness rules follow the **Unique** keyword. Each rule lists the attribute names whose values must be unique. When such a list has two or more attribute names, the values are *jointly unique*.

If an entity had three attributes called A, B, and C, we could have:

```
UNIQUE
  A;
  B;
  C;
```

which means that the uniqueness constraint applies to each of the attributes individually. Or we could have:

```
UNIQUE
  A,B;
  B;
  C;
```

This means that the uniqueness constraint applies jointly to A and B together, and also to B and C individually.

Examples

A person_name entity might look like:

```
ENTITY PERSON_NAME;
  LAST     : STRING;
  FIRST    : STRING;
  MIDDLE   : STRING;
  NICKNAME : STRING;
END_ENTITY;
```

and it might be used as:

```
ENTITY EMPLOYEE;
  BADGE : NUMBER;
  NAME  : PERSON_NAME;
  ...
UNIQUE
  BADGE, NAME;
  ...
END_ENTITY;
```

and as:

```
ENTITY ROSTER;
  NAME : LIST[0:#] OF PERSON_NAME;
  ...
END_ENTITY;
```

The uniqueness constraint is not stated within the person_name entity since it is not clear that names always have to be different. The roster entity does not insist that names are different. In the case of an employee, however, there is a requirement for unique identification. The example shows that BADGE and NAME together have to be unique. This allows the value of BADGE in one employee entity instance to be the same as another instance; likewise for the value of NAME. The two values taken together have to be unique however.

Uniqueness spans some collection of entity instances. That collection could reasonably be called a database. So, within a given database, the attribute, or set of attributes, or combination of attributes must be distinctly different throughout.

A.11.3.4 Local Rule

Description

Local rules are used to specify conditions that constrain the value of individual attributes or a combinations of attributes. All local rules must follow the Where keyword.

Syntax

```
266 WHERE-RULE = WHERE { EXPRESSION SEMICOLON } .
```

Each expression must yield a logical (**True** or **False**) result. The variables used in the expressions must be the names of attributes that are declared for this entity.

For example, a unit_vector requires that the length of the vector be exactly one. This constraint can be specified by:

```
ENTITY unit_vector ;
  a, b, c : real ;
WHERE
  a**2 + b**2 + c**2 = 1.0 ;
END_ENTITY ;
```

Local rules deal with optional attributes sometimes. That part of a rule which contains an optional attribute is treated as if it did not exist when the value of that attribute does not exist. Modifying the previous example:

```
ENTITY unit_vector ;
  a, b : real;
  c    : optional real ;
WHERE
  a**2 + b**2 + c**2 = 1.0 ;
END_ENTITY ;
```

When *c* has a value the rule expression is evaluated normally, but when *c* has no value the subexpression *+ c**2* has no evaluation.

A.11.4 Map Declaration

Description

A Map is a declaration that modifies an entity for some purpose. The effect of declaring a Map is to declare an entity. Mapping can give a different name to an entity, alter the type of an attribute (if the new type is compatible with the old type), introduce new subtypes and supertypes, and add local rules.

Syntax

```
228 MAP-DECL = MAP MAP-ID FROM ENTITY-ID [ SUBSUPER-DECL ]
               SEMICOLON { RETYPE-DECL } [ UNIQUE-RULE ]
               [ WHERE-RULE ] END-MAP SEMICOLON .
263 UNIQUE-RULE = UNIQUE { ID-LIST SEMICOLON } .
266 WHERE-RULE = WHERE { EXPRESSION SEMICOLON } .
```

Examples

A *vertex* entity is defined as:

```
ENTITY VERTEX;
  PT : OPTIONAL POINT;
END_ENTITY;
```

A specific application of the *vertex* entity (i.e., another schema) requires that the point component of *vertex* is mandatory. This is accomplished by:

```
MAP VERTEX FROM VERTEX;
WHERE
  (EXISTS(PT));
END_MAP;
```

This example assumes that there is an entity named *vertex* visible in the scope of the mapped entity (also called *vertex*) . The attributes of the mapped *vertex* do not have to be written as they (it in this case) are automatically part of the mapped entity. The local rule states that the attribute named *pt* must not be null, thus making it mandatory.

Another application wishes to call an entity defined some place else by a different name. The definition is in all other respects the same. This is done by:

```
MAP NODE FROM POINT;
END_MAP;
```

which simply allows an application to call Point by a more familiar name.

Even though the declaration is called **Map** an **Entity** declaration is created in the current schema block. Using a map is preferable to duplicating an entity (with appropriate changes) since mapping establishes the logical connection between the two entities.

A.11.5 Rule

Description

A **Where** clause in an entity declaration provides a set of constraints that apply within a given entity instance. The **Rule** permits the definition of constraints on the model as a whole.

Syntax

```
243 RULE-DECL = RULE RULE-ID FOR NESTED-ID-LIST SEMICOLON
                ACTION-BODY END-RULE SEMICOLON .
```

The rule header names the rule and specifies the entities affected by the rule. This statement is similar to a formal parameter list except the "parameters" are themselves entity types. Each of the entity types is regarded as a set of instances of that type; i.e., the entity set that makes up a model.

The body of the rule is much like the body of a function or procedure. The chief difference is that the "end state" of a rule is to indicate whether or not some global constraint is satisfied. The rule is satisfied if upon termination, the **violation** built-in procedure never was executed.

Examples

The following rule declares that for each point in the first octant, there must be a point in the seventh octant.

```
RULE POINT_MATCH FOR (POINT);
LOCAL
  K1, K2 : INTEGER;
END_LOCAL;
  K1 := 0;
  K2 := 0;
  REPEAT FOR EACH POINT IN MODEL;
    IF ((POINT.X>0) AND (POINT.Y>0) AND (POINT.Z>0)) THEN
      K1 := K1+1;
    END_IF;
    IF ((POINT.X<0) AND (POINT.Y<0) AND (POINT.Z<0)) THEN
      K2 := K2+1;
    END_IF;
  END_REPEAT;
  IF (K1<>K2) THEN
    VIOLATION;
  END_IF;
END_RULE;
```

A.11.6 Algorithms

An algorithm is a sequence of statements that produces some desired end state. The two kinds of algorithms that can be specified are procedures and functions (a rule is also an algorithm, but is discussed separately).

Formal parameters define the input to the algorithm. When the algorithm is called, actual parameters provide actual values. The actual parameters must agree in type, order, and number with the formal parameters.

Declarations local to the algorithm are given following the header. These declarations can be types, local variables, other algorithms, etc. as needed.

The body of the algorithm follows local declarations.

A.11.6.1 Parameters

Description

A Function or Procedure can have formal parameters. Each formal parameter has a name and a type. The name is treated as an identifier that is unique within the scope of the function or procedure. A formal parameter can also be declared as var (variable), which means that if the parameter is changed within the function the change is apparent to the point of invocation. Parameters not declared as var can be changed also, but the change will not be aparent when control is returned to the caller.

Syntax

```
208 FORMAL-PARAMETER = [ VAR ] ID-LIST COLON PARAMETER-CAN-BE .
```

Examples

```
FUNCTION dist(p1,p2:point):real ;

PROCEDURE midpt(p1,p2:point; var result:point) ;
```

A.11.6.2 Local Variables

Description

A Local variable has the same scope as a formal parameter and exists only within the algorithm in which it is declared. A local variable can be assigned a value or can participate in an expression.

Syntax

```
226 LOCAL-DECL = LOCAL { LOCAL-BODY-ITEM } END-LOCAL SEMICOLON .
224 LOCAL-BODY-ITEM = ID-LIST COLON LOCAL-CAN-BE [ INITIALIZER ] SEMICOLON .
225 LOCAL-CAN-BE = AGGREGATION-TYPE | BASE-TYPE | DEFINED-TYPE
    | ENTITY-TYPE .
181 AGGREGATION-TYPE = AGGREGATE-TYPE | ARRAY-TYPE | LIST-TYPE | SET-TYPE .
180 AGGREGATE-TYPE = AGGREGATE LIMIT-SPEC OF [ UNIQUE ] ATTRIBUTE-CAN-BE .
222 LIMIT-SPEC = LEFT-BRACKET EXPRESSION COLON ( EXPRESSION
    |INFINITY ) RIGHT-BRACKET .
182 ARRAY-TYPE = ARRAY INDEX-SPEC OF [ OPTIONAL ] [ UNIQUE ]
    ATTRIBUTE-CAN-BE .
218 INDEX-SPEC = LEFT-BRACKET EXPRESSION COLON EXPRESSION
    RIGHT-BRACKET .
223 LIST-TYPE = LIST LIMIT-SPEC OF [ UNIQUE ] ATTRIBUTE-CAN-BE .
247 SET-TYPE = SET [ LIMIT-SPEC ] OF ATTRIBUTE-CAN-BE .
186 BASE-TYPE = INTEGER-TYPE | LOGICAL-TYPE | NUMBER-TYPE |
    REAL-TYPE | STRING-TYPE .
220 INTEGER-TYPE = INTEGER [ PRECISION-SPEC ] .
233 PRECISION-SPEC = LEFT-PAREN EXPRESSION RIGHT-PAREN .
227 LOGICAL-TYPE = LOGICAL .
231 NUMBER-TYPE = NUMBER .
```

```
237 REAL-TYPE = REAL [ PRECISION-SPEC ] .
252 STRING-TYPE = STRING [ PRECISION-SPEC ] [ VARYING ] .
219 INITIALIZER = ASSIGNMENT-OPERATOR EXPRESSION .
```

When an algorithm is activated, numbers are initialized to zero, strings are empty, logicals are False and lists and sets are empty unless an initializer is explicitly given. The initializer value is given to the local variable upon entry to the algorithm.

A.11.6.3 Procedure

Description

A **Procedure** is an algorithm that receives parameters from the point of invocation, operates on those parameters in some manner to produce the desired end state. The value of those parameters might be changed. A given parameter can be altered only if the **Var** attribute is present for that parameter.

Syntax

```
235 PROCEDURE-DECL = PROCEDURE PROCEDURE-ID [ FORMAL-PARAMETER-LIST ]
    SEMICOLON ACTION-BODY END-PROCEDURE SEMICOLON .
```

A.11.6.4 Function

Description

A **Function** is an algorithm that operates on parameters and produces a specific result type. The invocation of a function is equivalent to having a variable of that result type at the point of invocation.

Syntax

```
211 FUNCTION-DECL = FUNCTION FUNCTION-ID [ FORMAL-PARAMETER-LIST ]
    COLON RESULT-CAN-BE SEMICOLON ACTION-BODY END-FUNCTION SEMICOLON .
```

function-id is the name of the function. *formal-parameter-list* is zero or more parameters supplying values for the function to operate on. *result-can-be* is the result produced by the function.

A **Return** statement is used to pass the function result to the point of invocation. Return also terminates the function. It is illegal to terminate a function except by a return statement with an argument.

A.11.6.5 Executable Statements

The executable statements are **Assignment Case Compound Escape If Procedure call Repeat Return Skip** and **With**.

Executable statements can appear only within an execution block.

An executable statement can be just a semicolon, in which case it is called a null statement.

Examples

```
IF A = 13 THEN
  ;   -- this is a null statement.
ELSE
  B := 5 ;
END_IF ;
```

Syntax

```
251 STATEMENT = ASSIGNMENT-STATEMENT | CASE-STATEMENT
    | COMPOUND-STATEMENT | DUMMY-STATEMENT | ESCAPE-STATEMENT
    | IF-STATEMENT | PROCEDURE-CALL-STATEMENT | REPEAT-STATEMENT
    | RETURN-STATEMENT | SKIP-STATEMENT | WITH-STATEMENT .
183 ASSIGNMENT-STATEMENT = ID ASSIGNMENT-OPERATOR EXPRESSION
    SEMICOLON .
191 CASE-STATEMENT = CASE EXPRESSION OF CASE-BLOCK END-CASE
    SEMICOLON .
189 CASE-BLOCK = CASE-ACTION { CASE-ACTION } [ CASE-OTHERWISE ] .
188 CASE-ACTION = EXPRESSION { COMMA EXPRESSION } COLON STATEMENT .
190 CASE-OTHERWISE = OTHERWISE COLON STATEMENT .
192 COMPOUND-STATEMENT = BEGIN { STATEMENT } END SEMICOLON .
198 DUMMY-STATEMENT = SEMICOLON .
202 ESCAPE-STATEMENT = ESCAPE SEMICOLON .
215 IF-STATEMENT = IF EXPRESSION THEN STATEMENT { STATEMENT }
    [ ELSE STATEMENT { STATEMENT } ] END-IF .
239 REPEAT-STATEMENT = REPEAT { REPEAT-CONTROL } SEMICOLON
    { STATEMENT } END-REPEAT SEMICOLON .
241 RETURN-STATEMENT = RETURN [ LEFT-PAREN EXPRESSION RIGHT-PAREN ]
    SEMICOLON
250 SKIP-STATEMENT = SKIP SEMICOLON .
268 WITH-STATEMENT = WITH ID STATEMENT .
```

A.11.6.5.1 Assignment Statement

Description

The assignment statement is used to assign a value to a variable.

Syntax

```
183 ASSIGNMENT-STATEMENT = ID ASSIGNMENT-OPERATOR EXPRESSION SEMICOLON .
```

Examples

```
LOCAL
  A, B, C : INTEGER ;
END_LOCAL ;

  A := 1 ;
  B := 2 ;
  C := A+B ;
```

A.11.6.5.2 Assignment Compatibility

An expression can be assigned to a variable only when the type of the expression is compatible with the type of the variable. Types can be compatible without being identical. Types are assignment compatible when:

1. The types are the same. Different user defined types are never the same even if their base types are the same.
2. One type is a subtype of the other type; e.g., integers and reals are subtypes of number, and integer is a subtype of real.
3. Both types are strings.
4. Both types are arrays where the bounds and the base types are identical.
5. Both types are lists with identical base types.
6. Both types are sets with identical base types.

A.11.6.5.3 Case Statement

Description

The Case statement causes the selection and execution of many possible statements depending on the value of a selector expression. The case statement consists of an expression, which is the case selector, and a list of alternative actions, each one preceded by a case label. The type of the case label must agree with the type of the case selector. The statement having the case label that matches the value of the case selector is executed. If none of the case labels match the value of the case selector then:

1. if the Otherwise clause is present the statement associated with otherwise is executed,

2. if the **Otherwise** clause is not present no statement (in the CASE) is executed.

Syntax

```
191 CASE-STATEMENT = CASE EXPRESSION OF CASE-BLOCK END-CASE SEMICOLON .
189 CASE-BLOCK = CASE-ACTION { CASE-ACTION } [ CASE-OTHERWISE ] .
188 CASE-ACTION = EXPRESSION { COMMA EXPRESSION } COLON STATEMENT .
190 CASE-OTHERWISE = OTHERWISE COLON STATEMENT .
```

Examples

```
LOCAL
  a : integer ;
  x : real ;
END_LOCAL ;

  a := 3 ;
  x := 34.97 ;
  CASE a OF
    1 : x := sin(x) ;
    2 : x := exp(x) ;
    3 : x := sqrt(x) ;  -- This is executed!
    4 : x := log(x) ;
  END_CASE ;
```

Restrictions:

- The type of the expression following *case* must agree with the expression that is part of the *case-action*.
- Only one *otherwise* case-action can be given. It must be the last case-action if it appears at all.
- Each case label must be different. However, it is possible that two case label expressions will evaluate the same. In that event, the first reading from top to bottom will be executed.

A.11.6.5.4 Compound Statement

Description

The compound statement is a sequence of statements delimited by **Begin** and **End**. A compound statement is treated as a single logical statement.

Syntax

```
192 COMPOUND-STATEMENT = BEGIN { STATEMENT } END SEMICOLON .
```

Examples

```
BEGIN
  A = A+1 ;
  IF A > 100 THEN
    A := 0 ;
  END_IF;
END ;
```

A.11.6.5.5 Escape Statement

Description

Escape causes an immediate transfer to the statement following the end of the block in which it appears. Note that this is the only way an indefinite repeat can be terminated.

Syntax

```
202 ESCAPE-STATEMENT = ESCAPE SEMICOLON .
```

Examples

```
...
REPEAT UNTIL (A=1);
  ...
  IF (A<0) THEN
    ESCAPE;     -- When executed, control passes to the statement
  END_IF;          after END_REPEAT.
  ...
END_REPEAT;
...
```

A.11.6.5.6 If Then Else Statement

Description

The If statement provides for the conditional execution of a statement according to the value of a logical (true or false) expression. The statement following **Then** is executed when the logical expression evaluates to **True**. When the expression evaluates to **False** the statement associated with Else is executed.

The Else clause is optional however. If an else clause is not present, and the result of the logical expression is False then the if statement has no effect.

Syntax

```
215 IF-STATEMENT = IF EXPRESSION THEN STATEMENT { STATEMENT }
    [ ELSE STATEMENT { STATEMENT } ] END-IF .
```

Examples

```
LOCAL
  A : INTEGER ;
END_LOCAL ;

  A = 5 ;
  IF A < 10 THEN
    A = A+1 ; -- THIS STATEMENT WILL BE EXECUTED.
  ELSE
    A = A-1 ;
  END_IF ;
```

A.11.6.5.7 Procedure Call Statement

Description

The Procedure call statement activates a procedure. The statement consists of a procedure identifier followed by an actual parameter list (which can be empty). The number and type of the actual parameters must agree with the formal parameters defined for that procedure.

Syntax

```
234 PROCEDURE-CALL-STATEMENT = PROCEDURE-ID [ ACTUAL-PARAMETER-LIST ]
    SEMICOLON .
```

Examples

The following procedure header defines two formal parameters; A, which is an integer variable, and B, which is a real. The actual parameters used with any call to this procedure must agree in number and type.

```
PROCEDURE XXX(VAR A:INTEGER; B:REAL) ;
```

The following procedure calls show both valid and invalid cases.

```
XXX(1,2);       (* Invalid since the first actual parameter is not a
                variable *)
XXX(a, 37);     (* This is a valid procedure call (assuming that a is
                typed as an integer).  The second actual parameter,
                although not a real, is valid since a type conversion takes
                place automatically *)

XXX(a);         (* This call is not valid since the correct number of
                    actual parameters is not given *)

   XXX(a,2.0,3);  (* Invalid, too many actual parameters *)
```

A.11.6.5.8 Repeat Statement

Description

The Repeat block is used to repeat a sequence of statements. The controlling conditions are finite iteration, while a condition is true, until a condition is true, and indefinite repetition. These controls can be used in combination to specify the conditions that terminate the repeat block.

Syntax

```
  239 REPEAT-STATEMENT = REPEAT { REPEAT-CONTROL } SEMICOLON
      { STATEMENT } END-REPEAT SEMICOLON .
```

Note – The repeat controls can be given in any order, but the same kind of control cannot be given more than once.

A.11.6.5.9 Until Control

Description

Causes the block to repeat Until the expression is true. The expression will be evaluated after each iteration. At least one iteration will always be executed.

Syntax

```
          264 UNTIL-CONTROL = UNTIL EXPRESSION .
```

A.11.6.5.10 While Control

Description

Causes the block to repeat While the expression is true. The expression will be evaluated before each iteration. If the expression is false initially, the block will not be executed.

Syntax

```
          267 WHILE-CONTROL = WHILE EXPRESSION .
```

A.11.6.5.11 Increment Control

Description

Causes the block to repeat while the active variable lies in the given interval. The active variable is initialized as the first bounding condition. After each iteration the active variable is incremented (or decremented) as specified. Before each iteration, the test:

```
        { expression1 <= active-var <= expression2 }
```

is evaluated. The block is executed only when this test yields true. expression3, if present, updates the value of the active variable after each iteration. If expression3 is omitted, the active variable is updated by one (1).

Syntax

```
217 INCREMENT-CONTROL = LOCAL-ID ASSIGNMENT-OPERATOR EXPRESSION TO
    EXPRESSION [ BY EXPRESSION ] .
```

A.11.6.5.12 Return Statement

Description

The **Return** statement terminates the execution of a function or procedure. A function return must include an expression, which is the result returned to the point of invocation. The expression must be the same type as the declared type of the function. A procedure return must not include an expression.

Syntax

```
241 RETURN-STATEMENT = RETURN [ LEFT-PAREN EXPRESSION RIGHT-PAREN ] SEMICOLON
```

Examples

```
RETURN(50) ;           (* from a function *)
RETURN(work_point) ;
RETURN ;               (* from a procedure *)
```

A.11.6.5.13 Skip Statement

Description

Skip causes an immediate transfer to the end of the block in which it appears. If the block is a repeat block, the terminal conditions are tested. The block will be repeated or terminated based on evaluation of the repeat controls.

Syntax

```
250 SKIP-STATEMENT = SKIP SEMICOLON .
```

Examples

```
...
REPEAT UNTIL (A=1);
  ...
  IF (A<0) THEN
    SKIP;       (* When executed, control passes to the END_REPEAT
                   statement where the terminal condition is
                   evaluated. *)
  END_IF;
  ...
END_REPEAT;
...
```

A.11.6.5.14 With Statement

Description

The With statement provides a partial variable qualification that simplifies the writing of separate components of a complex object, i.e., an entity. The with statement starts with the keyword With followed by a partial qualification, followed by a statement.

Syntax

```
268 WITH-STATEMENT = WITH ID STATEMENT .
```

Examples

```
local
  a : point ;   (* point has attributes x, y, and z *)
  b : number ;
end_local ;
  WITH a
    begin ;
    b := x + y + z ;    (* same as: a.x + a.y + a.z *)
    end ;
```

A.12 Expression

Description

Expressions are made up of operators and operands. Operands must be compatible with operators. Binary operators require two operands and the operator appears between those operands. A unary operator requires only one operand, which is given before the operand.

There are three kinds of expressions.

- Arithmetic expressions accept numeric operands and produce a numeric result.
- Relational expressions accept various kinds of operands and produce a logical (true or false) result.
- String expressions accept string operands and produce a string result.

Operators have computational precedence as defined below. Evaluation proceeds from left to right with the highest precedence being evaluated first.

	Operator Precedence	
1	Unary operators	`+ - not`
2	Exponentiation	`**`
3	Multiplication and Division	`* / div mod and`
4	Addition and Subtraction	`- + or ||`
5	Relational in like cardinality	`= <> <= >= > < :=:   :<>:`

An operand between two operators of different precedence is bound to the operator with the higher precedence. e.g., -10*20 or (-10)*20.

An operand between two operators of the same precedence is bound to the one on the left. e.g., 10/20*30 or (10/20)*30

Expression enclosed by parentheses are evaluated before being treated as a single operand.

Syntax

```
206 EXPRESSION = SIMPLE-EXPRESSION { RELATIONAL-OPERATOR-EXTENDED
    SIMPLE-EXPRESSION } .
248 SIMPLE-EXPRESSION = [ SIGN ] TERM { ADDITION-LIKE-OPERATIONS TERM } .
259 TERM = FACTOR { MULTIPLICATION-LIKE-OPERATIONS FACTOR } .
207 FACTOR = SIMPLE-FACTOR [ EXPONENTIATION-OPERATOR SIMPLE-FACTOR ] .
249 SIMPLE-FACTOR = LITERAL | FUNCTION-CALL | ID | SET-CONSTRUCT
    | LEFT-PAREN EXPRESSION RIGHT-PAREN | INTERVAL | NOT-OPERATOR
    SIMPLE-FACTOR .
```

A.12.1 Arithmetic Expressions

Description

The arithmetic operations are add (+), subtract (−), divide (/), integer divide (DIV), multiply (*), exponentiation (**), and modulo (MOD). Both operands must be numbers and the result is a number.

The type of the result of these operations, based on the type of the operands, is:

Operation		Operand-Types	Result-Type	
+	Add	real	real	
		integer	integer	
		integer, real	real	
-	Subtract	real	real	
		integer	integer	
		integer, real	real	
*	Multiply	real	real	
		integer	integer	
		integer, real	real	
/	Divide	real	real	
		integer	real	
		integer, real	real	
DIV	Integer Divide	real	integer	
		integer	integer	
		integer,real	integer	
MOD	Modulo	integer	integer	
	(remainder)	real	integer	*
		integer, real	integer	*
**	Exponentiation	integer	integer	
		real	real	
		integer,real	real	
		real,integer	real	

* Real operands are first truncated to integers.

A.12.2 Relational Expressions

Description

The value relational operators are equal (=) , not equal (<>) , greater than (>) , less than (<) , greater than or equal (>=) , less than or equal (<=) , set mttbership (In) , and string match (like) .

The instance relational operators are instance equal (:=:) and instance not equal (:<>:) .

The cardinality relational operator has the form [expression : expression].

The two operands must be compatible; e.g., a string cannot be compared to a number in this manner.

The result of a relational expression is a logical value true or false. The not operator may precede the operation to reverse the result.

Examples

```
    27 < 84   (* true *)
NOT (27 < 84) (* false *)
```

A.12.3 Interval Expressions

Description

An interval expression tests whether or not a value falls within a given interval yielding a True or False result.

Syntax

```
221 INTERVAL = LEFT-CURL EXPRESSION RELATIONAL-OPERATOR EXPRESSION
    RELATIONAL-OPERATOR EXPRESSION RIGHT-CURL .
```

Examples

```
IF { 10 <= A < MAXVAL } THEN
  ....
```

A.12.4 String Expressions

Description

The only string operation is string concatenation represented by the || symbol. Both operands must be strings and the result of a concatenation is also a string.

Examples

```
name := last_name || ' ' || first_name ;
```

A.12.5 Function Call

Description

The function call activates a function. It consists of a function identifier possibly followed by an actual parameter list. The number and type of the actual parameters must agree with the formal parameters defined for that function.

A function call can be qualified when the function returns some kind of aggregate type. "dot" qualification allows you to access individual attributes when the return type is an entity type. Subscript notation can be used when the return type is an array, list, or set type.

Examples

```
ENTITY POINT;
  X, Y, Z : NUMBER;
END_ENTITY;

FUNCTION MIDPOINT_OF_LINE(L:LINE):POINT;
  ...
END_FUNCTION;

IF MIDPOINT_OF_LINE(L506).X=9.0 THEN
  ...
END_IF;
```

Syntax

```
210 FUNCTION-CALL = FUNCTION-ID [ ACTUAL-PARAMETER-LIST ] { QUALIFICATION } .
236 QUALIFICATION = { SUBSCRIPT } [ DOT ID ] .
```

Examples

```
a := f1(1,2,3) ;
```

A.12.6 Set Construct

The set construct is used to establish a set value.

Syntax

```
246 SET-CONSTRUCT = LEFT-BRACKET [ EXPRESSION { COMMA EXPRESSION } ]
    RIGHT-BRACKET .
```

Examples

Given the declaration:

```
a : set of integer;
```

a value can be assigned as:

```
a := [ 1, 3, 6, 9*8, -12 ] ;
```

A.13 Express Specification

The formal definition of the *Express* Language is given in this section. This specification is organized as follows:

- Syntax of the specification
- Cross reference for rules
- Rules

A.13.1 The Syntax of the Specification

Regular expressions define the tokens of the *Express* language and the statements that can legally be constructed from those tokens. Tokens are composed of characters; statements are composed of tokens. Tokens can be constants or variables. For example, keywords and punctuation are token constants and identifiers and literals are token variables.

The general form of a regular expression is:

```
name = expression .
```

where

name	is the symbolic name given to expression where the name is made up entirely of letters, digits, or the dash (-) character.
=	is the assignment of a regular expression to a name
expression	is some valid regular expression composed from the following elements:
name	is a token or statement defined somewhere in the specification according to the definition given above.
'x'	is the character x or X (case insensitive). For example, 'xy' is the string xy, xY, Xy, or XY (case insensitive).
""	is the character '
|	is the choice operator, e.g., 'x'|'y' means either x or y
[element]	means element occurs zero or one times
{element}	means element occurs zero or many times
(element)	groups the element(s) enclosed by parentheses. e.g., 'x'('y'|'z') means xy or xz.
.	the period terminates a production.

The following are system dependent characters or character sets. For example, \t is the Tab character, which may or may not have meaning to a particular system.

\a	is any printable ASCII character.
\n	is the newline character
\q	is the quote (') character.
\t	is the tab character

ABS	1	BUILT-IN-FUNCTION-NAME(137)
ACOS	2	BUILT-IN-FUNCTION-NAME(137)
ACTION-BODY	178	FUNCTION-DECL(211) PROCEDURE-DECL(235) RULE-DECL(243)
ACTUAL-PARAMETER-LIST	179	FUNCTION-CALL(210) PROCEDURE-CALL-STATEMENT(234)
ADDITION-LIKE-OPERATIONS	134	SIMPLE-EXPRESSION(248)
AGGREGATE	3	AGGREGATE-TYPE(180) GENERAL-AGGREGATION(212)
AGGREGATE-TYPE	180	AGGREGATION-TYPE(181)
AGGREGATION-TYPE	181	ATTRIBUTE-CAN-BE(185) LOCAL-CAN-BE(225) TYPE-CAN-BE(260)
AND	4	AND-OPERATOR(135)
AND-OPERATOR	135	MULTIPLICATION-LIKE-OPERATIONS(164) SUPERTYPE-EXPRESSION(257)
ARRAY	5	ARRAY-TYPE(182) GENERAL-AGGREGATION(212)
ARRAY-TYPE	182	AGGREGATION-TYPE(181)
AS	6	RETYPE-DECL(242)
ASIN	7	BUILT-IN-FUNCTION-NAME(137)
ASSIGNMENT-OPERATOR	8	ASSIGNMENT-STATEMENT(183) INCREMENT-CONTROL(217) INITIALIZER(219)
ASSIGNMENT-STATEMENT	183	STATEMENT(251)
ASSUME	9	ASSUME-DIRECTIVE(184)
ASSUME-DIRECTIVE	184	DIRECTIVE(197)
ATAN	10	BUILT-IN-FUNCTION-NAME(137)
ATTRIBUTE-CAN-BE	185	AGGREGATE-TYPE(180) ARRAY-TYPE(182) EXPLICIT-ATTRIBUTE(203) LIST-TYPE(223) RETYPE-DECL(242) SET-TYPE(247)
ATTRIBUTE-ID	136	DERIVED-ATTRIBUTE(195)
BASE-TYPE	186	ATTRIBUTE-CAN-BE(185) LOCAL-CAN-BE(225) PARAMETER-CAN-BE(232) RESULT-CAN-BE(240) TYPE-CAN-BE(260)
BEGIN	11	COMPOUND-STATEMENT(192)
BLOCK-MEMBER	187	ACTION-BODY(178) SCHEMA-DECL(244)
BUILT-IN-FUNCTION-NAME	137	FUNCTION-ID(147)
BUILT-IN-PROCEDURE-NAME	138	PROCEDURE-ID(168)
BY	12	INCREMENT-CONTROL(217)
CARDINALITY-OPERATOR	139	RELATIONAL-OPERATOR-EXTENDED(171)
CASE	13	CASE-STATEMENT(191)
CASE-ACTION	188	CASE-BLOCK(189)
CASE-BLOCK	189	CASE-STATEMENT(191)
CASE-OTHERWISE	190	CASE-BLOCK(189)
CASE-STATEMENT	191	STATEMENT(251)
COLON	14	CASE-ACTION(188) CASE-OTHERWISE(190)

		DERIVED-ATTRIBUTE(195) EXPLICIT-ATTRIBUTE(203) FORMAL-PARAMETER(208) FUNCTION-DECL(211) INDEX-SPEC(218) LIMIT-SPEC(222) LOCAL-BODY-ITEM(224) RETYPE-DECL(242)
COMMA	15	ACTUAL-PARAMETER-LIST(179) ASSUME-DIRECTIVE(184) CASE-ACTION(188) ID-LIST(214) SET-CONSTRUCT(246)
COMPOUND-STATEMENT	192	STATEMENT(251)
CONCATENATION-OPERATOR	16	ADDITION-LIKE-OPERATIONS(134)
CONSTANT	140	LITERAL(158)
COS	17	BUILT-IN-FUNCTION-NAME(137)
DEFINE	18	DEFINE-DIRECTIVE(193)
DEFINE-DIRECTIVE	193	DIRECTIVE(197)
DEFINED-TYPE	194	ATTRIBUTE-CAN-BE(185) LOCAL-CAN-BE(225) PARAMETER-CAN-BE(232) RESULT-CAN-BE(240) TYPE-CAN-BE(260)
DEFINED-TYPE-ID	141	DEFINE-DIRECTIVE(193) DEFINED-TYPE(194) TYPE-ITEM(262)
DERIVE	19	DERIVED-ATTRIBUTE-DECL(196)
DERIVED-ATTRIBUTE	195	DERIVED-ATTRIBUTE-DECL(196)
DERIVED-ATTRIBUTE-DECL	196	ENTITY-DECL(199)
DIGIT	142	ID-CHAR(149) INTEGER-LITERAL(155)
DIRECTIVE	197	BLOCK-MEMBER(187)
DIV	20	INTEGER-DIVIDE-OPERATOR(154)
DIVIDE-OPERATOR	143	MULTIPLICATION-LIKE-OPERATIONS(164)
DOT	21	ID-QUALIFIED(151) REAL-LITERAL(169) QUALIFICATION(236)
DUMMY-STATEMENT	198	STATEMENT(251)
DYNAMIC	22	EXPLICIT-ATTRIBUTE(203)
ELSE	23	IF-STATEMENT(215)
EMBEDDED-REMARK	144	REMARK(172)
END	24	COMPOUND-STATEMENT(192)
END-CASE	25	CASE-STATEMENT(191)
END-ENTITY	26	ENTITY-DECL(199)
END-FUNCTION	27	FUNCTION-DECL(211)
END-IF	28	IF-STATEMENT(215)
END-LOCAL	29	LOCAL-DECL(226)
END-MAP	30	MAP-DECL(228)
END-PROCEDURE	31	PROCEDURE-DECL(235)
END-REPEAT	32	REPEAT-STATEMENT(239)
END-RULE	33	RULE-DECL(243)
END-SCHEMA	34	SCHEMA-DECL(244)
END-TYPE	35	TYPE-DECL(261)
ENTITY	36	ENTITY-DECL(199)
ENTITY-DECL	199	BLOCK-MEMBER(187)
ENTITY-ID	145	ENTITY-DECL(199) ENTITY-TYPE(200) MAP-DECL(228)

ENTITY-TYPE	200	ATTRIBUTE-CAN-BE(185) LOCAL-CAN-BE(225) PARAMETER-CAN-BE(232) RESULT-CAN-BE(240)
ENUMERATION	37	ENUMERATION-TYPE(201)
ENUMERATION-TYPE	201	TYPE-CAN-BE(260)
EQUAL	38	EQUAL-OPERATOR(146) TYPE-ITEM(262)
EQUAL-OPERATOR	146	RELATIONAL-OPERATOR(170)
ESCAPE	39	ESCAPE-STATEMENT(202)
ESCAPE-STATEMENT	202	STATEMENT(251)
EVERYTHING	40	EXPORT-DIRECTIVE(205)
EXCEPT	41	EXPORT-DIRECTIVE(205)
EXCLUSIVE-OR-OPERATOR	42	OR-OPERATOR(166)
EXISTS	43	BUILT-IN-FUNCTION-NAME(137)
EXP	44	BUILT-IN-FUNCTION-NAME(137)
EXPLICIT-ATTRIBUTE	203	EXPLICIT-ATTRIBUTE-DECL(204)
EXPLICIT-ATTRIBUTE-DECL	204	ENTITY-DECL(199)
EXPONENTIATION-OPERATOR	45	FACTOR(207)
EXPORT	46	EXPORT-DIRECTIVE(205)
EXPORT-DIRECTIVE	205	DIRECTIVE(197)
EXPRESSION	206	ACTUAL-PARAMETER-LIST(179) ASSIGNMENT-STATEMENT(183) CASE-ACTION(188) CASE-STATEMENT(191) IF-STATEMENT(215) INCREMENT-CONTROL(217) INDEX-SPEC(218) INITIALIZER(219) INTERVAL(221) LIMIT-SPEC(222) PRECISION-SPEC(233) RETURN-STATEMENT(241) SET-CONSTRUCT(246) SIMPLE-FACTOR(249) SUBSCRIPT(253) UNTIL-CONTROL(264) WHERE-RULE(266) WHILE-CONTROL(267)
EXTERNAL	47	EXPLICIT-ATTRIBUTE(203)
FACTOR	207	TERM(259)
FALSE	48	CONSTANT(140) LOGICAL-LITERAL(160)
FOR	49	RULE-DECL(243)
FORMAL-PARAMETER	208	FORMAL-PARAMETER-LIST(209)
FORMAL-PARAMETER-LIST	209	FUNCTION-DECL(211) PROCEDURE-DECL(235)
FORMAT	50	BUILT-IN-FUNCTION-NAME(137)
FROM	51	MAP-DECL(228)
FUNCTION	52	FUNCTION-DECL(211)
FUNCTION-CALL	210	SIMPLE-FACTOR(249)
FUNCTION-DECL	211	BLOCK-MEMBER(187)
FUNCTION-ID	147	FUNCTION-CALL(210) FUNCTION-DECL(211)
GENERAL-AGGREGATION	212	PARAMETER-CAN-BE(232)
GENERIC	53	GENERIC-TYPE(213)
GENERIC-TYPE	213	PARAMETER-CAN-BE(232) RESULT-CAN-BE(240)
GREATER-EQUAL-OPERATOR	54	RELATIONAL-OPERATOR(170)
GREATER-THAN-OPERATOR	55	RELATIONAL-OPERATOR(170)
HIBOUND	56	BUILT-IN-FUNCTION-NAME(137)
ID	148	ID-INDEXED(150) LOCAL-ID(159) ASSIGNMENT-STATEMENT(183)

		QUALIFICATION(236) SIMPLE-FACTOR(249) WITH-STATEMENT(268)
ID-CHAR	149	ID-SIMPLE(152)
ID-INDEXED	150	ID-QUALIFIED(151)
ID-LIST	214	EXPLICIT-ATTRIBUTE(203) FORMAL-PARAMETER(208) LOCAL-BODY-ITEM(224) NESTED-ID-LIST(230) RETYPE-DECL(242) UNIQUE-RULE(263)
ID-QUALIFIED	151	ID(148)
ID-SIMPLE	152	ATTRIBUTE-ID(136) DEFINED-TYPE-ID(141) ENTITY-ID(145) FUNCTION-ID(147) ID(148) MAP-ID(161) PROCEDURE-ID(168) RULE-ID(173) SCHEMA-ID(174) ID-LIST(214) SUPERTYPE-FACTOR(258)
IF	57	IF-STATEMENT(215)
IF-STATEMENT	215	STATEMENT(251)
IN	58	IN-OPERATOR(153)
IN-OPERATOR	153	RELATIONAL-OPERATOR-EXTENDED(171)
INCLUDE	59	INCLUDE-DIRECTIVE(216)
INCLUDE-DIRECTIVE	216	DIRECTIVE(197)
INCLUSIVE-OR-OPERATOR	60	OR-OPERATOR(166)
INCREMENT-CONTROL	217	REPEAT-CONTROL(238)
INDEX-SPEC	218	ARRAY-TYPE(182)
INFINITY	61	LIMIT-SPEC(222)
INITIALIZER	219	DERIVED-ATTRIBUTE(195) LOCAL-BODY-ITEM(224)
INSERT	62	BUILT-IN-PROCEDURE-NAME(138)
INSTANCE-EQUAL-OPERATOR	63	RELATIONAL-OPERATOR(170)
INSTANCE-NOTEQUAL-OPERATOR	64	RELATIONAL-OPERATOR(170)
INTEGER	65	INTEGER-TYPE(220)
INTEGER-DIVIDE-OPERATOR	154	DIVIDE-OPERATOR(143)
INTEGER-LITERAL	155	LITERAL(158) REAL-LITERAL(169)
INTEGER-TYPE	220	BASE-TYPE(186)
INTERNAL	66	EXPLICIT-ATTRIBUTE(203)
INTERVAL	221	SIMPLE-FACTOR(249)
LEFT-BRACKET	67	INDEX-SPEC(218) LIMIT-SPEC(222) SET-CONSTRUCT(246) SUBSCRIPT(253)
LEFT-CURL	68	INTERVAL(221)
LEFT-PAREN	69	ACTUAL-PARAMETER-LIST(179) ASSUME-DIRECTIVE(184) FORMAL-PARAMETER-LIST(209) NESTED-ID-LIST(230) PRECISION-SPEC(233) RETURN-STATEMENT(241) SIMPLE-FACTOR(249) SUPERTYPE-DECL(256) SUPERTYPE-FACTOR(258)
LESS-EQUAL-OPERATOR	70	RELATIONAL-OPERATOR(170)
LESS-THAN-OPERATOR	71	RELATIONAL-OPERATOR(170)

```
LETTER ...........................156 | ID-CHAR(149) ID-SIMPLE(152)
LIKE ............................. 72 | LIKE-OPERATOR(157)
LIKE-OPERATOR ....................157 | RELATIONAL-OPERATOR-EXTENDED(171)

LIMIT-SPEC .......................222 | CARDINALITY-OPERATOR(139)
                                        AGGREGATE-TYPE(180) LIST-TYPE(223)
                                        SET-TYPE(247)
LIST ............................. 73 | GENERAL-AGGREGATION(212) LIST-TYPE(223)
LIST-TYPE ........................223 | AGGREGATION-TYPE(181)
LITERAL ..........................158 | SIMPLE-FACTOR(249)
LOBOUND .......................... 74 | BUILT-IN-FUNCTION-NAME(137)
LOCAL ............................ 75 | LOCAL-DECL(226)
LOCAL-BODY-ITEM ..................224 | LOCAL-DECL(226)
LOCAL-CAN-BE .....................225 | LOCAL-BODY-ITEM(224)
LOCAL-DECL .......................226 | ACTION-BODY(178)
LOCAL-ID .........................159 | INCREMENT-CONTROL(217)
LOG .............................. 76 | BUILT-IN-FUNCTION-NAME(137)
LOG10 ............................ 77 | BUILT-IN-FUNCTION-NAME(137)
LOG2 ............................. 78 | BUILT-IN-FUNCTION-NAME(137)
LOGICAL .......................... 79 | LOGICAL-TYPE(227)
LOGICAL-LITERAL ..................160 | LITERAL(158)
LOGICAL-TYPE .....................227 | BASE-TYPE(186)
MAP .............................. 80 | MAP-DECL(228)
MAP-DECL .........................228 | BLOCK-MEMBER(187)
MAP-ID ...........................161 | MAP-DECL(228) MAP-TYPE(229)
MAP-TYPE .........................229 | ATTRIBUTE-CAN-BE(185)
                                        PARAMETER-CAN-BE(232) RESULT-CAN-BE(240)
MINUS ............................ 81 | MINUS-OPERATOR(162) SIGN(175)
MINUS-OPERATOR ...................162 | ADDITION-LIKE-OPERATIONS(134)
MOD .............................. 82 | MODULO-OPERATOR(163)
MODULO-OPERATOR ..................163 | MULTIPLICATION-LIKE-OPERATIONS(164)
MULTIPLICATION-LIKE-OPERATIONS .164 | TERM(259)
MULTIPLY-OPERATOR ................ 83 | MULTIPLICATION-LIKE-OPERATIONS(164)
NESTED-ID-LIST ...................230 | ENUMERATION-TYPE(201)
                                        EXPORT-DIRECTIVE(205) RULE-DECL(243)
                                        SELECT-TYPE(245) SUBTYPE-DECL(255)
                                        USES-DIRECTIVE(265)
NOT .............................. 84 | NOT-OPERATOR(165)
NOT-EQUAL-OPERATOR ............... 85 | RELATIONAL-OPERATOR(170)
NOT-OPERATOR .....................165 | SIMPLE-FACTOR(249)
NULL ............................. 86 | SUPERTYPE-FACTOR(258)
NULLIFY .......................... 87 | BUILT-IN-PROCEDURE-NAME(138)
NUMBER ........................... 88 | NUMBER-TYPE(231)
NUMBER-TYPE ......................231 | BASE-TYPE(186) TYPE-CAN-BE(260)
ODD .............................. 89 | BUILT-IN-FUNCTION-NAME(137)
OF ............................... 90 | AGGREGATE-TYPE(180) ARRAY-TYPE(182)
                                        CASE-STATEMENT(191)
                                        ENUMERATION-TYPE(201)
                                        GENERAL-AGGREGATION(212) LIST-TYPE(223)
                                        SET-TYPE(247) SUBTYPE-DECL(255)
```

		SUPERTYPE-DECL(256)
OPTIONAL	91	ARRAY-TYPE(182) EXPLICIT-ATTRIBUTE(203)
OR-OPERATOR	166	ADDITION-LIKE-OPERATIONS(134) SUPERTYPE-EXPRESSION(257)
OTHERWISE	92	CASE-OTHERWISE(190)
PARAMETER-CAN-BE	232	FORMAL-PARAMETER(208) GENERAL-AGGREGATION(212)
PI	93	CONSTANT(140)
PLUS	94	PLUS-OPERATOR(167) SIGN(175)
PLUS-OPERATOR	167	ADDITION-LIKE-OPERATIONS(134)
PRECISION-SPEC	233	INTEGER-TYPE(220) REAL-TYPE(237) STRING-TYPE(252)
PROCEDURE	95	PROCEDURE-DECL(235)
PROCEDURE-CALL-STATEMENT	234	STATEMENT(251)
PROCEDURE-DECL	235	BLOCK-MEMBER(187)
PROCEDURE-ID	168	PROCEDURE-CALL-STATEMENT(234) PROCEDURE-DECL(235)
QUALIFICATION	236	FUNCTION-CALL(210)
REAL	96	REAL-TYPE(237)
REAL-DIVIDE-OPERATOR	97	DIVIDE-OPERATOR(143)
REAL-LITERAL	169	LITERAL(158)
REAL-TYPE	237	BASE-TYPE(186)
RELATIONAL-OPERATOR	170	RELATIONAL-OPERATOR-EXTENDED(171) INTERVAL(221)
RELATIONAL-OPERATOR-EXTENDED	171	EXPRESSION(206)
REPEAT	98	REPEAT-STATEMENT(239)
REPEAT-CONTROL	238	REPEAT-STATEMENT(239)
REPEAT-STATEMENT	239	STATEMENT(251)
RESULT-CAN-BE	240	DERIVED-ATTRIBUTE(195) FUNCTION-DECL(211)
RETURN	99	RETURN-STATEMENT(241)
RETURN-STATEMENT	241	STATEMENT(251)
RETYPE	100	RETYPE-DECL(242)
RETYPE-DECL	242	MAP-DECL(228)
RIGHT-BRACKET	101	INDEX-SPEC(218) LIMIT-SPEC(222) SET-CONSTRUCT(246) SUBSCRIPT(253)
RIGHT-CURL	102	INTERVAL(221)
RIGHT-PAREN	103	ACTUAL-PARAMETER-LIST(179) ASSUME-DIRECTIVE(184) FORMAL-PARAMETER-LIST(209) NESTED-ID-LIST(230) PRECISION-SPEC(233) RETURN-STATEMENT(241) SIMPLE-FACTOR(249) SUPERTYPE-DECL(256) SUPERTYPE-FACTOR(258)
RULE	104	RULE-DECL(243)
RULE-DECL	243	BLOCK-MEMBER(187)
RULE-ID	173	RULE-DECL(243)
SCHEMA	105	SCHEMA-DECL(244)
SCHEMA-DECL	244	BLOCK-MEMBER(187)

SCHEMA-ID	174	ASSUME-DIRECTIVE(184) SCHEMA-DECL(244)
SELECT	106	SELECT-TYPE(245)
SELECT-TYPE	245	TYPE-CAN-BE(260)
SEMICOLON	107	ASSIGNMENT-STATEMENT(183) ASSUME-DIRECTIVE(184) CASE-STATEMENT(191) COMPOUND-STATEMENT(192) DEFINE-DIRECTIVE(193) DERIVED-ATTRIBUTE(195) DUMMY-STATEMENT(198) ENTITY-DECL(199) ESCAPE-STATEMENT(202) EXPLICIT-ATTRIBUTE(203) EXPORT-DIRECTIVE(205) FORMAL-PARAMETER-LIST(209) FUNCTION-DECL(211) INCLUDE-DIRECTIVE(216) LOCAL-BODY-ITEM(224) LOCAL-DECL(226) MAP-DECL(228) PROCEDURE-CALL-STATEMENT(234) PROCEDURE-DECL(235) REPEAT-STATEMENT(239) RETURN-STATEMENT(241) RETYPE-DECL(242) RULE-DECL(243) SCHEMA-DECL(244) SKIP-STATEMENT(250) TYPE-DECL(261) TYPE-ITEM(262) UNIQUE-RULE(263) USES-DIRECTIVE(265) WHERE-RULE(266)
SET	108	GENERAL-AGGREGATION(212) SET-TYPE(247)
SET-CONSTRUCT	246	SIMPLE-FACTOR(249)
SET-TYPE	247	AGGREGATION-TYPE(181)
SIGN	175	REAL-LITERAL(169) SIMPLE-EXPRESSION(248)
SIMPLE-EXPRESSION	248	EXPRESSION(206)
SIMPLE-FACTOR	249	FACTOR(207)
SIN	109	BUILT-IN-FUNCTION-NAME(137)
SIZEOF	110	BUILT-IN-FUNCTION-NAME(137)
SKIP	111	SKIP-STATEMENT(250)
SKIP-STATEMENT	250	STATEMENT(251)
SQRT	112	BUILT-IN-FUNCTION-NAME(137)
STATEMENT	251	ACTION-BODY(178) CASE-ACTION(188) CASE-OTHERWISE(190) COMPOUND-STATEMENT(192) IF-STATEMENT(215) REPEAT-STATEMENT(239) WITH-STATEMENT(268)
STRING	113	STRING-TYPE(252)
STRING-LITERAL	176	LITERAL(158) DEFINE-DIRECTIVE(193) INCLUDE-DIRECTIVE(216)
STRING-TYPE	252	BASE-TYPE(186)
SUBSCRIPT	253	ID-INDEXED(150) QUALIFICATION(236)
SUBSUPER-DECL	254	ENTITY-DECL(199) MAP-DECL(228)
SUBTYPE	114	SUBTYPE-DECL(255)
SUBTYPE-DECL	255	SUBSUPER-DECL(254)
SUPERTYPE	115	SUPERTYPE-DECL(256)

SUPERTYPE-DECL	256	SUBSUPER-DECL(254)
SUPERTYPE-EXPRESSION	257	SUPERTYPE-DECL(256) SUPERTYPE-FACTOR(258)
SUPERTYPE-FACTOR	258	SUPERTYPE-EXPRESSION(257)
TAIL-REMARK	177	REMARK(172)
TAN	116	BUILT-IN-FUNCTION-NAME(137)
TERM	259	SIMPLE-EXPRESSION(248)
THEN	117	IF-STATEMENT(215)
TO	118	INCREMENT-CONTROL(217)
TRUE	119	CONSTANT(140) LOGICAL-LITERAL(160)
TYPE	120	TYPE-DECL(261)
TYPE-CAN-BE	260	TYPE-ITEM(262)
TYPE-DECL	261	BLOCK-MEMBER(187)
TYPE-ITEM	262	TYPE-DECL(261)
TYPEOF	121	BUILT-IN-FUNCTION-NAME(137)
UNDERSCORE	122	ID-CHAR(149)
UNIQUE	123	AGGREGATE-TYPE(180) ARRAY-TYPE(182) LIST-TYPE(223) UNIQUE-RULE(263)
UNIQUE-RULE	263	ENTITY-DECL(199) MAP-DECL(228)
UNKNOWN	124	CONSTANT(140) LOGICAL-LITERAL(160)
UNTIL	125	UNTIL-CONTROL(264)
UNTIL-CONTROL	264	REPEAT-CONTROL(238)
USES	126	USES-DIRECTIVE(265)
USES-DIRECTIVE	265	DIRECTIVE(197)
VALUE	127	BUILT-IN-FUNCTION-NAME(137)
VAR	128	FORMAL-PARAMETER(208)
VARYING	129	STRING-TYPE(252)
VIOLATION	130	BUILT-IN-PROCEDURE-NAME(138)
WHERE	131	WHERE-RULE(266)
WHERE-RULE	266	ENTITY-DECL(199) MAP-DECL(228)
WHILE	132	WHILE-CONTROL(267)
WHILE-CONTROL	267	REPEAT-CONTROL(238)
WITH	133	WITH-STATEMENT(268)
WITH-STATEMENT	268	STATEMENT(251)

bf RULE DEFINITION

```
 1 ABS = 'ABS' .
 2 ACOS = 'ACOS' .
 3 AGGREGATE = 'AGGREGATE' .
 4 AND = 'AND' .
 5 ARRAY = 'ARRAY' .
 6 AS = 'AS' .
 7 ASIN = 'ASIN' .
 8 ASSIGNMENT-OPERATOR = ':=' .
 9 ASSUME = 'ASSUME' .
10 ATAN = 'ATAN' .
```

```
11 BEGIN = 'BEGIN' .
12 BY = 'BY' .
13 CASE = 'CASE' .
14 COLON = ':' .
15 COMMA = ',' .
16 CONCATENATION-OPERATOR = '||' .
17 COS = 'COS' .
18 DEFINE = 'DEFINE' .
19 DERIVE = 'DERIVE' .
20 DIV = 'DIV' .


21 DOT = '.' .
22 DYNAMIC = 'DYNAMIC' .
23 ELSE = 'ELSE' .
24 END = 'END' .
25 END-CASE = 'END_CASE' .
26 END-ENTITY = 'END_ENTITY' .
27 END-FUNCTION = 'END_FUNCTION' .
28 END-IF = 'END_IF' .
29 END-LOCAL = 'END_LOCAL' .
30 END-MAP = 'END_MAP' .


31 END-PROCEDURE = 'END_PROCEDURE' .
32 END-REPEAT = 'END_REPEAT' .
33 END-RULE = 'END_RULE' .
34 END-SCHEMA = 'END_SCHEMA' .
35 END-TYPE = 'END_TYPE' .
36 ENTITY = 'ENTITY' .
37 ENUMERATION = 'ENUMERATION' .
38 EQUAL = '=' .
39 ESCAPE = 'ESCAPE' .
40 EVERYTHING = 'EVERYTHING' .


41 EXCEPT = 'EXCEPT' .
42 EXCLUSIVE-OR-OPERATOR = 'XOR' .
43 EXISTS = 'EXISTS' .
44 EXP = 'EXP' .
45 EXPONENTIATION-OPERATOR = '**' .
46 EXPORT = 'EXPORT' .
47 EXTERNAL = 'EXTERNAL' .
48 FALSE = 'FALSE' .
```

```
49 FOR = 'FOR' .
50 FORMAT = 'FORMAT' .



51 FROM = 'FROM' .
52 FUNCTION = 'FUNCTION' .
53 GENERIC = 'GENERIC' .
54 GREATER-EQUAL-OPERATOR = '>=' .
55 GREATER-THAN-OPERATOR = '>' .
56 HIBOUND = 'HIBOUND' .
57 IF = 'IF' .
58 IN = 'IN' .
59 INCLUDE = 'INCLUDE' .
60 INCLUSIVE-OR-OPERATOR = 'OR' .



61 INFINITY = '#' .
62 INSERT = 'INSERT' .
63 INSTANCE-EQUAL-OPERATOR = ':=:' .
64 INSTANCE-NOTEQUAL-OPERATOR = ':<>:' .
65 INTEGER = 'INTEGER' .
66 INTERNAL = 'INTERNAL' .
67 LEFT-BRACKET = '[' .
68 LEFT-CURL = '{' .
69 LEFT-PAREN = '(' .
70 LESS-EQUAL-OPERATOR = '<=' .



71 LESS-THAN-OPERATOR = '<' .
72 LIKE = 'LIKE' .
73 LIST = 'LIST' .
74 LOBOUND = 'LOBOUND' .
75 LOCAL = 'LOCAL' .
76 LOG = 'LOG' .
77 LOG10 = 'LOG10' .
78 LOG2 = 'LOG2' .
79 LOGICAL = 'LOGICAL' .
80 MAP = 'MAP' .



81 MINUS = '-' .
82 MOD = 'MOD' .
83 MULTIPLY-OPERATOR = '*' .
84 NOT = 'NOT' .
85 NOT-EQUAL-OPERATOR = '<>' .
```

```
 86 NULL = 'NULL' .
 87 NULLIFY = 'NULLIFY' .
 88 NUMBER = 'NUMBER' .
 89 ODD = 'ODD' .
 90 OF = 'OF' .


 91 OPTIONAL = 'OPTIONAL' .
 92 OTHERWISE = 'OTHERWISE' .
 93 PI = 'PI' .
 94 PLUS = '+' .
 95 PROCEDURE = 'PROCEDURE' .
 96 REAL = 'REAL' .
 97 REAL-DIVIDE-OPERATOR = '/' .
 98 REPEAT = 'REPEAT' .
 99 RETURN = 'RETURN' .
100 RETYPE = 'RETYPE' .


101 RIGHT-BRACKET = ']' .
102 RIGHT-CURL = '}' .
103 RIGHT-PAREN = ')' .
104 RULE = 'RULE' .
105 SCHEMA = 'SCHEMA' .
106 SELECT = 'SELECT' .
107 SEMICOLON = ';' .
108 SET = 'SET' .
109 SIN = 'SIN' .
110 SIZEOF = 'SIZEOF' .


111 SKIP = 'SKIP' .
112 SQRT = 'SQRT' .
113 STRING = 'STRING' .
114 SUBTYPE = 'SUBTYPE' .
115 SUPERTYPE = 'SUPERTYPE' .
116 TAN = 'TAN' .
117 THEN = 'THEN' .
118 TO = 'TO' .
119 TRUE = 'TRUE' .
120 TYPE = 'TYPE' .


121 TYPEOF = 'TYPEOF' .
122 UNDERSCORE = '_' .
```

```
123 UNIQUE = 'UNIQUE' .
124 UNKNOWN = 'UNKNOWN' .
125 UNTIL = 'UNTIL' .
126 USES = 'USES' .
127 VALUE = 'VALUE' .
128 VAR = 'VAR' .
129 VARYING = 'VARYING' .
130 VIOLATION = 'VIOLATION' .



131 WHERE = 'WHERE' .
132 WHILE = 'WHILE' .
133 WITH = 'WITH' .
134 ADDITION-LIKE-OPERATIONS = PLUS-OPERATOR | MINUS-OPERATOR
    | OR-OPERATOR | CONCATENATION-OPERATOR .
135 AND-OPERATOR = AND .
136 ATTRIBUTE-ID = ID-SIMPLE .
137 BUILT-IN-FUNCTION-NAME = ABS | ACOS | ASIN | ATAN | COS | EXISTS
    | EXP | FORMAT | HIBOUND | LOBOUND | LOG | LOG10 | LOG2 | ODD
    | SIN | SIZEOF | SQRT | TAN | TYPEOF | VALUE .
138 BUILT-IN-PROCEDURE-NAME = INSERT | NULLIFY | VIOLATION .
139 CARDINALITY-OPERATOR = LIMIT-SPEC .
140 CONSTANT = FALSE | TRUE | UNKNOWN | PI .



141 DEFINED-TYPE-ID = ID-SIMPLE .
142 DIGIT = '0' | '1' | '2' | '3' | '4' | '5' | '6' | '7' | '8' | '9' .
143 DIVIDE-OPERATOR = INTEGER-DIVIDE-OPERATOR | REAL-DIVIDE-OPERATOR .
144 EMBEDDED-REMARK = '(*' { \A | \T | \N } '*)' .
145 ENTITY-ID = ID-SIMPLE .
146 EQUAL-OPERATOR = EQUAL .
147 FUNCTION-ID = BUILT-IN-FUNCTION-NAME | ID-SIMPLE .
148 ID = ID-SIMPLE | ID-QUALIFIED .
149 ID-CHAR = LETTER | DIGIT | UNDERSCORE .
150 ID-INDEXED = ID { SUBSCRIPT } .



151 ID-QUALIFIED = ID-INDEXED { DOT ID-INDEXED } .
152 ID-SIMPLE = LETTER { ID-CHAR } .
153 IN-OPERATOR = IN .
154 INTEGER-DIVIDE-OPERATOR = DIV .
155 INTEGER-LITERAL = DIGIT { DIGIT } .
156 LETTER = 'A' | 'B' | 'C' | 'D' | 'E' | 'F' | 'G' | 'H' | 'I' | 'J'
    | 'K' | 'L' | 'M' | 'N' | 'O' | 'P' | 'Q' | 'R' | 'S' | 'T' | 'U'
    | 'V' | 'W' | 'X' | 'Y' | 'Z' .
157 LIKE-OPERATOR = LIKE .
```

```
158 LITERAL = INTEGER-LITERAL | REAL-LITERAL | STRING-LITERAL
    | LOGICAL-LITERAL | CONSTANT .
159 LOCAL-ID = ID .
160 LOGICAL-LITERAL = TRUE | FALSE | UNKNOWN .



161 MAP-ID = ID-SIMPLE .
162 MINUS-OPERATOR = MINUS .
163 MODULO-OPERATOR = MOD .
164 MULTIPLICATION-LIKE-OPERATIONS = MULTIPLY-OPERATOR | DIVIDE-OPERATOR
    | MODULO-OPERATOR | AND-OPERATOR .
165 NOT-OPERATOR = NOT .
166 OR-OPERATOR = INCLUSIVE-OR-OPERATOR | EXCLUSIVE-OR-OPERATOR .
167 PLUS-OPERATOR = PLUS .
168 PROCEDURE-ID = BUILT-IN-PROCEDURE-NAME | ID-SIMPLE .
169 REAL-LITERAL = INTEGER-LITERAL DOT [ INTEGER-LITERAL ] [ 'E' [ SIGN ]
    INTEGER-LITERAL ] .
170 RELATIONAL-OPERATOR = LESS-THAN-OPERATOR | GREATER-THAN-OPERATOR
    | EQUAL-OPERATOR | LESS-EQUAL-OPERATOR | GREATER-EQUAL-OPERATOR
    | NOT-EQUAL-OPERATOR | INSTANCE-EQUAL-OPERATOR
    | INSTANCE-NOTEQUAL-OPERATOR .

171 RELATIONAL-OPERATOR-EXTENDED = RELATIONAL-OPERATOR | IN-OPERATOR
    | LIKE-OPERATOR | CARDINALITY-OPERATOR .
172 REMARK = EMBEDDED-REMARK | TAIL-REMARK .
173 RULE-ID = ID-SIMPLE .
174 SCHEMA-ID = ID-SIMPLE .
175 SIGN = PLUS | MINUS .
176 STRING-LITERAL = \Q { \A | ( \Q \Q ) } \Q .
177 TAIL-REMARK = '--' { \A | \T } \N .
178 ACTION-BODY = { BLOCK-MEMBER | LOCAL-DECL } ( STATEMENT } .
179 ACTUAL-PARAMETER-LIST = LEFT-PAREN EXPRESSION { COMMA EXPRESSION }
    RIGHT-PAREN .
180 AGGREGATE-TYPE = AGGREGATE LIMIT-SPEC OF [ UNIQUE ] ATTRIBUTE-CAN-BE .



181 AGGREGATION-TYPE = AGGREGATE-TYPE | ARRAY-TYPE | LIST-TYPE | SET-TYPE .
182 ARRAY-TYPE = ARRAY INDEX-SPEC OF [ OPTIONAL ] [ UNIQUE ] ATTRIBUTE-CAN-BE .
183 ASSIGNMENT-STATEMENT = ID ASSIGNMENT-OPERATOR EXPRESSION SEMICOLON .
184 ASSUME-DIRECTIVE = ASSUME LEFT-PAREN SCHEMA-ID { COMMA SCHEMA-ID }
    RIGHT-PAREN SEMICOLON .
185 ATTRIBUTE-CAN-BE = AGGREGATION-TYPE | BASE-TYPE | DEFINED-TYPE
    | ENTITY-TYPE | MAP-TYPE .
186 BASE-TYPE = INTEGER-TYPE | LOGICAL-TYPE | NUMBER-TYPE | REAL-TYPE
    | STRING-TYPE .
187 BLOCK-MEMBER = ENTITY-DECL | MAP-DECL | FUNCTION-DECL | PROCEDURE-DECL
    | RULE-DECL | SCHEMA-DECL | TYPE-DECL | DIRECTIVE .
```

188 CASE-ACTION = EXPRESSION { COMMA EXPRESSION } COLON STATEMENT .
189 CASE-BLOCK = CASE-ACTION { CASE-ACTION } [CASE-OTHERWISE] .
190 CASE-OTHERWISE = OTHERWISE COLON STATEMENT .

191 CASE-STATEMENT = CASE EXPRESSION OF CASE-BLOCK END-CASE SEMICOLON .
192 COMPOUND-STATEMENT = BEGIN { STATEMENT } END SEMICOLON .
193 DEFINE-DIRECTIVE = DEFINE DEFINED-TYPE-ID STRING-LITERAL SEMICOLON .
194 DEFINED-TYPE = DEFINED-TYPE-ID .
195 DERIVED-ATTRIBUTE = ATTRIBUTE-ID COLON RESULT-CAN-BE INITIALIZER SEMICOLON .
196 DERIVED-ATTRIBUTE-DECL = DERIVE DERIVED-ATTRIBUTE { DERIVED-ATTRIBUTE } .
197 DIRECTIVE = ASSUME-DIRECTIVE | DEFINE-DIRECTIVE | EXPORT-DIRECTIVE | INCLUDE-DIRECTIVE | USES-DIRECTIVE .
198 DUMMY-STATEMENT = SEMICOLON .
199 ENTITY-DECL = ENTITY ENTITY-ID [SUBSUPER-DECL] SEMICOLON [EXPLICIT-ATTRIBUTE-DECL] [DERIVED-ATTRIBUTE-DECL] [UNIQUE-RULE] [WHERE-RULE] END-ENTITY SEMICOLON .
200 ENTITY-TYPE = ENTITY-ID .

201 ENUMERATION-TYPE = ENUMERATION OF NESTED-ID-LIST .
202 ESCAPE-STATEMENT = ESCAPE SEMICOLON .
203 EXPLICIT-ATTRIBUTE = ID-LIST COLON [OPTIONAL] [EXTERNAL | INTERNAL | DYNAMIC] ATTRIBUTE-CAN-BE SEMICOLON .
204 EXPLICIT-ATTRIBUTE-DECL = EXPLICIT-ATTRIBUTE { EXPLICIT-ATTRIBUTE } .
205 EXPORT-DIRECTIVE = EXPORT (NESTED-ID-LIST | EVERYTHING | EVERYTHING EXCEPT NESTED-ID-LIST) SEMICOLON .
206 EXPRESSION = SIMPLE-EXPRESSION { RELATIONAL-OPERATOR-EXTENDED SIMPLE-EXPRESSION } .
207 FACTOR = SIMPLE-FACTOR [EXPONENTIATION-OPERATOR SIMPLE-FACTOR] .
208 FORMAL-PARAMETER = [VAR] ID-LIST COLON PARAMETER-CAN-BE .
209 FORMAL-PARAMETER-LIST = LEFT-PAREN FORMAL-PARAMETER { SEMICOLON FORMAL-PARAMETER } RIGHT-PAREN .
210 FUNCTION-CALL = FUNCTION-ID [ACTUAL-PARAMETER-LIST] { QUALIFICATION } .

211 FUNCTION-DECL = FUNCTION FUNCTION-ID [FORMAL-PARAMETER-LIST] COLON RESULT-CAN-BE SEMICOLON ACTION-BODY END-FUNCTION SEMICOLON .
212 GENERAL-AGGREGATION = (AGGREGATE | ARRAY | LIST | SET) OF PARAMETER-CAN-BE .
213 GENERIC-TYPE = GENERIC .
214 ID-LIST = ID-SIMPLE { COMMA ID-SIMPLE } .
215 IF-STATEMENT = IF EXPRESSION THEN STATEMENT { STATEMENT } [ELSE STATEMENT { STATEMENT }] END-IF .
216 INCLUDE-DIRECTIVE = INCLUDE STRING-LITERAL SEMICOLON .
217 INCREMENT-CONTROL = LOCAL-ID ASSIGNMENT-OPERATOR EXPRESSION TO EXPRESSION [BY EXPRESSION] .
218 INDEX-SPEC = LEFT-BRACKET EXPRESSION COLON EXPRESSION RIGHT-BRACKET .

219 INITIALIZER = ASSIGNMENT-OPERATOR EXPRESSION .
220 INTEGER-TYPE = INTEGER [PRECISION-SPEC] .

221 INTERVAL = LEFT-CURL EXPRESSION RELATIONAL-OPERATOR EXPRESSION
    RELATIONAL-OPERATOR EXPRESSION RIGHT-CURL .
222 LIMIT-SPEC = LEFT-BRACKET EXPRESSION COLON (EXPRESSION | INFINITY)
    RIGHT-BRACKET .
223 LIST-TYPE = LIST LIMIT-SPEC OF [UNIQUE] ATTRIBUTE-CAN-BE .
224 LOCAL-BODY-ITEM = ID-LIST COLON LOCAL-CAN-BE [INITIALIZER] SEMICOLON .
225 LOCAL-CAN-BE = AGGREGATION-TYPE | BASE-TYPE | DEFINED-TYPE | ENTITY-TYPE .
226 LOCAL-DECL = LOCAL { LOCAL-BODY-ITEM } END-LOCAL SEMICOLON .
227 LOGICAL-TYPE = LOGICAL .
228 MAP-DECL = MAP MAP-ID FROM ENTITY-ID [SUBSUPER-DECL] SEMICOLON
    { RETYPE-DECL } [UNIQUE-RULE] [WHERE-RULE] END-MAP SEMICOLON .
229 MAP-TYPE = MAP-ID .
230 NESTED-ID-LIST = LEFT-PAREN ID-LIST RIGHT-PAREN .

231 NUMBER-TYPE = NUMBER .
232 PARAMETER-CAN-BE = GENERIC-TYPE | GENERAL-AGGREGATION | BASE-TYPE
    | DEFINED-TYPE | ENTITY-TYPE | MAP-TYPE .
233 PRECISION-SPEC = LEFT-PAREN EXPRESSION RIGHT-PAREN .
234 PROCEDURE-CALL-STATEMENT = PROCEDURE-ID [ACTUAL-PARAMETER-LIST]
    SEMICOLON .
235 PROCEDURE-DECL = PROCEDURE PROCEDURE-ID [FORMAL-PARAMETER-LIST]
    SEMICOLON ACTION-BODY END-PROCEDURE SEMICOLON .
236 QUALIFICATION = { SUBSCRIPT } [DOT ID] .
237 REAL-TYPE = REAL [PRECISION-SPEC] .
238 REPEAT-CONTROL = INCREMENT-CONTROL | WHILE-CONTROL | UNTIL-CONTROL .
239 REPEAT-STATEMENT = REPEAT { REPEAT-CONTROL } SEMICOLON { STATEMENT }
    END-REPEAT SEMICOLON .
240 RESULT-CAN-BE = BASE-TYPE | DEFINED-TYPE | ENTITY-TYPE | MAP-TYPE |
   GENERIC-TYPE .

241 RETURN-STATEMENT = RETURN [LEFT-PAREN EXPRESSION RIGHT-PAREN] SEMICOLON
242 RETYPE-DECL = ID-LIST COLON RETYPE AS ATTRIBUTE-CAN-BE SEMICOLON
243 RULE-DECL = RULE RULE-ID FOR NESTED-ID-LIST SEMICOLON ACTION-BODY
    END-RULE SEMICOLON .
244 SCHEMA-DECL = SCHEMA SCHEMA-ID SEMICOLON { BLOCK-MEMBER } END-SCHEMA
    SEMICOLON .
245 SELECT-TYPE = SELECT NESTED-ID-LIST .
246 SET-CONSTRUCT = LEFT-BRACKET [EXPRESSION { COMMA EXPRESSION }]
    RIGHT-BRACKET .
247 SET-TYPE = SET [LIMIT-SPEC] OF ATTRIBUTE-CAN-BE .
248 SIMPLE-EXPRESSION = [SIGN] TERM { ADDITION-LIKE-OPERATIONS TERM } .
249 SIMPLE-FACTOR = LITERAL | FUNCTION-CALL | ID | SET-CONSTRUCT |

```
    LEFT-PAREN EXPRESSION RIGHT-PAREN | INTERVAL | NOT-OPERATOR SIMPLE-FACTOR .
250 SKIP-STATEMENT = SKIP SEMICOLON .

251 STATEMENT = ASSIGNMENT-STATEMENT | CASE-STATEMENT | COMPOUND-STATEMENT
    | DUMMY-STATEMENT | ESCAPE-STATEMENT | IF-STATEMENT
    | PROCEDURE-CALL-STATEMENT | REPEAT-STATEMENT | RETURN-STATEMENT
    | SKIP-STATEMENT | WITH-STATEMENT .
252 STRING-TYPE = STRING [ PRECISION-SPEC ] [ VARYING ] .
253 SUBSCRIPT = LEFT-BRACKET EXPRESSION RIGHT-BRACKET .
254 SUBSUPER-DECL = SUBTYPE-DECL [ SUPERTYPE-DECL ] | SUPERTYPE-DECL
    [ SUBTYPE-DECL ] .
255 SUBTYPE-DECL = SUBTYPE OF NESTED-ID-LIST .
256 SUPERTYPE-DECL = SUPERTYPE OF LEFT-PAREN SUPERTYPE-EXPRESSION RIGHT-PAREN .
257 SUPERTYPE-EXPRESSION = SUPERTYPE-FACTOR { ( AND-OPERATOR | OR-OPERATOR )
    SUPERTYPE-FACTOR } .
258 SUPERTYPE-FACTOR = ID-SIMPLE | NULL | LEFT-PAREN SUPERTYPE-EXPRESSION
    RIGHT-PAREN .
259 TERM = FACTOR { MULTIPLICATION-LIKE-OPERATIONS FACTOR } .
260 TYPE-CAN-BE = AGGREGATION-TYPE | BASE-TYPE | DEFINED-TYPE
    | ENUMERATION-TYPE | NUMBER-TYPE | SELECT-TYPE .

261 TYPE-DECL = TYPE TYPE-ITEM { TYPE-ITEM } END-TYPE SEMICOLON .
262 TYPE-ITEM = DEFINED-TYPE-ID EQUAL TYPE-CAN-BE SEMICOLON .
263 UNIQUE-RULE = UNIQUE { ID-LIST SEMICOLON } .
264 UNTIL-CONTROL = UNTIL EXPRESSION .
265 USES-DIRECTIVE = USES NESTED-ID-LIST SEMICOLON .
266 WHERE-RULE = WHERE { EXPRESSION SEMICOLON } .
267 WHILE-CONTROL = WHILE EXPRESSION .
268 WITH-STATEMENT = WITH ID STATEMENT .
```

A.13.2 EXPRESS Glossary

Attribute An essential property, trait, quality, or characteristic (of an entity).

BNF Baucus-Nauer Form. A method of defining the morphology of a grammar.

Constraint Same as rule.

Data The representation forms of information dealt with by information processing systems and users thereof.

Data Base Also database. See Information Base.

Entity An information unit that has a uniform meaning and behavior within a UoD.

Fact A fact is any assertion that can be proved (or is said) to be true for some UoD.

Grammar The system of rules that governs the use of a language; the morphology and semantics of a language.

ICAM Integrated Computer Aided Manufacturing. A project of the United States Air Force.

IGES Initial Graphic Exchange Specification.

Information Any kind of knowledge about things, facts, concepts, etc. that is exchangeable among users. Data that has meaning.

Information Base A consistent collection of data that can be interpreted and operated on by the information system.

Information System The system of elements including the schema, information base, hardware devices, and the user that forms a predictable mechanism for keeping and manipulating information.

PDDI Product Data Definition Interface.

PDES Product Data Exchange Specification.

Rule A procedure that enforces a fact.

Schema A consistent collection of statements expressing the necessary propositions that hold for some UoD. A description of a UoD.

STEP STandard for the Exchange of Product data.

Token An element (word) of a grammar, which can be distinguished from all other tokens.

Type A particular representation form of data such as an integer or a character string.

Universe of Discourse (UoD) A Universe of Discourse is an area of interest that is of importance to an individual or a group of individuals.

User Anybody or anything that issues messages to the information system and receives messages in return.

A.13.3 Case Study One

This case study deals with rooms, doors, and wharehousing of doors.

A door is either an interior door or an exterior door.

```
SCHEMA DOORS;
  ENTITY DOOR SUPERTYPE OF (INTERIOR_DOOR XOR EXTERIOR_DOOR);
  END_ENTITY;
  ENTITY INTERIOR_DOOR SUBTYPE OF (DOOR);
  END_ENTITY;
  ENTITY EXTERIOR_DOOR SUBTYPE OF (DOOR);
  END_ENTITY;
  ENTITY ROOM;
  END_ENTITY;
  SCHEMA WHAREHOUSING;
  END_SCHEMA;
  SCHEMA BUILDING_DESIGN;
  END_SCHEMA;
END_SCHEMA;
```

Title: The STEP File Structure

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THE STEP FILE STRUCTURE

DOCUMENT NUMBER: 4.2.1

VERSION: 12.0

TITLE: THE STEP FILE STRUCTURE

ABSTRACT:

This document identifies the physical file structure for a STEP exchange file.

KEY WORDS:

Section, Data Type, Entity, Tokens, Exchange Format, Character Set, Medium, File Structure

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THE STEP FILE STRUCTURE

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Table of Contents

Table of Contents

CHAPTER 1 - INTRODUCTION

1.0 <u>INTRODUCTION</u>

The Standard for the Exchange of Product Data (STEP) is a neutral exchange medium capable of completely representing product definition data. It has been designed to meet both present and future requirements for exchanging such data between dissimilar CAD/CAM/CAE/CIM Systems.

1.1 DOCUMENT ORGANIZATION

This document specifies the STEP file structure format and the initial STEP entity set. The STEP File Structure document consists of seven chapters.

CHAPTER 1: <u>INTRODUCTION</u> - This section identifies the purpose of this document.

CHAPTER 2: <u>EXCHANGE FORMAT OVERVIEW</u> - This section provides a high level overview of the STEP file structure.

CHAPTER 3: <u>FORMAL DEFINITIONS</u> - This section presents a formal description of the exact syntax of the STEP file structure.

CHAPTER 4: <u>TOKENS</u> - This section presents an informal description of the parsing tokens as they should be recognized by STEP processors.

CHAPTER 5: <u>STRUCTURED DATA TYPES</u> - This section presents an informal description of the Structured Data Types.

CHAPTER 6: <u>HEADER SECTION</u> - This section presents an informal description of the HEADER Section.

CHAPTER 7: <u>DATA SECTION</u> - This section presents an informal description of the DATA Section.

Appendices have been included to provide additional information and relevant examples.

CHAPTER 2 - EXCHANGE FORMAT OVERVIEW

2.0 EXCHANGE FORMAT OVERVIEW

2.1 THEORETICAL BASIS

The STEP file structure is language-based and is described by an unambiguous, context-free grammar to facilitate parsing by software. The grammar is expressed in Wirth Syntax Notation and is included in Chapter 3.0. The majority of this document is devoted to the logical and syntactical description of a STEP exchange file. See Appendix D for detailed descriptions of the format of the file on various exchange media.

2.2 GENERAL STRUCTURE

2.2.1 File Format

The STEP exchange file is a sequential file. The information contained within the file is in free format. There is no column-dependent information.

2.2.2 Organization

The STEP exchange file is organized in a modular manner. The file consists of several sections. These sections consist of one or many entities. An entity consists of attributes. These file components are defined below.

Sections	A section is a collection of data of the same functional category of information.
Entity	An entity is a collection of logically associated data.
Attribute	An attribute is a (data) fact about an entity. It is conceptually atomic (i.e., it represents a single fact) although it may be arbitrarily complex in structure. An entity is defined or described by its attributes.

2.2.3 High Level File Syntax

The STEP file is begun by "STEP;" and is terminated by "ENDSTEP;". Following the "STEP;", the HEADER and DATA sections will be added. These sections are described in subsections 2.3.1 and 2.3.2 of this document.

Additional sections may be added to the STEP file structure in the future in response to technological advances or industry requirements. Therefore, in order to preserve future compatibility, postprocessors should be prepared to encounter and ignore any information found before, between, or following file sections.

2.3 SECTIONS - FUNCTIONAL DESCRIPTIONS

Collections of data serving similar functions in the exchange are grouped into sections. There will be two sections in the STEP file structure: the HEADER section and the DATA section. Each section begins with a keyword and each section keyword is followed by a semicolon ";". The keywords for the two sections are listed below.

<u>Section</u>	<u>Keyword</u>
HEADER	HEADER
DATA	DATA

2.3.1 <u>HEADER Section</u>

The HEADER section provides information such as author and creation date, which is applicable to the entire exchange format file. The section is begun by "HEADER;" and is terminated by "ENDSEC;". This section must appear exactly once in the file and must be first in the file. For more information concerning the HEADER section, refer to Chapter 6.0 of this document.

2.3.2 <u>DATA Section</u>

The DATA section is used to define the product data to be transferred. It is a collection of occurrences of the standard types defined in the Conceptual Schema. The DATA section is begun by "DATA;" and is followed by DATA section entities. The DATA section is terminated by "ENDSEC;". This section must appear exactly once in the file. For more information concerning the DATA section, refer to Chapter 7.0 of this document.

CHAPTER 3 - FORMAL DEFINITIONS

3.0 FORMAL DEFINITIONS

3.1 FORMAL NOTATION

The STEP exchange format file may be considered as a continuous stream of characters from the basic alphabet. These can be collected into recognizable strings of characters called tokens.

The neutral file can therefore be considered as a sequence of tokens. The tokens can be formally defined by a regular set R(G) over the graphical alphabet G. STEP tokens are discussed in detail in Chapter 3.3.

3.1.1 WSN NOTATIONAL CONVENTIONS

The syntax of the STEP exchange file is defined in Wirth Syntax Notation (WSN). WSN was first described in a letter by Niklaus Wirth, which was published in Communications of the ACM, 20:11 (Nov 77), 822-823. The additional notational conventions are given below. Table 3-1 presents WSN defined in itself.

1. A string in uppercase (capital letters) is an element of the language; the string is the name of the element. In syntax diagrams, this corresponds to anything in a box with square corners. (For convenience, lowercase is used for undefined identifiers and commentary.)

2. Any string enclosed in double quotation marks (") is literally what is contained within the quotation marks. In syntax diagrams, this corresponds to anything in a box with curved corners. The one exception to this rule occurs when one wishes to specify a double quotation mark within a literal. In order to accomplish this, the double quotation mark is immediately repeated one time.

   (e.g., " " " " is interpreted as ")

3. The equals sign (=) indicates a production. The element on the left is defined to be the combination of the elements on the right. Any spaces appearing between the elements of a production are meaningless unless they appear within a quoted literal. A production is terminated by a period (.).

4. The semantics of the enclosing braces are defined below.

CURLY BRACKETS	--	"{}" indicates zero or more repetitions
SQUARE BRACKETS	--	"[]" indicate optional parameters
VERTICAL BAR	--	"|" indicates the logical OR
PARENTHESIS	--	"(" and ")" indicate priority operations. In particular, when they enclose elements separated by vertical bars, one of the elements is to be chosen in conjunction with any other operation.

e.g. A(B|C|D) = AB|AC|AD

Table 3-1 Wirth Syntax Notation (WSN)

```
SYNTAX          = { PRODUCTION }.

PRODUCTION      = IDENTIFIER "=" EXPRESSION ".".

EXPRESSION      = TERM { "|" TERM }.

TERM            = FACTOR { FACTOR }.

FACTOR          = IDENTIFIER
                | LITERAL
                | "{" EXPRESSION "}".

IDENTIFIER      = letter { letter }.

LITERAL         = """" character { character } """".
```

3.2 ALPHABET DEFINITION

The alphabet of the STEP neutral file language is defined as a set of bytes with integer values ranging from 32 to 126. The standard "ISO 6937/1 1983(E)" defines the correspondence of the neutral file alphabet into graphical representation on paper and terminals. This function is limited by the capability of the hardware to accommodate such transformation from code to graphics.

The correspondence of the neutral file alphabet into graphical representation is presented in Appendix B - The Graphical Alphabet within this document. To define the syntax of the neutral file language, only the graphical representation is used, where G(k) denotes the graphical representation of the byte with the decimal value "k". The international monetary symbol cannot be printed by the text system that generates this document. In its place, a dollar sign will appear.

3.2.1 ALPHABET SUBSETS

Table 3-2 Alphabet Subsets

```
SPACE          = " ".

DIGIT          = "0" | "1" | "2" | "3" | "4" | "5" | "6" | "7"
               | "8" | "9" .

LOWER          = "a" | "b" | "c" | "d" | "e" | "f" | "g" | "h"
               | "i" | "k" | "l" | "m" | "n" | "o" | "p" | "q"
               | "r" | "s" | "t" | "u" | "v" | "w" | "x" | "y"
               | "z" .

UPPER          = "A" | "B" | "C" | "D" | "E" | "F" | "G" | "H"
               | "I" | "K" | "L" | "M" | "N" | "O" | "P" | "Q"
               | "R" | "S" | "T" | "U" | "V" | "W" | "X" | "Y"
               | "Z" | "_" .

SPECIAL        = "!" | """" | "*" | "$" | "%" | "&" | "'" | "." | "#" | "+" |
               | "," | "-"  | "(" | ")" | "?" | "/" | ":" | ";" | "<" | "=" |
               | ">" | "@"  | "[" | "\" | "]" | "{" | "|" | "}" | "~" | "^" |
               | "`" .

ALPHABET       = SPACE | DIGIT | LOWER | UPPER | SPECIAL.
```

3.3 TOKENS DEFINED BY REGULAR EXPRESSIONS

The following regular expressions in Table 3-3 will refer to those regular expressions defined previously in Table 3-2 Alphabet Subsets. The tokens that are intended to be recognized during lexical analysis are given below in the TOKEN definition. Please note that this TOKEN definition has been supplied only as a convenience to the reader, it will not be referenced by the WSN description of the file.

TOKEN = DELIMITER|RESERVED WORD|KEYWORD|INTEGER|REAL|STRING|COMMENT ENTITY_IDENTIFIER|ENUMERATION|ENTITY

Table 3-3 Token Definition (1 of 2)

COMMENT	= "/*" any_sequence_except_*_followed_by_/ "*/".
DELIMITER	= "(" | ")" | "," | ";" | "/" | "=" | "ENDSEC;" | "ENDSTEP;".
KEYWORD	= UPPER{UPPER|DIGIT}|"!" UPPER{UPPER|DIGIT}.
SIGN	= "+" | "-".
INTEGER	= [SIGN] DIGIT { DIGIT }.
REAL	= [SIGN] DIGIT { DIGIT } "." { DIGIT } ["E" [SIGN] DIGIT { DIGIT }].
NON_Q_CHAR	= any_character_from_the_alphabet_except_the_single_apostrophe.
QUOTE_CHAR	= "''".
ESC_CHAR	= "!:!:".
ESC_ITEM	= "ISO6937" | "GREEK" | "KANJI" | INTEGER.
ESC_SEQ	= "!: [ESC_ITEM { "," ESC_ITEM }] ":!".
STRING	= "'"{ NON_Q_CHAR | QUOTE_CHAR | ESC_CHAR | ESC_SEQ }"'".

Table 3-3 Token Definition (2 of 2)

ENTITY_NAME	= DIGIT [DIGIT [DIGIT [DIGIT [DIGIT [DIGIT = [DIGIT [DIGIT [DIGIT]]]]]]]].
ENTITY_IDENTIFIER	= "@" ENTITY_NAME.
ENTITY_REFERENCE	= "#" ENTITY_NAME.
ENUMERATION	= "." UPPER{UPPER|DIGIT} ".".

3.4 WSN OF THE STEP FILE STRUCTURE

Table 3-4 identifies the WSN for the syntax of a STEP file. This WSN does not take into account any particular conceptual schema, but represents the physical structure for all possible conceptual schemata.

This syntax includes the tokens defined in section 3.3 of this document and corresponds to the syntax diagrams in Appendix C of this document.

Table 3-4 WSN of the STEP File Structure

EXCHANGE_FILE	= "STEP;" HEADER_SECTION DATA_SECTION "ENDSTEP;".
HEADER_SECTION	= "HEADER;FILE_IDENTIFICATION(" STRING "," STRING "," STRING "," STRING "," STRING "," STRING "," STRING ");FILE_DESCRIPTION(" STRING ");IMP_LEVEL(" STRING ");" HEADER_ENTITY_LIST "ENDSEC;".
HEADER_ENTITY_LIST	= HEADER_ENTITY | HEADER_ENTITY_LIST HEADER_ENTITY.
HEADER_ENTITY	= KEYWORD "(" PARAMETER_LIST ")" ";".
PARAMETER_LIST	= PARAMETER | PARAMETER_LIST "," PARAMETER.
PARAMETER	= INTEGER | REAL | STRING | ENTITY_REFERENCE | ENUMERATION | LIST | EMBEDDED_ENTITY.
LIST	= "(" ([INTEGER]{ "," [INTEGER]} |[REAL]{ "," [REAL]} |[STRING]{ "," [STRING]} |[ENUMERATION]{ "," [ENUMERATION]} |[LIST]{ "," [LIST]}) |[ENTITY]{ "," [ENTITY]} ")".
DATA_SECTION	= "DATA;" ENTITY_OCCUR_LIST "ENDSEC;".
ENTITY_OCCUR_LIST	= ENTITY_OCCURRENCE | ENTITY_OCCUR_LIST ENTITY_OCCURRENCE.
ENTITY_OCCURRENCE	= ENTITY_IDENTIFIER "=" EMBEDDED_ENTITY ";".
EMBEDDED_ENTITY	= [KEYWORD [" SCOPE" ENTITY_OCCUR_LIST "ENDSCOPE" [ENTITY_EXPORT_LIST]]] "(" PARAMETER_LIST ")".
ENTITY_EXPORT_LIST	= "/" ENTITY_REFERENCE {"," ENTITY_REFERENCE} "/".

CHAPTER 4 - TOKENS

4.0 TOKENS

A STEP file can be represented by a sequence of tokens. In the STEP file structure, a token is defined to be a delimiter, reserved word, keyword, or simple data type. The definition of the tokens in regular expression form can be found in Chapter 3.0 of this document. Syntax diagrams for the simple data types can be found in Appendix C of this document.

4.1 TOKEN SEPARATORS

A token separator is a character or a string of characters that can appear between any two tokens. Any number or combination of token separators may appear together between any two tokens. Token separators are insignificant and should be ignored during lexical analysis. Token separators may not appear within integers, real numbers, lists, entity references, entity identifiers, reserved words, keywords, or delimiters.

Blanks and comments are token separators. The blank is the space character. A comment is a slash followed by an asterisk "/*" followed by any number of characters, and terminated by an asterisk immediately followed by a slash "*/". Any characters appearing inside a comment are meaningless to the file structure. These characters are intended to be read by humans.

4.2 DELIMITERS

Delimiters are special characters or combinations of special characters that serve to separate, terminate, or otherwise denote meaningful collections of data. Note that some reserved words function as delimiters. Delimiters are listed in Table 4-1

Table 4-1 Delimiters

CHARACTER(S)	DELIMITER	FUNCTION
SCOPE	reserved word	Begins a scope section
ENDSCOPE	reserved word	Terminates a scope section
,	comma	Separates fields
;	semicolon	Terminates an entity occurrence
=	equal sign	Separates identifier from entity type keyword
( )	parenthesis	Encloses a list, set, array or parameter list
ENDSEC;	reserved word	Terminates a section
ENDSTEP;	reserved word	Terminates a STEP file
/*	slash-asterisk	Begins a comment
*/	asterisk-slash	Terminates a comment
/	slash	Encloses an entity export list

4.3 RESERVED WORDS

Reserved words are special strings of characters associated with pre-designated meanings or functions. Reserved words consist of uppercase letters, digits, underscore characters, and possibly a semicolon. The first character must be a letter. Only the last character may be a semicolon. Throughout this document, a reserved word or keyword is expressed in uppercase letters. These reserved words as a whole or their leading portion (not including the semicolon) cannot be used in entity type keywords.

List of Reserved Words:

SCOPE
ENDSCOPE
DATA;
ENDSEC;
STEP;
HEADER;
ENDSTEP;

4.4 KEYWORDS

Keywords are special strings of characters indicating the occurrence of an entity of a specific type on the STEP file. Keywords consist of uppercase letters, digits, underscore characters, and possibly an exclamation mark. The exclamation mark may occur at most once, and only as the first character in a keyword. Keywords beginning with the exclamation mark are "user-defined entity" keywords. Keywords not beginning with the exclamation mark are standard keywords. The first character in standard keywords as well as the second character of user-defined entity keywords (which is the first one following the exclamation mark) must be an uppercase letter.

The meaning of the user-defined entity keywords is not defined in the standard but is rather a matter of agreement among the partners exchanging STEP files.

The standard keywords are specified with respect to their appearance in the STEP file and with respect to their meaning in this standard. For the header section entities, this specification is given in chapter 6 of this document. For the data section entities, the appearance is defined by the mapping of EXPRESS ENTITIES onto the STEP file format as given in Appendix C. Their semantic meaning is specified in STEP DOCUMENT 4.1.2.

4.5 SIMPLE DATA TYPES

There are six simple data types utilized in STEP exchange format files: integer, real, string, entity identifier, entity reference, and enumeration. The detailed definitions of the data types are presented on the following pages.

4.5.1 Integer

An integer is a string of one or more digits, optionally preceded by a minus sign "-" or a plus sign "+". Integers are expressed in base 10. If there is no sign associated with the integer, it is assumed to be positive.

Examples:

Valid STEP Expressions of Integer	REMARKS
16	Positive 16
+12	Positive 12
-349	Negative 349
012	Positive 12
00	Zero

Invalid STEP Expressions of Integer	REMARKS
26 54	Contains blanks
32.0	Contains decimal point
+ 12	Contains blank between sign and digits

4.5.2 Real

A Real consists of a required decimal mantissa followed by an optional decimal exponent. The mantissa consists of an optional plus sign "+" or minus sign "-", followed by a string of one or more digits, followed by a decimal point ".", followed by a string of zero or more digits. A decimal exponent consists of the character E followed by an optional plus "+" or minus "-" sign, followed by one or more digits.

Examples:

Valid STEP Expressions of Real	REMARKS
+0.0E0	0.0
-0.0E-0	0.0, as above example
1.5	1.5
-32.178E+02	-3217.8
0.25E8	25 million
0.E25	0.0
2.	2.0
05.	5.0

Invalid STEP Expressions of Real	REMARKS
1.2E3.	Decimal point not allowed in exponent
1E05	Decimal point required in mantissa
1,000.00	Comma not allowed
3.E	Digit(s) required in exponent
.5	At least one digit must precede decimal point
1	Decimal point required in mantissa

4.5.3 String

A string consists of an apostrophe "'", followed by zero or more characters, and ended by a single apostrophe "'". The null string is defined by two apostrophes in a row. Within a string, a single apostrophe is coded as two apostrophes in a row. The default characters to be used within a string are the printable characters defined by the table entries 32 through 126 (inclusive) of ISO 6937/2. This table is presented in Appendix B of this document. Four examples are listed below.

String	Contents
'CAT'	CAT
'Don''t'	Don't
''''	'
''	Null

4.5.3.1 Alternate Character Sets

An alternate character set may be used if an escape sequence is coded into the character string. A description of a character string that contains an escape sequence is defined as follows:

1. A single apostrophe to start the character string.
2. Any number of characters from the default character set.
3. A single exclamation point immediately followed by a single colon to open or begin the escape sequence.
4. A reserved word to indicate the character set table to be used (e.g., GREEK or KANJI).
5. A comma to delimit the reserved word.

6. An integer value that corresponds to the table index of the desired character in the character set table.

7. A comma to delimit the integer value.

8. Successive integer values, each separated from the next by a comma.

9. The final integer value corresponding to a table index for the desired character.

10. The closing escape sequence character pair (i.e., a single colon immediately followed by an exclamation point).

11. Any additional characters or escape sequences.

12. A single apostrophe to close the character string.

In order to avoid being interpreted as an escape sequence, the character "!:" must be encoded in a normal character string by being repeated once as a pair, (e.g., "!:!:").

The recognized character set tables and their associated reserved words are presented in Appendix B.

4.5.3.2 Maximum String Length

The maximum length of a string in a STEP file is 32767 characters not counting the beginning and ending apostrophes.

4.5.4 Entity Identifier

An entity identifier consists of an at sign "@" followed by an unsigned integer. The integer may consist of any combination of 1 to 9 digits as long as uniqueness within the file is maintained. Leading zeroes in entity identifiers are not significant. The entity identifier is not based on a relative record position. They need not be sequentially ordered in the file. (See Section 7.1).

Valid STEP Expressions of Entity Identifiers	REMARKS
@23	Names this entity with identifier 23
@012	Names this entity with identifier 12

Invalid STEP Expressions of Entity Identifier	REMARKS
@+23	Contains '+' sign
@500.1	Contains decimal point

4.5.5 Entity Reference

An entity reference consists of a number sign "#", followed by an unsigned integer. The integer may consist of any combination of 1 to 9 digits. This integer value must equal the integer value within some previously defined entity identifier. The entity reference is not based on a relative record position. Leading zeroes are not significant.

Examples:

Valid STEP Expressions of Entity References	REMARKS
#23	Refers to entity occurrence with identifier 23
#023	Refers to entity occurrence with identifier 23
#694376142	Refers to entity occurrence with identifier 694376142

Invalid STEP Expressions of Entity References	REMARKS
74	Does not begin with a number sign
#439A6	Contains alphabetic character
#1234567890	Exceeds nine digits
#0000000009	Exceeds nine digits

4.5.6 Enumeration

An enumeration value consists of some combination of uppercase letters or digits beginning with an uppercase letter. The entire collection of uppercase letters and digits is bracketed by periods. The meaning of a given value is determined by the conceptual schema which defined the enumerated list.

Examples:

Valid STEP Expressions of Enumerated Values	REMARKS
.FALSE.	Indicates a value of FALSE
.STEEL.	Indicates a value of STEEL

Invalid STEP Expressions of Enumerated Values	REMARKS
.TRUE	Missing ending period
.123.	Did not start with an alphabetic character.

CHAPTER 5 - STRUCTURED DATA TYPES

5.0 STRUCTURED DATA TYPE

The list is the only structured data type in the STEP file structure.

5.1 LIST

A list is a homogeneous collection of instances of simple or structured data types. It is begun by a left parenthesis "(" and terminated by a right parenthesis ")". Instances are delimited by commas. Lists may be nested arbitrarily deep.

Examples:

```
List of List of Real  = ((0.0, 1.0, 2.0), (3.0, 4.0, 5.0))
List of Integer       =  (0,1,2,3,7,2,4)
List of String        =  ('CAT', 'HELLO')
```

CHAPTER 6 - HEADER SECTION

6.0 HEADER SECTION

The HEADER section contains information that is applicable to the entire exchange format file. This section must be present in any STEP file. Refer to Appendix A for a complete example.

6.1 HEADER SECTION ENTITIES

These entities are to aid in the overall data exchange process. The HEADER section entities follow the same general syntax of the DATA section entities, which simplifies postprocessor parsing software. HEADER section entity occurrences are defined in the following manner:

ENTITY_TYPE (one or more attributes);

where

Entity Type - A keyword through which the type of the entity is identified. The keywords correspond to those listed in Table 6-1. The keyword is delimited by a left parenthesis "(".

Attribute - An instance of a simple or structured data type. The correspondence of attributes and keywords is maintained in Table 6-1. Attributes are separated by commas. The final attribute is delimited by a right parenthesis ")".

Table 6-1 Keyword-To-Attribute Relationships

HEADER SECTION ENTITY DEFINITIONS

ENTITY KEYWORD	ATTRIBUTE NAME	DATATYPE	ATTRIBUTE POSITION	STATUS OF ENTITY OR ATTRIBUTE	DESCRIPTION
FILE_IDENTIFICATION				Required	
	FILE NAME	String	1	Required	This string of characters is used to name this STEP file. It is intended to be used as a person-to-person communication between sender and receiver. There are no special restrictions on the content of this field.
	DATE	String	2	Required	This identifies the local date and time the file was created, expressed as YYYY MM DD HH MM SS This format corresponds to one of those specified in ISO Standard 2016.
	AUTHOR	List of String	3	Required	This identifies the person responsible for creating the exchange format file and the mailing address of that person.
	ORGANIZATION	List of String	4	Required	This identifies the group or organization with whom the author is associated.
	STEP VERSION	String	5	Required	This indicates the STEP version used in creating the file.
	PREPROCESSOR VERSION	String	6	Required	This identifies the preprocessor software used to create the STEP file. It includes the software product name and version.
	ORIGINATING SYSTEM	String	7	Required	This identifies the CAD/CAM/CIM system from which the data in this STEP file originated.
FILE_DESCRIPTION				Required	
	DESCRIPTION	String	1	Required	This is an informal description of the contents of this STEP file.
IMP_LEVEL				Required	
	IMPLEMENTATION LEVEL	String	1	Required	This indicates the required implementation level of the postprocessor software in order for it to completely process all of the data in this STEP file. The actual values for this will be determined at a later date.
CLASSIFICATION				Optional	
	SECURITY CLASSIFICATION	String	1	Required	This identifies the restrictions on the use of the information contained in this file. The default is an empty string.
MAXSIG				Optional	
	MAXIMUM SIGNIFICANT DIGIT	Integer	1	Required	This indicates the number of decimal digits of significance that can be represented accurately on this file.

6.1.1 HEADER Section User Defined Entities

User defined entities may be placed into the HEADER section under specific restrictions. Post-processor translator software should be prepared to ignore those entities it does not recognize. This precaution will allow the future introduction of new HEADER section entities without adversely affecting any existing translator software.

The four restrictions that limit the specification of user defined entities are listed below.

1. User defined entities must conform to the same general syntax of all HEADER section entities with the exception that the entity-type keyword is immediately preceded by an exclamation point "!".
2. User defined entities may not appear as embedded entities within a standard entity.
3. User defined entities may only be embedded within other user defined entities.
4. User defined entities may not use any delimiters, simple data types, or structured data types beyond those defined in the standard.

Example

```
HEADER;
        .
        .
        .
IMP_LEVEL ('BREP - LEVEL 1.0');
!A_SPECIAL_ENTITY ('ABC',123);    /* SAMPLE USER DEFINED ENTITY */
        .
        .
        .
ENDSEC;
```

CHAPTER 7 - DATA SECTION

7.0 DATA SECTION

The DATA section is used to define the product data to be transferred. It contains occurrences of entities defined in the STEP conceptual schema. This section must appear in the file. Throughout the DATA section, entity occurrences must be defined before they may be referenced. Refer to Appendix A for a complete example.

7.1 DATA SECTION ENTITIES

DATA section entity occurrences are defined in the following manner:

ENTITY_IDENTIFIER = ENTITY_TYPE optional SCOPE Structure (one or more attribute values);

where

Entity Identifier -	Refer to the definition given in section 4.5.4.
Entity Type -	A keyword through which the type of the entity is identified. The keyword is delimited by a left parenthesis "(",or a space " ". These keywords correspond to the entities defined in the conceptual schema. Refer to the definition given in section 4.4.
Optional SCOPE Structure	See the discussion in Chapter 7.2.
Attribute -	An instance of a simple or structured data type, or an instance of an embedded entity. Attributes are separated by commas. The final attribute is delimited by a right parenthesis ")". The entire entity occurrence is delimited by a semicolon ";".
Embedded Entity -	An embedded entity is an entity that is serving as an attribute of the entity in which it is embedded. Syntactically, it appears like an entity occurrence that is missing the entity identifier, the equal sign "=", and the final semicolon ";". Under circumstances described in Normative Annex C, the entity type keyword may be omitted. The significance of an embedded entity is discussed within Normative Annex C, "Mapping From EXPRESS To Physical File Structure".

7.1.1 Optional Values

When an optional attribute value is not provided, all delimiters that would normally appear when the value is present will be maintained.

```
Example:   @32 = NODE(1.0,,2.0,'ABC');
                         |
                         This entity has an optional second attribute value
                         that is not provided in this occurrence.
```

7.2 SCOPE STRUCTURE

The SCOPE structure within entity definitions is a mechanism for providing a scope of reference.

7.2.1 Syntax

The SCOPE structure is optional for all entity types. If it appears, it must appear following the entity type keyword and before the actual defining attributes of the entity in which it is appearing. It is begun by the reserved word "SCOPE". Following that are any number of entity occurrences. Syntactically, it is legal for the entity occurrences to be of any type of entity. The structure is terminated by the reserved word "ENDSCOPE". After the ENDSCOPE reserved word, an optional entity export list may appear. Entities within a scope structure may themselves have scope sections. See Chapter 3.4 for the formal syntactical descriptions.

7.2.2 Referencability

In a similar manner to the scoping of variables in common structured programming languages, entities defined in a SCOPE structure are not "visible" to, or referencable by, entities that reside in outer scopes unless they are explicitly made "visible" by means of their inclusion in the entity export list. The defining attributes of the entity may refer to any entity occurrences in its SCOPE structure. Entities which need to be "shared" i.e., multiply referenced, by a number of entities, need to be defined within a scope that is common to the referencing entities.

7.2.3 Behavior

The behavior of entity occurrences which appear within a SCOPE structure is defined as follows:

- o Modifications of the parent entity will be passed onto the scoped entity(s) if and only if that modification is applicable to the scoped entity(s). For example, transformation of the parent entity will transform all the scoped entities to which the transformation operation applies; deletion of the parent entity will delete all the scoped entities (deletion applies to entities of any type). Approval of the parent entity will approve all the scoped entities to which this operation applies.

- o Scoped entity occurrences made "visible" by the entity export list are considered in the same scope of reference as the parent entity. Other entities, capable of referencing the parent entity, may legally reference the entities appearing in the entity export list.

- o When modifications to an exported entity conflict with modifications performed on the parent entity, the modifications on the parent entity will take precedence. For example, if an exported entity is referenced by a given transformation matrix (TM_1), and the parent entity is referenced by a different transformation matrix (TM_2), the exported entity is transformed by TM_2 and not TM_1.

Some examples of the use of scoping follow:

Example 1

```
@1  = TRIANGLE
      SCOPE
@2  = POINT (0.0,0.0,0.0);
@3  = POINT (0.0,1.0,0.0);
@4  = POINT (3.0,1.0,0.0);
      ENDSCOPE
      (LINE(#2,#3),LINE(#3,#4),LINE(#4,#2));
```

In the above example the entity TRIANGLE is defined by three LINE entities. Since the LINE entities are embedded within the TRIANGLE, they have an existence dependency upon the TRIANGLE. The POINT entities which define the lines are also dependent upon the TRIANGLE for their existence. Since the POINT entities have entity identifiers, they are available to be referenced by the embedded LINE entities in the attribute list.

Example 2

```
@1  = ASSEMBLY
      SCOPE
@12 = PART ('PART #74A',,,);
@13 = PART ('PART #68B',,,);
@14 = PART ('PART #12C',,,);
       .
       .
       .
      ENDSCOPE/#13, #14/
      ((#6,#7),,,);
@15 = APPROVAL ((#13), 'JOHN SMITH APP. AUTHORITY');
```

In the above example, the PART entities with entity identifiers @13 and @14 are exported, or made referencable, from the SCOPE structure of the ASSEMBLY entity. Following the defining attributes of the ASSEMBLY entity, an APPROVAL entity occurs which references the PART entity with entity identifies @13. In this case, it is only that particular PART entity which is approved, while at the same time maintaining the existence dependency of that PART entity upon its parent ASSEMBLY.

7.3 EXTERNAL REFERENCES

An external reference is the mechanism by which an entity in a STEP file may refer to information that is physically external to the STEP file being processed. The type of information that is referred to can be of any type, not necessarily geometric in nature. An external reference can be thought of as an extension of the basic entity reference capability that has already been provided (see Chapter 4.5.5). A number of specialized entities have been formulated to support external references. Specifically, these are the EXPORT, LIBRARY, and EXTERNAL REFERENCE entities. Their definitions and the details of their use can be found in the Conceptual Schema document (STEP document 4.1.2).

7.4 INDEX OF ENTITY ALIASES

An INDEX entity has been formulated which allows the establishment of a character string alias(s) for a given entity. Its definition and the details of its use can be found in the Conceptual Schema document (STEP document 4.1.2).

7.5 DATA SECTION USER DEFINED ENTITIES

User defined entities may be placed into the DATA section under specific restrictions. Post-processor translator software should be prepared to ignore those entities it does not recognize. This precaution will allow the future introduction of new DATA section entities without adversely affecting any existing translator software.

The four restrictions that limit the specification of user defined entities are listed below.

1. User defined entities must conform to the same general syntax of all DATA section entities with the exception that the entity-type keyword is immediately preceded by an exclamation point "!".

2. User defined entities may not appear as embedded entities within a standard entity.

3. User defined entities may only be embedded within other user defined entities.

4. User defined entities may not use any delimiters, simple data types, or structured data types beyond those defined in the standard.

EXAMPLE

```
    DATA;
         .
         .
         .
    @1=PT(1.0,2.0,3.0);      /* STANDARD POINT ENTITY */
    @2=PT(1.0,2.0,5.0);
         .
         .
         .
    @12=!MYCURVE(0.0,0.0,0.0,1.0,,,);    /* SAMPLE USER DEFINED ENTITY */
         .
         .
         .
    ENDSEC;
```

N279

APPENDIX A - SAMPLE STEP EXCHANGE FORMAT FILE

A.1 STEP FILE FORMAT

An example STEP file is presented below.

```
STEP;
HEADER;
FILE_IDENTIFICATION('EXAMPLE STEP FILE #1','19880211.153000',('JOHN DOE' 'ACME
INC.' 'METROPOLIS USA'),('ACME INC. A SUBSIDIARY OF GIANT INDUSTRIES'
'METROPOLIS USA'),'STEP VERSION 1.0','CIM/STEP VERSION2','SUPER CIM SYSTEM
RELEASE 4.0');
FILE_DESCRIPTION('THIS FILE CONTAINS A SMALL SAMPLE STEP MODEL');IMP_LEVEL
('BREP-LEVEL 1.0');
ENDSEC;
DATA;
/*
   THE FOLLOWING 13 ENTITIES REPRESENT A TRIANGULAR EDGE LOOP       */
@1=PT(0.0,0.0,0.0);     /* THIS IS A POINT ENTITY */
@2=PT(0.0,1.0,0.0);
@3=PT(1.0,0.0,0.0);
@11=VX(#1);             /* THIS IS A VERTEX ENTITY */
@12=VX(#2);
@13=VX(#3);
@16=ED(#11,#12);        /* THIS IS AN EDGE ENTITY */
@17=ED(#11,#13);
@18=ED(#13,#12);
@21=ED_STRC(#17,0);     /* THIS IS AN EDGE STRUCTURE ENTITY */
@22=ED_STRC(#18,0);
@23=ED_STRC(#16,1);
@24=ED_LOOP((#21,#22,#23));   /* THIS IS AN EDGE_LOOP ENTITY */

/*
   ANOTHER WAY OF REPRESENTING THE TRIANGULAR EDGE_LOOP FOLLOWS:       */
@110=VX(PT(0.0,0.0,0.0));
@120=VX(PT(0.0,1.0,0.0));
@130=VX(PT(1.0,0.0,0.0));
@160=ED(#110,#120);
@170=ED(#110,#130);
@180=ED(#130,#120);
@240=ED_LOOP((ED_STRC(#170,0),ED_STRC(#180,0),ED_STRC(#160,1)));
```

(Continued on next page)

(STEP file example continued)

```
/*
   YET ANOTHER WAY OF REPRESENTING THE TRIANGULAR EDGE_LOOP FOLLOWS:      */
@1100=VX(PT(0.0,0.0,0.0));
@1200=VX(PT(0.0,1.0,0.0));
@1300=VX(PT(1.0,0.0,0.0));
@2400=ED_LOOP
      SCOPE
      @1600=ED(#1100,#1200);
      @1700=ED(#1100,#1300);
      @1800=ED(#1300,#1200);
      ENDSCOPE
      ((ED_STRC(#1700,0),ED_STRC(#1800,0),ED_STRC(#1600,1)));
/*  OTHER SYNTACTICAL REPRESENTATIONS WERE POSSIBLE.  THE PREVIOUS THREE
      EXAMPLES ARE REPRESENTATIVE OF COMMON APPROACHES.  IT SHOULD BE NOTED
      THAT EACH APPROACH PRESENTED HERE CARRIES DIFFERENT SEMANTICS.*/

ENDSEC;
ENDSTEP;
```

NOTE: This example STEP file has been presented in a line-oriented or record-oriented manner in order to aid readability. Unnecessary spaces have also been added to aid readability. Note that an ordinary STEP file is not aligned in this manner, but is instead a continuous stream of characters.

APPENDIX B - THE GRAPHICAL ALPHABET

B.0 THE GRAPHICAL ALPHABET

The graphical alphabet of this standard comprises an extendible set of alphabets. Each alphabet is identified by a reserved word. Each alphabet contains:

1) a listing of the graphical representations of all symbols of the alphabet.

2) an algorithm that uniquely maps each of these symbols onto a positive integer (called decimal coded character, DCC).

The representation of these DCC's on the physical file is subject to the various presentation techniques allowed in this standard (see Appendix D of this document). At this time, only the "clear text encoding" is defined (see also ESC_CHAR, ESC_SEQ, and ESC_ITEM in Table 3-3 "Token definition").

At this time the following alphabets are defined:

Reserved Word	meaning
-	the basic character set
ISO6937	the Latin alphabet
GREEK	the Greek alphabet
KANJI	the Kanji alphabet

Other alphabets will be included in this standard:

an alphabet for drafting symbols
alphabets for various other applications

B.1 BASIC CHARACTER SET (Escape Sequence Reserved Word = ISO6937)

The character set used to encode STEP files is ASCII defined by ISO 6937/1. Furthermore, only the printable characters defined by the table entries 32 through 126 (inclusive) are ever allowed within a STEP file.

The decimal value of the alphabet element appears in the first line of each pair of lines illustrated below. The graphical representation of the alphabet element appears in the second line where G(i) denotes the graphical representation of the decimal i. The international monetary symbol cannot be printed in the text system that generates this report, therefore a dollar sign is shown for G(36).

Table B-1 Graphical Character Set

32	33	34	35	36	37	38	39	40	41	42	43	44
SPACE	!	"	#	$	%	&	'	(	)	*	+	,
45	46	47	48	49	50	51	52	53	54	55	56	57
-	.	/	0	1	2	3	4	5	6	7	8	9
58	59	60	61	62	63	64	65	66	67	68	69	70
:	;	<	=	>	?	@	A	B	C	D	E	F
71	72	73	74	75	76	77	78	79	80	81	82	83
G	H	I	J	K	L	M	N	O	P	Q	R	S
84	85	86	87	88	89	90	91	92	93	94	95	96
T	U	V	W	X	Y	Z	[	\	]	^	_	`
97	98	99	100	101	102	103	104	105	106	107	108	109
a	b	c	d	e	f	g	h	i	j	k	l	m
110	111	112	113	114	115	116	117	118	119	120	121	122
n	o	p	q	r	s	t	u	v	w	x	y	z
123	124	125	126									
{	|	}	~									

B.1.1 Subsets

The range of characters, 32 through 126, are further refined into the following subsets.

B.1.2 Digit

ASCII Decimal Number	Character	Meaning
48	0	Zero
49	1	One
50	2	Two
51	3	Three
52	4	Four
53	5	Five
54	6	Six
55	7	Seven
56	8	Eight
57	9	Nine

B.1.3 Upper

ASCII Decimal Number	Character	Meaning
65	A	UPPERCASE A
66	B	UPPERCASE B
67	C	UPPERCASE C
68	D	UPPERCASE D
69	E	UPPERCASE E
70	F	UPPERCASE F
71	G	UPPERCASE G
72	H	UPPERCASE H
73	I	UPPERCASE I
74	J	UPPERCASE J
75	K	UPPERCASE K
76	L	UPPERCASE L
77	M	UPPERCASE M
78	N	UPPERCASE N
79	O	UPPERCASE O
80	P	UPPERCASE P
81	Q	UPPERCASE Q
82	R	UPPERCASE R
83	S	UPPERCASE S
84	T	UPPERCASE T
85	U	UPPERCASE U
86	V	UPPERCASE V
87	W	UPPERCASE W
88	X	UPPERCASE X
89	Y	UPPERCASE Y
90	Z	UPPERCASE Z
95	_	Underscore

B.1.4 Lower

ASCII Decimal Number	Character	Meaning
97	a	lowercase A
98	b	lowercase B
99	c	lowercase C
100	d	lowercase D
101	e	lowercase E
102	f	lowercase F
103	g	lowercase G
104	h	lowercase H
105	i	lowercase I
106	j	lowercase J
107	k	lowercase K
108	l	lowercase L
109	m	lowercase M
110	n	lowercase N
111	o	lowercase O
112	p	lowercase P
113	q	lowercase Q
114	r	lowercase R
115	s	lowercase S
116	t	lowercase T
117	u	lowercase U
118	v	lowercase V
119	w	lowercase W
120	x	lowercase X
121	y	lowercase Y
122	z	lowercase Z

B.2 THE LATIN ALPHABET (ISO6937)

ISO6937/2 is used as a basis for coding the "decimal coded character" representations (DCC) of Latin characters. The coding method B of the ISO standard is used. According to this method, Latin characters are coded by one or two pairs of integers:

(1) n_4/n_3 n_2/n_1

(2) n_4/n_3 -

(3) - n_2/n_1

where n_4 is greater than or equal to 8 and less than or equal to 15

n_3 is greater than or equal to 0 and less than or equal to 7

n_2 is greater than or equal to 0 and less than or equal to 7

n_1 is greater than or equal to 0 and less than or equal to 7

Syntactically the three forms are distinguished as

```
<one_to_seven>       ::=  1 | 2 | 3 | 4 | 5 | 6 | 7
<eight_to_fifteen>   ::=  8 | 9 | 10 | 11 | 12 | 13 | 14 | 15
<form1>              ::=  <form2> <form3>
<form2>              ::=  <eight_to_fifteen> | <one_to_seven>
<form3>              ::=  <one_to_seven> | <one_to_seven>
```

The second form defines implicitly $n_2 = n_1 = 0$.

The third form defines implicitly $n_4 = 8$, $n_3 = 0$.

From this representation method the DCC is defined as follows:

$$DCC = 16*(8*(16*(n_4-8) + n_3) + n_2) + n_1$$

The algorithm (formulated in FORTRAN77) to derive the 4 numbers n_1-n_4 from a DCC is as follows:

```
subroutine tran(dcc,n1,n2,n3,n4)
integer dcc,var1,var2,n1,n2,n3,n4
var1=dcc
var2=var1/16
n1=var1-(16*var2)
var1=var2
var2=var1/8
n2=var1-(8*var2)
var1=var2
var2=var1/16
n3=var1-(16*var2)
n4=var2+8
return
end
```

B.3 GREEK CHARACTER SET (Escape Sequence Reserved Word = GREEK)

The Greek character set is conveyed by the character set encoding in ISO/DIS 6937/7 "Information processing -- Coded character sets for text communication -- Part 7 Greek graphic characters".

APPENDIX C - ENTITY SYNTAX ON THE PHYSICAL FILE

In this appendix, words typed in lowercase letters represent items that were previously defined by the file structure syntax (See Tables 3-3 and 3-4).

```
AXIS1_PLACEMENT-AXIS = entity_reference | DIRECTION .
AXIS1_PLACEMENT-LOCATION = entity_reference | POINT .
AXIS1_PLACEMENT = "("
                   [ AXIS1_PLACEMENT-AXIS ] ","
                   AXIS1_PLACEMENT-LOCATION
                  ")" .

AXIS2_PLACEMENT-AXIS = entity_reference | DIRECTION .
AXIS2_PLACEMENT-LOCATION = entity_reference | DIRECTION .
AXIS2_PLACEMENT-REF_DIRECTION = entity_reference | DIRECTION .
AXIS2_PLACEMENT = "("
                   [ AXIS2_PLACEMENT-AXIS ] ","
                   AXIS2_PLACEMENT-LOCATION ","
                   [ AXIS2_PLACEMENT-REF_DIRECTION ]
                  ")" .

AXIS_PLACEMENT =  AXIS2_PLACEMENT
                | AXIS1_PLACEMENT  .

BEZIER_CURVE-CONTROL_POINTS = list .
BEZIER_CURVE-DEGREE = integer .
BEZIER_CURVE-FORM_NUMBER = "."string"." .
BEZIER_CURVE-KNOTS = list .
BEZIER_CURVE-RATIONAL = logical .
BEZIER_CURVE-SELF_INTERSECT = logical .
BEZIER_CURVE-WEIGHTS = list .
BEZIER_CURVE = "("
                BEZIER_CURVE-CONTROL_POINTS ","
                BEZIER_CURVE-DEGREE ","
                [ BEZIER_CURVE-FORM_NUMBER ] ","
                BEZIER_CURVE-KNOTS ","
                BEZIER_CURVE-RATIONAL ","
                BEZIER_CURVE-SELF_INTERSECT ","
                BEZIER_CURVE-WEIGHTS
               ")" .

BEZIER_SURFACE-CONTROL_POINTS = list .
BEZIER_SURFACE-FORM_NUMBER = "."string"." .
BEZIER_SURFACE-U_DEGREE = integer .
BEZIER_SURFACE-U_RATIONAL = integer .
BEZIER_SURFACE-U_UNIFORM = logical .
BEZIER_SURFACE-U_UPPER = integer .
BEZIER_SURFACE-V_DEGREE = integer .
BEZIER_SURFACE-V_RATIONAL = logical .
BEZIER_SURFACE-V_UNIFORM = logical .
BEZIER_SURFACE-V_UPPER = integer .
BEZIER_SURFACE-WEIGHTS = list .
BEZIER_SURFACE = "("
                  BEZIER_SURFACE-CONTROL_POINTS ","
                  [ BEZIER_SURFACE-FORM_NUMBER ] ","
                  BEZIER_SURFACE-U_DEGREE ","
                  BEZIER_SURFACE-U_RATIONAL ","
```

```
                    BEZIER_SURFACE-U_UNIFORM ","
                    BEZIER_SURFACE-U_UPPER ","
                    BEZIER_SURFACE-V_DEGREE ","
                    BEZIER_SURFACE-V_RATIONAL ","
                    BEZIER_SURFACE-V_UNIFORM ","
                    BEZIER_SURFACE-V_UPPER ","
                    [ BEZIER_SURFACE-WEIGHTS ]
                   ")" .

BOUNDED_CURVE =    COMPOSITE_CURVE
                 | TRIMMED_CURVE
                 | B_SPLINE_CURVE
                 | BEZIER_CURVE
                 | LINE_SEGMENT  .

BOUNDED_SURFACE =  CURVE_BOUNDED_SURFACE
                 | RECTANGULAR_TRIMMED_SURFACE
                 | BEZIER_SURFACE
                 | B_SPLINE_SURFACE  .

B_SPLINE_CURVE-CONTROL_POINTS = list .
B_SPLINE_CURVE-DEGREE = integer .
B_SPLINE_CURVE-FORM_NUMBER = "."string"." .
B_SPLINE_CURVE-KNOTS = list .
B_SPLINE_CURVE-KNOT_MULTIPLICITIES = list .
B_SPLINE_CURVE-RATIONAL = logical .
B_SPLINE_CURVE-SELF_INTERSECT = logical .
B_SPLINE_CURVE-UNIFORM = logical .
B_SPLINE_CURVE-UPPER_INDEX_ON_CONTROL_POINTS = integer .
B_SPLINE_CURVE-WEIGHTS = list .
B_SPLINE_CURVE = "("
                    B_SPLINE_CURVE-CONTROL_POINTS ","
                    B_SPLINE_CURVE-DEGREE ","
                    [ B_SPLINE_CURVE-FORM_NUMBER ] ","
                    [ B_SPLINE_CURVE-KNOTS ] ","
                    B_SPLINE_CURVE-KNOT_MULTIPLICITIES ","
                    B_SPLINE_CURVE-RATIONAL ","
                    B_SPLINE_CURVE-SELF_INTERSECT ","
                    B_SPLINE_CURVE-UNIFORM ","
                    B_SPLINE_CURVE-UPPER_INDEX_ON_CONTROL_POINTS ","
                    B_SPLINE_CURVE-WEIGHTS
                   ")" .

B_SPLINE_SURFACE-CONTROL_POINTS = list .
B_SPLINE_SURFACE-FORM_NUMBER = "."string"." .
B_SPLINE_SURFACE-U_DEGREE = integer .
B_SPLINE_SURFACE-U_KNOTS = list .
B_SPLINE_SURFACE-U_MULTIPLICITIES = list .
B_SPLINE_SURFACE-U_RATIONAL = logical .
B_SPLINE_SURFACE-U_UNIFORM = logical .
B_SPLINE_SURFACE-U_UPPER = integer .
B_SPLINE_SURFACE-V_DEGREE = integer .
B_SPLINE_SURFACE-V_KNOTS = list .
```

```
B_SPLINE_SURFACE-V_MULTIPLICITIES = list .
B_SPLINE_SURFACE-V_RATIONAL = logical .
B_SPLINE_SURFACE-V_UNIFORM = logical .
B_SPLINE_SURFACE-V_UPPER = integer .
B_SPLINE_SURFACE-WEIGHTS = list .
B_SPLINE_SURFACE = "("
                    B_SPLINE_SURFACE-CONTROL_POINTS ","
                   [ B_SPLINE_SURFACE-FORM_NUMBER ] ","
                    B_SPLINE_SURFACE-U_DEGREE ","
                    B_SPLINE_SURFACE-U_KNOTS ","
                    B_SPLINE_SURFACE-U_MULTIPLICITIES ","
                    B_SPLINE_SURFACE-U_RATIONAL ","
                    B_SPLINE_SURFACE-U_UNIFORM ","
                    B_SPLINE_SURFACE-U_UPPER ","
                    B_SPLINE_SURFACE-V_DEGREE ","
                    B_SPLINE_SURFACE-V_KNOTS ","
                    B_SPLINE_SURFACE-V_MULTIPLICITIES ","
                    B_SPLINE_SURFACE-V_RATIONAL ","
                    B_SPLINE_SURFACE-V_UNIFORM ","
                    B_SPLINE_SURFACE-V_UPPER ","
                   [ B_SPLINE_SURFACE-WEIGHTS ]
                  ")" .

CARTESIAN_POINT =  CARTESIAN_THREE_COORDINATE
                 | CARTESIAN_TWO_COORDINATE  .

CARTESIAN_THREE_COORDINATE-X_COORDINATE = real .
CARTESIAN_THREE_COORDINATE-Y_COORDINATE = real .
CARTESIAN_THREE_COORDINATE-Z_COORDINATE = real .
CARTESIAN_THREE_COORDINATE = "("
                              CARTESIAN_THREE_COORDINATE-X_COORDINATE ","
                              CARTESIAN_THREE_COORDINATE-Y_COORDINATE ","
                              CARTESIAN_THREE_COORDINATE-Z_COORDINATE
                             ")" .

CARTESIAN_TWO_COORDINATE-X_COORDINATE = real .
CARTESIAN_TWO_COORDINATE-Y_COORDINATE = real .
CARTESIAN_TWO_COORDINATE = "("
                            CARTESIAN_TWO_COORDINATE-X_COORDINATE ","
                            CARTESIAN_TWO_COORDINATE-Y_COORDINATE
                           ")" .

CIRCLE-POSITION__ = entity_reference | AXIS2_PLACEMENT .
CIRCLE-RADIUS = real .
CIRCLE = "("
          CIRCLE-POSITION__ ","
          CIRCLE-RADIUS
         ")" .

CLOSED_SHELL-CSHELL_BOUNDARY = list .
CLOSED_SHELL = "("
                CLOSED_SHELL-CSHELL_BOUNDARY
               ")" .
```

```
COMPOSITE_CURVE-CLOSED_CURVE = logical .
COMPOSITE_CURVE-PARAM_RANGE = list .
COMPOSITE_CURVE-SEGMENTS = list .
COMPOSITE_CURVE-SELF_INTERSECT = logical .
COMPOSITE_CURVE-SENSES = list .
COMPOSITE_CURVE-TRANSITIONS = list .
COMPOSITE_CURVE = "("
                   COMPOSITE_CURVE-CLOSED_CURVE ","
                   [ COMPOSITE_CURVE-PARAM_RANGE ] ","
                   COMPOSITE_CURVE-SEGMENTS ","
                   COMPOSITE_CURVE-SELF_INTERSECT ","
                   COMPOSITE_CURVE-SENSES ","
                   COMPOSITE_CURVE-TRANSITIONS
                  ")" .

COMPOSITE_CURVE_ON_SURFACE-BASIS_SURFACE = entity_reference | SURFACE .
COMPOSITE_CURVE_ON_SURFACE-CLOSED_CURVE = logical .
COMPOSITE_CURVE_ON_SURFACE-SEGMENTS = list .
COMPOSITE_CURVE_ON_SURFACE-SENSES = list .
COMPOSITE_CURVE_ON_SURFACE-TRANSITIONS = list .
COMPOSITE_CURVE_ON_SURFACE = "("
                              COMPOSITE_CURVE_ON_SURFACE-BASIS_SURFACE ","
                              COMPOSITE_CURVE_ON_SURFACE-CLOSED_CURVE ","
                              COMPOSITE_CURVE_ON_SURFACE-SEGMENTS ","
                              COMPOSITE_CURVE_ON_SURFACE-SENSES ","
                              COMPOSITE_CURVE_ON_SURFACE-TRANSITIONS
                             ")" .

CONIC =  PARABOLA
       | HYPERBOLA
       | ELLIPSE
       | CIRCLE  .

CONICAL_SURFACE-POSITION__ = entity_reference | AXIS2_PLACEMENT .
CONICAL_SURFACE-RADIUS = real .
CONICAL_SURFACE-SEMI_ANGLE = real .
CONICAL_SURFACE = "("
                   CONICAL_SURFACE-POSITION__ ","
                   CONICAL_SURFACE-RADIUS ","
                   CONICAL_SURFACE-SEMI_ANGLE
                  ")" .

CURVE =  OFFSET_CURVE
       | CURVE_ON_SURFACE
       | BOUNDED_CURVE
       | CONIC
       | LINE  .

CURVE_BOUNDED_SURFACE-BASIS_SURFACE = entity_reference | SURFACE .
CURVE_BOUNDED_SURFACE-BOUNDARIES = list .
CURVE_BOUNDED_SURFACE-OUTER_PRESENT = logical .
CURVE_BOUNDED_SURFACE = "("
                          CURVE_BOUNDED_SURFACE-BASIS_SURFACE ","
                          CURVE_BOUNDED_SURFACE-BOUNDARIES ","
                          CURVE_BOUNDED_SURFACE-OUTER_PRESENT
                         ")" .

CURVE_LOGICAL_STRUCTURE-CURVE_ELEMENT = logical .
CURVE_LOGICAL_STRUCTURE-FLAG = logical .
CURVE_LOGICAL_STRUCTURE = "("
                           CURVE_LOGICAL_STRUCTURE-CURVE_ELEMENT ","
                           CURVE_LOGICAL_STRUCTURE-FLAG
                          ")" .

CURVE_ON_SURFACE =  COMPOSITE_CURVE_ON_SURFACE
                  | INTERSECTION_CURVE
                  | SURFACE_CURVE
                  | PCURVE  .

CYLINDRICAL_SURFACE-POSITION__ = entity_reference | AXIS2_PLACEMENT .
CYLINDRICAL_SURFACE-RADIUS = real .
CYLINDRICAL_SURFACE = "("
                       CYLINDRICAL_SURFACE-POSITION__ ","
                       CYLINDRICAL_SURFACE-RADIUS
                      ")" .

D2_OFFSET_CURVE-BASIS_CURVE = integer .
D2_OFFSET_CURVE-DISTANCE = real .
D2_OFFSET_CURVE-SELF_INTERSECT = logical .
D2_OFFSET_CURVE = "("
                   D2_OFFSET_CURVE-BASIS_CURVE ","
                   D2_OFFSET_CURVE-DISTANCE ","
                   D2_OFFSET_CURVE-SELF_INTERSECT
                  ")" .

D3_OFFSET_CURVE-BASIS_CURVE = entity_reference | CURVE .
D3_OFFSET_CURVE-DISTANCE = real .
D3_OFFSET_CURVE-REF_DIRECTION = entity_reference | DIRECTION .
D3_OFFSET_CURVE-SELF_INTERSECT = entity_reference | DIRECTION .
D3_OFFSET_CURVE = "("
                   D3_OFFSET_CURVE-BASIS_CURVE ","
                   D3_OFFSET_CURVE-DISTANCE ","
                   D3_OFFSET_CURVE-REF_DIRECTION ","
                   D3_OFFSET_CURVE-SELF_INTERSECT
                  ")" .

DIRECTION =  THREE_SPACE_DIRECTION
           | TWO_SPACE_DIRECTION  .

EDGE-EDGE_CURVE = entity_reference | CURVE_LOGICAL_STRUCTURE .
EDGE-EDGE_END = entity_reference | VERTEX .
EDGE-EDGE_START = entity_reference | VERTEX .
EDGE = "("
        [ EDGE-EDGE_CURVE ] ","
        EDGE-EDGE_END ","
```

```
         EDGE-EDGE_START
        ")" .

EDGE_LOGICAL_STRUCTURE-EDGE_ELEMENT = entity_reference | EDGE .
EDGE_LOGICAL_STRUCTURE-FLAG = logical .
EDGE_LOGICAL_STRUCTURE = "("
                          EDGE_LOGICAL_STRUCTURE-EDGE_ELEMENT ","
                          EDGE_LOGICAL_STRUCTURE-FLAG
                         ")" .

EDGE_LOOP-LOOP_EDGES = list .
EDGE_LOOP = "("
             EDGE_LOOP-LOOP_EDGES
            ")" .

ELEMENTARY_SURFACE =  TOROIDAL_SURFACE
                    | SPHERICAL_SURFACE
                    | CONICAL_SURFACE
                    | CYLINDRICAL_SURFACE
                    | PLANE  .

ELLIPSE-POSITION__ = entity_reference | AXIS2_PLACEMENT .
ELLIPSE-SEMI_AXIS_1 = real .
ELLIPSE-SEMI_AXIS_2 = real .
ELLIPSE = "("
           ELLIPSE-POSITION__ ","
           ELLIPSE-SEMI_AXIS_1 ","
           ELLIPSE-SEMI_AXIS_2
          ")" .

FACE-BOUNDS = list .
FACE-FACE_SURFACE = entity_reference | SURFACE_LOGICAL_STRUCTURE .
FACE-OUTER_BOUND = entity_reference | LOOP_LOGICAL_STRUCTURE .
FACE = "("
        FACE-BOUNDS ","
        [ FACE-FACE_SURFACE ] ","
        [ FACE-OUTER_BOUND ]
       ")" .

FACE_LOGICAL_STRUCTURE-FACE_ELEMENT = entity_reference | FACE .
FACE_LOGICAL_STRUCTURE-FLAG = logical .
FACE_LOGICAL_STRUCTURE = "("
                          FACE_LOGICAL_STRUCTURE-FACE_ELEMENT ","
                          FACE_LOGICAL_STRUCTURE-FLAG
                         ")" .

GEOMETRY =  SURFACE
          | CURVE
          | TRANSFORMATION
          | AXIS_PLACEMENT
          | VECTOR
          | POINT  .
```

```
HYPERBOLA-POSITION__ = entity_reference | AXIS2_PLACEMENT .
HYPERBOLA-SEMI_AXIS = real .
HYPERBOLA-SEMI_IMAG_AXIS = real .
HYPERBOLA = "("
             HYPERBOLA-POSITION__ ","
             HYPERBOLA-SEMI_AXIS ","
             HYPERBOLA-SEMI_IMAG_AXIS
            ")" .

INTERSECTION_CURVE-BASIS_CURVE = entity_reference | CURVE .
INTERSECTION_CURVE-MASTER_REPRESENTATION = "."string"." .
INTERSECTION_CURVE-PCURVE_S1 = entity_reference | PCURVE .
INTERSECTION_CURVE-PCURVE_S2 = entity_reference | PCURVE .
INTERSECTION_CURVE-SELF_INTERSECT = logical .
INTERSECTION_CURVE-SURFACE_S1 = entity_reference | SURFACE .
INTERSECTION_CURVE-SURFACE_S2 = entity_reference | SURFACE .
INTERSECTION_CURVE = "("
                      INTERSECTION_CURVE-BASIS_CURVE ","
                      [ INTERSECTION_CURVE-MASTER_REPRESENTATION ] ","
                      [ INTERSECTION_CURVE-PCURVE_S1 ] ","
                      [ INTERSECTION_CURVE-PCURVE_S2 ] ","
                      INTERSECTION_CURVE-SELF_INTERSECT ","
                      [ INTERSECTION_CURVE-SURFACE_S1 ] ","
                      [ INTERSECTION_CURVE-SURFACE_S2 ]
                     ")" .

LINE-DIR = entity_reference | DIRECTION .
LINE-PNT = entity_reference | CARTESIAN_POINT .
LINE = "("
        LINE-DIR ","
        LINE-PNT
       ")" .

LINE_SEGMENT-FIRST_POINT = entity_reference | CARTESIAN_POINT .
LINE_SEGMENT-LAST_POINT = entity_reference | CARTESIAN_POINT .
LINE_SEGMENT = "("
                LINE_SEGMENT-FIRST_POINT ","
                LINE_SEGMENT-LAST_POINT
               ")" .

LOOP =  POLY_LOOP
      | EDGE_LOOP
      | VERTEX_LOOP  .

LOOP_LOGICAL_STRUCTURE-FLAG = logical .
LOOP_LOGICAL_STRUCTURE-LOOP_ELEMENT = entity_reference | LOOP .
LOOP_LOGICAL_STRUCTURE = "("
                          LOOP_LOGICAL_STRUCTURE-FLAG ","
                          LOOP_LOGICAL_STRUCTURE-LOOP_ELEMENT
                         ")" .

OFFSET_CURVE =  D3_OFFSET_CURVE
              | D2_OFFSET_CURVE  .
```

```
OFFSET_SURFACE-BASIS_SURFACE = entity_reference | SURFACE .
OFFSET_SURFACE-DISTANCE = real .
OFFSET_SURFACE-SELF_INTERSECT = logical .
OFFSET_SURFACE = "("
                  OFFSET_SURFACE-BASIS_SURFACE ","
                  OFFSET_SURFACE-DISTANCE ","
                  OFFSET_SURFACE-SELF_INTERSECT
                 ")" .

OPEN_SHELL-SHELL_BOUNDARY = list .
OPEN_SHELL = "("
              OPEN_SHELL-SHELL_BOUNDARY
             ")" .

PARABOLA-FOCAL_DIST = real .
PARABOLA-POSITION__ = entity_reference | AXIS2_PLACEMENT .
PARABOLA = "("
            PARABOLA-FOCAL_DIST ","
            PARABOLA-POSITION__
           ")" .

PATH-OPEN_EDGE_LIST = list .
PATH = "("
        PATH-OPEN_EDGE_LIST
       ")" .

PCURVE-BASIS_CURVE = entity_reference | CURVE .
PCURVE-BASIS_SURFACE = entity_reference | SURFACE .
PCURVE = "("
          PCURVE-BASIS_CURVE ","
          PCURVE-BASIS_SURFACE
         ")" .

PLANE-POSITION__ = entity_reference | AXIS2_PLACEMENT .
PLANE = "("
         PLANE-POSITION__
        ")" .

POINT =  POINT_ON_SURFACE
       | POINT_ON_CURVE
       | CARTESIAN_POINT  .

POINT_ON_CURVE-BASIS_CURVE = entity_reference | CURVE .
POINT_ON_CURVE-POINT_PARAMETER = real .
POINT_ON_CURVE = "("
                  POINT_ON_CURVE-BASIS_CURVE ","
                  POINT_ON_CURVE-POINT_PARAMETER
                 ")" .

POINT_ON_SURFACE-BASIS_SURFACE = entity_reference | SURFACE .
POINT_ON_SURFACE-POINT_PARAMETER_1 = real .
POINT_ON_SURFACE-POINT_PARAMETER_2 = real .
```

```
POINT_ON_SURFACE = "("
                    POINT_ON_SURFACE-BASIS_SURFACE ","
                    POINT_ON_SURFACE-POINT_PARAMETER_1 ","
                    POINT_ON_SURFACE-POINT_PARAMETER_2
                   ")" .

POLY_LOOP-POLYGON = list .
POLY_LOOP = "("
             POLY_LOOP-POLYGON
            ")" .

RECTANGULAR_COMPOSITE_SURFACE-N_U = integer .
RECTANGULAR_COMPOSITE_SURFACE-N_V = integer .
RECTANGULAR_COMPOSITE_SURFACE-SURFACES = list .
RECTANGULAR_COMPOSITE_SURFACE-U_SENSES = list .
RECTANGULAR_COMPOSITE_SURFACE-V_SENSES = list .
RECTANGULAR_COMPOSITE_SURFACE = "("
                                 RECTANGULAR_COMPOSITE_SURFACE-N_U ","
                                 RECTANGULAR_COMPOSITE_SURFACE-N_V ","
                                 RECTANGULAR_COMPOSITE_SURFACE-SURFACES ","
                                 RECTANGULAR_COMPOSITE_SURFACE-U_SENSES ","
                                 RECTANGULAR_COMPOSITE_SURFACE-V_SENSES
                                ")" .

RECTANGULAR_TRIMMED_SURFACE-BASIS_SURFACE = integer .
RECTANGULAR_TRIMMED_SURFACE-UMAX = real .
RECTANGULAR_TRIMMED_SURFACE-UMIN = real .
RECTANGULAR_TRIMMED_SURFACE-VMAX = real .
RECTANGULAR_TRIMMED_SURFACE-VMIN = real .
RECTANGULAR_TRIMMED_SURFACE = "("
                               RECTANGULAR_TRIMMED_SURFACE-BASIS_SURFACE ","
                               RECTANGULAR_TRIMMED_SURFACE-UMAX ","
                               RECTANGULAR_TRIMMED_SURFACE-UMIN ","
                               RECTANGULAR_TRIMMED_SURFACE-VMAX ","
                               RECTANGULAR_TRIMMED_SURFACE-VMIN
                              ")" .

REGION-OUTER_REGION_BOUNDARY = entity_reference | SHELL_LOGICAL_STRUCTURE .
REGION-REGION_BOUNDARIES = list .
REGION = "("
          [ REGION-OUTER_REGION_BOUNDARY ] ","
          REGION-REGION_BOUNDARIES
         ")" .

SHELL =  CLOSED_SHELL
       | OPEN_SHELL
       | WIRE_SHELL
       | VERTEX_SHELL  .

SELECT_FACE_OR_SUBFACE =
                         | FACE
                         | SUBFACE .
```

```
SHELL_LOGICAL_STRUCTURE-FLAG = logical .
SHELL_LOGICAL_STRUCTURE-SHELL_ELEMENT = entity_reference | SHELL .
SHELL_LOGICAL_STRUCTURE = "("
                           SHELL_LOGICAL_STRUCTURE-FLAG ","
                           SHELL_LOGICAL_STRUCTURE-SHELL_ELEMENT
                          ")" .

SPHERICAL_SURFACE-POSITION__ = entity_reference | AXIS2_PLACEMENT .
SPHERICAL_SURFACE-RADIUS = real .
SPHERICAL_SURFACE = "("
                     SPHERICAL_SURFACE-POSITION__ ","
                     SPHERICAL_SURFACE-RADIUS
                    ")" .

SUBFACE-BOUNDS = list .
SUBFACE-OUTER_BOUND = entity_reference | LOOP_LOGICAL_STRUCTURE .
SUBFACE-TRIMMING = entity_reference | SELECT_FACE_OR_SUBFACE .
SUBFACE = "("
           SUBFACE-BOUNDS ","
           SUBFACE-OUTER_BOUND ","
           SUBFACE-TRIMMING
          ")" .

SURFACE =  RECTANGULAR_COMPOSITE_SURFACE
         | OFFSET_SURFACE
         | BOUNDED_SURFACE
         | SWEPT_SURFACE
         | ELEMENTARY_SURFACE  .

SURFACE_CURVE-CURVE_1 = entity_reference | CURVE .
SURFACE_CURVE-MASTER = "."string"." .
SURFACE_CURVE-PCURVE_S1 = entity_reference | PCURVE .
SURFACE_CURVE-SURFACE_1 = entity_reference | SURFACE .
SURFACE_CURVE = "("
                 SURFACE_CURVE-CURVE_1 ","
                 [ SURFACE_CURVE-MASTER ] ","
                 [ SURFACE_CURVE-PCURVE_S1 ] ","
                 SURFACE_CURVE-SURFACE_1
                ")" .

SURFACE_LOGICAL_STRUCTURE-FLAG = logical .
SURFACE_LOGICAL_STRUCTURE-SURFACE_ELEMENT = logical .
SURFACE_LOGICAL_STRUCTURE = "("
                             SURFACE_LOGICAL_STRUCTURE-FLAG ","
                             SURFACE_LOGICAL_STRUCTURE-SURFACE_ELEMENT
                            ")" .

SURFACE_OF_LINEAR_EXTRUSION-AXIS = entity_reference | DIRECTION .
SURFACE_OF_LINEAR_EXTRUSION-EXTRUDED_CURVE = entity_reference | CURVE .
SURFACE_OF_LINEAR_EXTRUSION = "("
                               SURFACE_OF_LINEAR_EXTRUSION-AXIS ","
                               SURFACE_OF_LINEAR_EXTRUSION-EXTRUDED_CURVE
                              ")" .
```

```
SURFACE_OF_REVOLUTION-AXIS = entity_reference | DIRECTION .
SURFACE_OF_REVOLUTION-AXIS_POINT = entity_reference | CARTESIAN_POINT .
SURFACE_OF_REVOLUTION-REVOLVED_CURVE = entity_reference | CURVE .
SURFACE_OF_REVOLUTION = "("
                            SURFACE_OF_REVOLUTION-AXIS ","
                            SURFACE_OF_REVOLUTION-AXIS_POINT ","
                            SURFACE_OF_REVOLUTION-REVOLVED_CURVE
                           ")" .

SWEPT_SURFACE =  SURFACE_OF_LINEAR_EXTRUSION
               | SURFACE_OF_REVOLUTION  .

THREE_SPACE_DIRECTION-X = real .
THREE_SPACE_DIRECTION-Y = real .
THREE_SPACE_DIRECTION-Z = real .
THREE_SPACE_DIRECTION = "("
                            THREE_SPACE_DIRECTION-X ","
                            THREE_SPACE_DIRECTION-Y ","
                            THREE_SPACE_DIRECTION-Z
                           ")" .

TOPOLOGY =  REGION
          | SHELL
          | SUBFACE
          | FACE
          | LOOP
          | PATH
          | EDGE
          | VERTEX  .

TOROIDAL_SURFACE-MAJOR_RADIUS = real .
TOROIDAL_SURFACE-MINOR_RADIUS = real .
TOROIDAL_SURFACE-POSITION__ = entity_reference | AXIS2_PLACEMENT .
TOROIDAL_SURFACE = "("
                       TOROIDAL_SURFACE-MAJOR_RADIUS ","
                       TOROIDAL_SURFACE-MINOR_RADIUS ","
                       TOROIDAL_SURFACE-POSITION__
                      ")" .

TRANSFORMATION-AXIS1 = entity_reference | DIRECTION .
TRANSFORMATION-AXIS2 = entity_reference | THREE_SPACE_DIRECTION .
TRANSFORMATION-AXIS3 = entity_reference | THREE_SPACE_DIRECTION .
TRANSFORMATION-LOCAL_ORIGIN = entity_reference | CARTESIAN_POINT .
TRANSFORMATION-SCALE = real .
TRANSFORMATION = "("
                   [ TRANSFORMATION-AXIS1 ] ","
                   [ TRANSFORMATION-AXIS2 ] ","
                   [ TRANSFORMATION-AXIS3 ] ","
                   [ TRANSFORMATION-LOCAL_ORIGIN ] ","
                   [ TRANSFORMATION-SCALE ]
                  ")" .
```

```
TRIMMED_CURVE-BASIS_CURVE = integer .
TRIMMED_CURVE-PARAMETER_1 = real .
TRIMMED_CURVE-PARAMETER_2 = real .
TRIMMED_CURVE-POINT_1 = entity_reference | CARTESIAN_POINT .
TRIMMED_CURVE-POINT_2 = entity_reference | CARTESIAN_POINT .
TRIMMED_CURVE-SENSE = logical .
TRIMMED_CURVE = "("
                 TRIMMED_CURVE-BASIS_CURVE ","
                 [ TRIMMED_CURVE-PARAMETER_1 ] ","
                 [ TRIMMED_CURVE-PARAMETER_2 ] ","
                 [ TRIMMED_CURVE-POINT_1 ] ","
                 [ TRIMMED_CURVE-POINT_2 ] ","
                 TRIMMED_CURVE-SENSE
                ")" .

TWO_SPACE_DIRECTION-X = real .
TWO_SPACE_DIRECTION-Y = real .
TWO_SPACE_DIRECTION = "("
                       TWO_SPACE_DIRECTION-X ","
                       TWO_SPACE_DIRECTION-Y
                      ")" .

VECTOR =  VECTOR_WITH_MAGNITUDE
        | DIRECTION  .

VECTOR_WITH_MAGNITUDE-MAGNITUDE = real .
VECTOR_WITH_MAGNITUDE-ORIENTATION = entity_reference | DIRECTION .
VECTOR_WITH_MAGNITUDE = "("
                         VECTOR_WITH_MAGNITUDE-MAGNITUDE ","
                         VECTOR_WITH_MAGNITUDE-ORIENTATION
                        ")" .

VERTEX-VERTEX_POINT =  entity_reference | POINT .
VERTEX = "("
          [ VERTEX-VERTEX_POINT ]
         ")" .

VERTEX_LOOP-LOOP_VERTEX = entity_reference | VERTEX .
VERTEX_LOOP = "("
               VERTEX_LOOP-LOOP_VERTEX
              ")" .

VERTEX_SHELL-VERTEX_SHELL_BOUNDARY = entity_reference | VERTEX_LOOP .
VERTEX_SHELL = "("
                VERTEX_SHELL-VERTEX_SHELL_BOUNDARY
               ")" .

WIRE_SHELL-WIRE_SHELL_BOUNDARY = list .
WIRE_SHELL = "("
              WIRE_SHELL-WIRE_SHELL_BOUNDARY
             ")" .

ENTITY_DEF = (
AXIS1_PLACEMENTalias AXIS1_PLACEMENT
AXIS2_PLACEMENTalias AXIS2_PLACEMENT
BEZIER_CURVEalias BEZIER_CURVE
BEZIER_SURFACEalias BEZIER_SURFACE
B_SPLINE_CURVEalias B_SPLINE_CURVE
B_SPLINE_SURFACEalias B_SPLINE_SURFACE
CARTESIAN_THREE_COORDINATEalias CARTESIAN_THREE_COORDINATE
CARTESIAN_TWO_COORDINATEalias CARTESIAN_TWO_COORDINATE
CIRCLEalias CIRCLE
CLOSED_SHELLalias CLOSED_SHELL
COMPOSITE_CURVEalias COMPOSITE_CURVE
COMPOSITE_CURVE_ON_SURFACEalias COMPOSITE_CURVE_ON_SURFACE
CONICAL_SURFACEalias CONICAL_SURFACE
CURVE_BOUNDED_SURFACEalias CURVE_BOUNDED_SURFACE
CURVE_LOGICAL_STRUCTUREalias CURVE_LOGICAL_STRUCTURE
CYLINDRICAL_SURFACEalias CYLINDRICAL_SURFACE
D2_OFFSET_CURVEalias D2_OFFSET_CURVE
D3_OFFSET_CURVEalias D3_OFFSET_CURVE
EDGEalias EDGE
EDGE_LOGICAL_STRUCTUREalias EDGE_LOGICAL_STRUCTURE
EDGE_LOOPalias EDGE_LOOP
ELLIPSEalias ELLIPSE
FACEalias FACE
FACE_LOGICAL_STRUCTUREalias FACE_LOGICAL_STRUCTURE
HYPERBOLAalias HYPERBOLA
INTERSECTION_CURVEalias INTERSECTION_CURVE
LINEalias LINE
LINE_SEGMENTalias LINE_SEGMENT
LOOP_LOGICAL_STRUCTUREalias LOOP_LOGICAL_STRUCTURE
OFFSET_SURFACEalias OFFSET_SURFACE
OPEN_SHELLalias OPEN_SHELL
PARABOLAalias PARABOLA
PATHalias PATH
PCURVEalias PCURVE
PLANEalias PLANE
POINT_ON_CURVEalias POINT_ON_CURVE
POINT_ON_SURFACEalias POINT_ON_SURFACE
POLY_LOOPalias POLY_LOOP
RECTANGULAR_COMPOSITE_SURFACEalias RECTANGULAR_COMPOSITE_SURFACE
RECTANGULAR_TRIMMED_SURFACEalias RECTANGULAR_TRIMMED_SURFACE
REGIONalias REGION
SHELL_LOGICAL_STRUCTUREalias SHELL_LOGICAL_STRUCTURE
SPHERICAL_SURFACEalias SPHERICAL_SURFACE
SUBFACEalias SUBFACE
SURFACE_CURVEalias SURFACE_CURVE
SURFACE_LOGICAL_STRUCTUREalias SURFACE_LOGICAL_STRUCTURE
SURFACE_OF_LINEAR_EXTRUSIONalias SURFACE_OF_LINEAR_EXTRUSION
SURFACE_OF_REVOLUTIONalias SURFACE_OF_REVOLUTION
THREE_SPACE_DIRECTIONalias THREE_SPACE_DIRECTION
TOROIDAL_SURFACEalias TOROIDAL_SURFACE
TRANSFORMATIONalias TRANSFORMATION
TRIMMED_CURVEalias TRIMMED_CURVE
TWO_SPACE_DIRECTIONalias TWO_SPACE_DIRECTION
```

```
          | VECTOR_WITH_MAGNITUDEalias VECTOR_WITH_MAGNITUDE
          | VERTEXalias VERTEX
          | VERTEX_LOOPalias VERTEX_LOOP
          | VERTEX_SHELLalias VERTEX_SHELL
          | WIRE_SHELLalias WIRE_SHELL
          } .

AXIS1_PLACEMENTalias = "AXIS1_PLACEMENT" | "AX1" .
AXIS2_PLACEMENTalias = "AXIS2_PLACEMENT" | "AX2" .
BEZIER_CURVEalias = "BEZIER_CURVE" | "CVZ" .
BEZIER_SURFACEalias = "BEZIER_SURFACE" | "SFZ" .
B_SPLINE_CURVEalias = "B_SPLINE_CURVE" | "CVB" .
B_SPLINE_SURFACEalias = "B_SPLINE_SURFACE" | "SFB" .
CARTESIAN_THREE_COORDINATEalias = "CARTESIAN_THREE_COORDINATE" | "PT3" .
CARTESIAN_TWO_COORDINATEalias = "CARTESIAN_TWO_COORDINATE" | "PT2" .
CIRCLEalias = "CIRCLE" | "CI" .
CLOSED_SHELLalias = "CLOSED_SHELL" | "SHC" .
COMPOSITE_CURVEalias = "COMPOSITE_CURVE" | "CVC" .
COMPOSITE_CURVE_ON_SURFACEalias = "COMPOSITE_CURVE_ON_SURFACE" | "CVCS" .
CONICAL_SURFACEalias = "CONICAL_SURFACE" | "SFCN" .
CURVE_BOUNDED_SURFACEalias = "CURVE_BOUNDED_SURFACE" | "SFCD" .
CURVE_LOGICAL_STRUCTUREalias = "CURVE_LOGICAL_STRUCTURE" | "CVD" .
CYLINDRICAL_SURFACEalias = "CYLINDRICAL_SURFACE" | "SFCYL" .
D2_OFFSET_CURVEalias = "D2_OFFSET_CURVE" | "CVF2" .
D3_OFFSET_CURVEalias = "D3_OFFSET_CURVE" | "CVF3" .
EDGEalias = "EDGE" | "ED" .
EDGE_LOGICAL_STRUCTUREalias = "EDGE_LOGICAL_STRUCTURE" | "EGD" .
EDGE_LOOPalias = "EDGE_LOOP" | "LPE" .
ELLIPSEalias = "ELLIPSE" | "EL" .
FACEalias = "FACE" | "FC" .
FACE_LOGICAL_STRUCTUREalias = "FACE_LOGICAL_STRUCTURE" | "FCD" .
HYPERBOLAalias = "HYPERBOLA" | "HP" .
INTERSECTION_CURVEalias = "INTERSECTION_CURVE" | "CVX" .
LINEalias = "LINE" | "LN" .
LINE_SEGMENTalias = "LINE_SEGMENT" | "LS" .
LOOP_LOGICAL_STRUCTUREalias = "LOOP_LOGICAL_STRUCTURE" | "LPD" .
OFFSET_SURFACEalias = "OFFSET_SURFACE" | "SFF" .
OPEN_SHELLalias = "OPEN_SHELL" | "SHO" .
PARABOLAalias = "PARABOLA" | "PB" .
PATHalias = "PATH" | "PA" .
PCURVEalias = "PCURVE" | "CVP" .
PLANEalias = "PLANE" | "PL" .
POINT_ON_CURVEalias = "POINT_ON_CURVE" | "PTC" .
POINT_ON_SURFACEalias = "POINT_ON_SURFACE" | "PTS" .
POLY_LOOPalias = "POLY_LOOP" | "LPP" .
RECTANGULAR_COMPOSITE_SURFACEalias = "RECTANGULAR_COMPOSITE_SURFACE" | "SFRC" .
RECTANGULAR_TRIMMED_SURFACEalias = "RECTANGULAR_TRIMMED_SURFACE" | "SFR" .
REGIONalias = "REGION" | "RG" .
SHELL_LOGICAL_STRUCTUREalias = "SHELL_LOGICAL_STRUCTURE" | "SHD" .
SPHERICAL_SURFACEalias = "SPHERICAL_SURFACE" | "SFSP" .
SUBFACEalias = "SUBFACE" | "FCS" .
SURFACE_CURVEalias = "SURFACE_CURVE" | "CVS" .
SURFACE_LOGICAL_STRUCTUREalias = "SURFACE_LOGICAL_STRUCTURE" | "SFD" .
```

```
SURFACE_OF_LINEAR_EXTRUSIONalias = "SURFACE_OF_LINEAR_EXTRUSION" | "SFLE" .
SURFACE_OF_REVOLUTIONalias = "SURFACE_OF_REVOLUTION" | "SFRV" .
THREE_SPACE_DIRECTIONalias = "THREE_SPACE_DIRECTION" | "DI3" .
TOROIDAL_SURFACEalias = "TOROIDAL_SURFACE" | "SFT" .
TRANSFORMATIONalias = "TRANSFORMATION" | "TM" .
TRIMMED_CURVEalias = "TRIMMED_CURVE" | "CVT" .
TWO_SPACE_DIRECTIONalias = "TWO_SPACE_DIRECTION" | "DI2" .
VECTOR_WITH_MAGNITUDEalias = "VECTOR_WITH_MAGNITUDE" | "VCM" .
VERTEXalias = "VERTEX" | "VX" .
VERTEX_LOOPalias = "VERTEX_LOOP" | "LPV" .
VERTEX_SHELLalias = "VERTEX_SHELL" | "SHV" .
WIRE_SHELLalias = "WIRE_SHELL" | "SHW" .

ENTITY_OCCURRENCE = entity_identifier "=" ENTITY_DEF ";" .
```

APPENDIX D - PHYSICAL EXCHANGE MEDIUM FORMATS

D.0 PHYSICAL EXCHANGE MEDIUM FORMATS

D.1 MAGNETIC TAPE

When a STEP file is to be transported via magnetic tape, the magnetic tape should have the following characteristics:

- o STANDARD
- o UNLABELED
- o 9 TRACK
- o 1600 BPI
- o PHYSICAL BLOCKSIZE = 800 BYTES
- o 1/2-INCH TAPE
- o DATA ENCODING ACCORDING TO ISO 6937 (See Appendix B for more detail).

The above characteristics are in accord with ISO 3788 "Information Processing Information Interchange Via Magnetic Tape".

D.2 TELECOMMUNICATION FORMAT

To be determined.

Title: Mapping from EXPRESS to Physical File

Owner: Jeff Altemueller

Date: September 1988

Corresponding ISO Document Number: N280

ISO TC184/SC4/WG1 ANNEX C (Normative) (Document 4.2.2) September 1988

MAPPING FROM EXPRESS TO PHYSICAL FILE STRUCTURE

DOCUMENT NUMBER: 4.2.2 **VERSION:** 7.0

TITLE: MAPPING FROM EXPRESS TO PHYSICAL FILE STRUCTURE

ABSTRACT:

This document presents the mapping from the Data Specification Language EXPRESS to the STEP Physical File Structure.

KEY WORDS:

DATE: September 1988

OWNER: Jeff Altemueller

PHONE NUMBER: (314) 234-5272

ISO REPRESENTATIVE: Jeff Altemueller

STATUS: Working Paper

Table of Contents

CHAPTER 1 - INTRODUCTION

1.0 INTRODUCTION

This document identifies the process through which Product Data entities defined in EXPRESS are mapped to the physical file format of PDES/STEP. It is assumed that the audience of this document is familiar with the EXPRESS language (refer to STEP Document 4.1.1, The Use Of Formal Language) and the PDES/STEP exchange format (refer to STEP Document 4.2.1, The STEP File Structure).

This document presents the simpler concept of data type mapping first and then discusses the more complex concept of entity mapping. Mapping is performed strictly from EXPRESS to the physical file structure, specifically to the Data section of the exchange format. Therefore, the headings used throughout this document utilize the same terms used within STEP Document 4.1.1, The EXPRESS User Guide. As a convenience to the reader of this document, EXPRESS constructs are written in bold upper case letters, while the file structure constructs are written in bold, lower case, italicized letters.

The EXPRESS language is an extremely powerful data modeling language that contains declarative statements, executable statements, and algorithms. For the purposes of exchange, only the declarative statements are actually mapped to the exchange format. The executable statements and algorithms of EXPRESS are used to clarify and refine the definition of and to impose constraints upon the attributes of Product Data entities. The executable statements are not mapped to the exchange format.

Several mapping examples have been provided throughout this document. Blank spaces and blank lines have been inserted into the exchange format of several examples to aid readability. The reader should note that these blank spaces and blank lines need not appear in an actual exchange format file.

CHAPTER 2 - MAPPING FROM EXPRESS TO PHYSICAL FILE STRUCTURE

2.0 MAPPING FROM EXPRESS TO PHYSICAL FILE STRUCTURE

Table 2-1 provides a quick reference of the mappings between the Conceptual Schema and the Physical File Structure. Specifically, these are the mappings from the elements or constructs of EXPRESS onto their counterparts in the DATA section of the STEP file structure. This table has been organized in alphabetical order while the content of this document has been organized in increasing order of complexity. A more detailed discussion of the individual mappings is presented in chapters 3 and 4 of this document.

2.1 QUICK REFERENCE MAPPING TABLE

Table 2-1 Conceptual Schema to Physical File Structure Mapping

EXPRESS CONSTRUCTS	DATA SECTION CONSTRUCTS
ARRAY	*list*
DERIVED ATTRIBUTE	NO INSTANTIATION
ENTITY	*entity or embedded entity*
ENTITY AS ATTRIBUTE	*embedded entity or entity reference*
ENTITY AS SUPERTYPES	NO INSTANTIATION
ENUMERATION	*enumeration*
FUNCTION	NO INSTANTIATION
INTEGER	*integer*
LIST	*list*
LOGICAL	*enumeration*
MAP	NO INSTANTIATION
PROCEDURE	NO INSTANTIATION
REAL	*real*
REMARKS	NO INSTANTIATION
RULE	NO INSTANTIATION
SCHEMA	NO INSTANTIATION
SELECT	NO INSTANTIATION
SET	*list*
STRING	*string*
TYPE	NO INSTANTIATION
WHERE RULES	NO INSTANTIATION

CHAPTER 3 - DATA TYPE MAPPINGS

3.0 DATA TYPE MAPPINGS

3.1 BASE DATA TYPES

3.1.1 INTEGER

The EXPRESS construct of **INTEGER** will map syntactically to the DATA section as an ***integer*** data type. Any restrictions on the domain of the data type will be validated at a level higher than the file structure. See the mapping example in Section 3.1.5.

3.1.2 STRING

The EXPRESS construct of **STRING** will map syntactically to the DATA section as a ***string*** data type. Any restrictions on the domain of the data type will be validated at a level higher than the file structure. See the mapping example in Section 3.1.5.

3.1.3 LOGICAL

The EXPRESS construct of **LOGICAL** will map syntactically to the DATA section as an ***enumeration*** data type. See the mapping example in Section 3.1.5. The EXPRESS construct of **LOGICAL** is treated as a predefined enumerated data type with the values of .T., .F., .U..

3.1.4 REAL

The EXPRESS construct of **REAL** will map syntactically to the DATA section as a ***real*** data type. Any restrictions on the domain of the data type will be validated at a higher level than the file structure. See the mapping example in Section 3.1.5.

3.1.5 MAPPING EXAMPLE

Entity Definition in EXPRESS

```
ENTITY WIDGET;
i1: INTEGER(2); <------------ Ⓐ
i2: INTEGER;    <---------------- Ⓑ
s1: STRING(3);  <-------------------- Ⓒ
s2: STRING;     <------------ Ⓓ
l : LOGICAL;    <---------------- Ⓔ
r1: REAL(4);    <-------------------- Ⓕ
r2: REAL;       <------------ Ⓖ
END_ENTITY;
```

Sample Entity Occurrence in DATA Section

```
@12=WIDGET(99,99999,'ABC','ABCDEFG',.T.,9.0,1.2345);
        ^    ^     ^       ^       ^   ^    ^
        |    |     |       |       |   |    |
        Ⓐ    Ⓑ     Ⓒ       Ⓓ       Ⓔ   Ⓕ    Ⓖ
```

Ⓐ i1 had a value of 99 in this entity occurrence. The number 2 in parenthesis indicates the number of decimal digits allowed in values for this attribute. In this case, the value falls within the specified range (-99..99) for this attribute. The value is syntactically and semantically legal.

Ⓑ i2 had a value of 99999 in this entity occurrence.

Ⓒ s1 had a value of 'ABC' in this entity occurrence. This value falls within the range (3 characters) specified for this attribute. The value is syntactically and semantically legal.

Ⓓ s2 had a value of 'ABCDEFG' in this entity occurrence.

Ⓔ l had a value of TRUE in this entity occurrence.

Ⓕ r1 had a value of 9.0 in this entity occurrence. This value falls within the range (4 decimal digits in the fractional part of a number) specified for this attribute. The value is syntactically and semantically legal.

Ⓖ r2 had a value of 1.2345 in this entity occurrence.

3.2 LIST

The EXPRESS construct of LIST will map syntactically to the DATA section as a *list* data type. If a list is optional and does not exist, it is treated as a defaulted field in the DATA section (refer to Chapter 7 of STEP Document ANNEX B Normative, The STEP File Structure). If the list is empty, it will appear in the DATA section as an open parenthesis immediately followed by a close parenthesis.

3.2.1 Mapping Example

Entity Definition In EXPRESS

```
ENTITY WIDGET;
  attribute1:  LIST [0 : #] OF INTEGER; <--------Ⓐ
  attribute2:  LIST [1 : #] OF INTEGER; <------------Ⓑ
  attribute3:  OPTIONAL LIST [1 : #] OF INTEGER; <------Ⓒ
  attribute4:  REAL;
END_ENTITY;
```

Sample Entity Occurrence In DATA Section

```
@24 = WIDGET( (), (1,2,4), , 2.56);
              |      |    |
              |      |    |___________Ⓒ attribute 3 did not exist
              |      |                  in this occurrence.
              |      |
              |      |________________Ⓑ attribute 2 contained three
              |                         elements in this occurrence.
              |
              |_______________________Ⓐ attribute 1 was an empty
                                        list.
```

3.3 ARRAY

The EXPRESS construct of **ARRAY** will map syntactically in the DATA section as a *List* data type. The restrictions on the bounds of the array implied in the Conceptual Schema will be validated at a level higher than that of the file structure. An **ARRAY** [i:j] where j > i has j-i+1 elements.

3.3.1 Mapping Example

Entity Definition In EXPRESS

```
ENTITY WIDGET;
  attribute1:  ARRAY [-1 : 3] OF INTEGER; <-------Ⓐ
  attribute2:  ARRAY [1 : 5] OF OPTIONAL INTEGER; <-------Ⓑ
  attribute3:  ARRAY [1 : 2] OF ARRAY [1 : 3] OF INTEGER; <-------Ⓒ
END_ENTITY;
```

Sample Entity Occurrence In DATA Section

```
@30 = WIDGET((1,2,3,4,5) , (1,2,3,,5)) , ((1,2,3),(4,5,6)));
                 ^              ^                 ^
                 |              |                 |

                 Ⓐ              Ⓑ                 Ⓒ
```

Ⓐ attribute1 contained the following values

```
attribute1 [-1] = 1
attribute1 [0]  = 2
attribute1 [1]  = 3
attribute1 [1]  = 4
attribute1 [1]  = 5
```

Ⓑ attribute2 contained the following values. The meaning of a missing value must be defined in the conceptual schema document.

```
attribute2 [1] = 1
attribute2 [2] = 2
attribute2 [3] = 3
attribute2 [4] = MISSING
attribute2 [5] = 5
```

Mapping Example (continued)

Ⓒ attribute3 contained the following values

```
attribute3 [1,1] = 1
attribute3 [1,2] = 2
attribute3 [1,3] = 3
attribute3 [2,1] = 4
attribute3 [2,2] = 5
attribute3 [2,3] = 6
```

3.4 SET

The EXPRESS construct of SET will map syntactically in the DATA section as a *list* data type. The constraint that no two elements of a SET may have the same value will be validated at a higher level than the file structure. The constraint that a SET may not have missing members will be validated at a higher level than the file structure.

3.4.1. Mapping Example

Entity Definition In EXPRESS

```
ENTITY WIDGET;
  a_number: SET OF INTEGER; <-(A)
END_ENTITY;
```

Sample Occurrence In DATA Section

```
@22 = WIDGET((0,1,2));
              ^
              |
```

(A) The attribute a_number was defined by the set of numbers 0, 1, 2 in this occurrence. It is semantically and syntactically correct.

```
@23 = WIDGET((0, ,2));
              ^
              |
```

(A) In this occurrence the attribute is semantically incorrect according to the definition of a SET in EXPRESS. In EXPRESS a SET may not have missing or defaulted members.

```
@24 = WIDGET((0,0,2));
              ^
              |
```

(A) In this occurrence the attribute is semantically incorrect according to the definition of a SET in EXPRESS. In EXPRESS a SET may not have duplicate values.

3.5 DEFINED TYPE

The EXPRESS construct of TYPE has no instantiation of its own within the DATA section. The type is treated as the element(s) it defines. For example, if a type is defined as a **Real**, a real number is put into the DATA section. If a type is defined to be a **List**, a list is put into the DATA section. A mapping example is provided below.(see 3.6.1) Two other important kinds of defined types, the ENUMERATION and the SELECT are discussed separately.

3.5.1 Mapping Example

Entity Definition In EXPRESS

```
TYPE
  type1 =           INTEGER;
  type2 =           LIST [1 : 2] of REAL;
END_TYPE;
ENTITY WIDGET;
  attribute1:       LOGICAL; <------------ Ⓐ
  attribute2:       TYPE1;  <----------------- Ⓑ
  attribute3:       TYPE2;  <-------------------- Ⓒ
END_ENTITY;
```

Sample Occurrence In DATA Section

```
@14 = WIDGET( .T., 256, (1.0,0.0));
              ^    ^       ^
              |    |       |
              Ⓐ    Ⓑ       Ⓒ
```

3.5.2 ENUMERATION

The EXPRESS construct of **ENUMERATION** will map syntactically to the DATA section as an enumeration. The actual value in an occurrence of the enumeration will be one of the original enumerated values enclosed by periods.

3.5.2.1 Mapping Example

Entity Definition In EXPRESS

```
TYPE
  primary_color = ENUMERATION OF (RED, GREEN, BLUE);
END_TYPE;
ENTITY WIDGET;
  color: PRIMARY_COLOR; <-(A)
END_ENTITY;
```

Sample Occurrence In DATA Section

```
@22 = WIDGET(.RED.);
              ^
              |
             (A)    The color attribute of the entity occurrence
                    contained a value of RED.
```

3.5.3 SELECT

The EXPRESS construct of SELECT has no instantiation of its own within the DATA section. The type is treated as a reference to or an occurrence of one of the entity types in its select-from list. A mapping example is provided below.

3.5.3.1 Mapping Example

```
TYPE
  AAA = SELECT (XXX,YYY, ZZZ);
END_TYPE

ENTITY WIDGET;
  attrl:  LIST [1:#] OF AAA; <---(A)
END_ENTITY;
```

Sample Entity Occurrence in DATA Section

```
@11 = XXX (0.0,0.0,0.0, 1.0,1.0,1.0);

@12 = YYY(0.0,0.0,0.0, 1.0,2.0,0.0, 3.0,2.0,0.0);

@13 = WIDGET((#11,#12,XXX(3.0,2.0,0.0,5.0,4.0,0.0)));
                                  ^
                                  |
                                 (A)
```

(A) The attribute attrl in this entity occurrence had values of a reference to a XXX, a reference to an YYY, and an embedded XXX entity occurrence.

CHAPTER 4 - ENTITY MAPPING

4.0 ENTITY MAPPING

The EXPRESS construct of **ENTITY** will map syntactically to the DATA section as an ***entity***. Due to the possible complexity of entity definitions in EXPRESS, a number of mapping examples are provided. These examples will address the following entity definitions:

o Entities defined with simple, explicit attributes
o Entities defined with optional attributes
o Entities defined with derived attributes
o Entities defined with other entities as attributes
o Entities defined with WHERE Rules

4.1 ENTITY WITH EXPLICIT ATTRIBUTES

Entities with explicit attributes map in a straightforward manner to the representative entity occurrences in the DATA section of the exchange format file structure. The mapping of entities with explicit attributes is illustrated in the example below and described on the following page.

4.1.1 <u>Mapping Example</u>

Entity Definition In EXPRESS

```
TYPE
  primary_color_abbreviation = (R,G,B);
END_TYPE;

ENTITY WIDGET; <------------------------- Ⓐ
  attribute1: INTEGER; <--------------------- Ⓑ
  attribute2: STRING;  <------------------------ Ⓒ
  attribute3: LOGICAL; <---------------------------- Ⓓ
  attribute4: REAL; <-------------------- Ⓔ
  attribute5: LIST [1 : 2] of LOGICAL;  <--- Ⓕ
  attribute6: ARRAY [-1:3]  of INTEGER;  <------- Ⓖ
  attribute7: PRIMARY_COLOR_ABBREVIATION; <---------- Ⓗ
END_ENTITY
```

Sample Entity Occurrence In DATA Section

```
@1 = WIDGET( 1, 'A', .T., 1.0, (.T.,.F.), (1,0,1,2,3), .R.);
       |     |   |    |    |       |           |         |
       Ⓐ     Ⓑ   Ⓒ    Ⓓ    Ⓔ       Ⓕ           Ⓖ         Ⓗ
```

(A) The EXPRESS **ENTITY-NAME** "WIDGET" is mapped to the ***entity-type keyword*** of the DATA section entity.

NOTE: In order to optimize file size yet ensure human readability, it is expected that a table will be created to relate the actual EXPRESS **ENTITY-NAME** to an abbreviated exchange format ***entity-type keyword***.

e.g., **POINT ---> PT, LINE ---> LN**, etc.

(B) attribute 1 had a value of 1 in this entity occurrence.

(C) attribute 2 had a value of 'A' in this entity occurrence.

(D) attribute 3 had a value of .T. in this entity occurrence.

(E) attribute 4 had a value of 1.0 in this entity occurrence.

(F) attribute 5 was a list of logicals in this entity occurrence. The list values were; **LIST(1) = .T., LIST(2) = .F.**

(G) attribute 6 was an array of integers in this entity occurrence. The array values were;

```
ARRAY (-1) = 1
ARRAY ( 0) = 0
ARRAY ( 1) = 1
ARRAY ( 2) = 2
ARRAY ( 3) = 3
```

(H) Attribute 7 was an enumeration. The entity occurrence contained a value of R.

The attribute order of EXPRESS entity definitions is interpreted such that the first entity attribute below the EXPRESS **ENTITY-NAME** is considered to be the first entity attribute. The second entity attribute below the EXPRESS **ENTITY-NAME** is considered to be the second attribute, and so on.

The EXPRESS entity attributes are mapped one-to-one in the order indicated above onto DATA section entity occurrences. The attribute order of DATA section entity occurrences is defined so that the first data value that follows sequentially from the ***entity-type keyword*** is considered to be the value of the first attribute. The second value that follows the ***entity-type keyword*** is considered to be the value of the second attribute, and so on.

The basic data types of EXPRESS (e.g. **INTEGER**, **REAL**, etc.) are always assumed to be **INTERNAL** attributes to the entities in which they appear. It is not permitted to refer to a simple data type in the file structure. Therefore all references in the file structure must refer to other entities.

4.2 ENTITY WITH OPTIONAL ATTRIBUTES

Entities with explicit but optional attributes (assuming the optional attribute value is supplied) follow the same mapping algorithm as entities with explicit and required attributes. (Refer to Section 4.1, "Entity With Explicit Attributes".) When the optional value is not supplied in an entity occurrence, the delimiter that would have appeared (e.g., "," or ")") is still placed into the entity occurrence. The semantics of missing attribute values must be defined by the Application Area that was responsible for defining the entity.

4.2.1 Mapping Example

Entity Definition In EXPRESS

```
ENTITY XXX;
  attribute1: REAL;
  attribute2: REAL;
END_ENTITY;

ENTITY YYY;  <-------------------- Ⓐ
  attribute1: OPTIONAL LOGICAL; <----- Ⓑ
  attribute2: EXTERNAL POINT ;  <-------- Ⓒ
  attribute3: EXTERNAL POINT ;  <-- Ⓓ
  attribute4: OPTIONAL INTEGER; <----- Ⓔ
  attribute5: OPTIONAL REAL;  <---------- Ⓕ
END_ENTITY;
```

Sample Entity Occurrences In DATA Section

```
@1=XXX(1.0,2.0);
@2=XXX(3.0,4.0);

@22=YYY(__,#2,#1,__,__);
        |  |  |  |  |  |
        Ⓐ  Ⓑ  Ⓒ  Ⓓ  Ⓔ  Ⓕ
```

Ⓐ The EXPRESS ENTITY-NAME "YYY" is mapped to the ***entity-type keyword*** of the DATA Section entity.

Ⓑ attribute 1 does not have a value in this entity occurrence.

Ⓒ attribute 2 is a reference to the XXX entity with entity identifier 2.

Ⓓ attribute 3 is a reference to the XXX entity with entity identifier 1.

Ⓔ attribute 4 does not have a value in this entity occurrence.

Ⓕ attribute 5 does not have a value in this entity occurrence.

4.3 ENTITY WITH DERIVED ATTRIBUTES

Derived attributes contain information about an entity in addition to containing those attributes that define the entity explicitly and completely. The derived attributes carry redundant information since they can be calculated from the explicit attributes.

Derived attributes do not map to the DATA section: only explicit attributes are mapped. In the example below, note that the derived attributes (attrib5 and attrib4) do not appear in the entity occurrence.

4.3.1 Mapping Example

Entity Definition In EXPRESS

```
ENTITY XXX;   <---------------------- Ⓐ
  p0: YYY;    <------------------------- Ⓑ
  p1: YYY;    <---------------------------- Ⓒ
  p2: YYY;    <------------------------------- Ⓓ
DERIVE
  attrib5 = FUNC_NORMAL (P0,P1,P2);  <-- Ⓔ
  attrib4 = FUNC_DIAMETER (P0,P1,P2);<------ Ⓕ
END_ENTITY;
```

Sample Entity Occurrences In DATA Section

```
 @9 = YYY( 0.0, 0.0, 0.0);

@10 = YYY( 1.0, 2.0, 3.0);

@11 = INT( 4.0, 5.0, 6.0);

@12 = XXX( #9, #10, #11);
       |    |    |    |
       Ⓐ    Ⓑ    |    |
                 Ⓒ    Ⓓ
```

Ⓐ The EXPRESS ENTITY-NAME "XXX" is mapped to the ***entity-type keyword*** of the DATA Section entity.

Ⓑ p0 is a reference to the YYY entity with an entity identifier of 9.

Ⓒ p1 is a reference to the YYY entity with an entity identifier of 10.

Ⓓ p3 is a reference to the YYY entity with an entity identifier of 11.

Ⓔ attrib5 does not map to the entity occurrence.

Ⓕ attrib4 does not map to the entity occurrence.

4.4 ENTITY WITH ENTITY ATTRIBUTES

When an entity is specified as an attribute of a second (parent) entity, the first (child) entity will be mapped to the DATA section as either an ***entity reference*** or an ***embedded entity***. The exact mapping is controlled by the presence or absence of specific keywords within the attribute declaration: **INTERNAL** and **EXTERNAL**.

If the keyword **INTERNAL** is present, the entity will map to an ***embedded entity***. If the keyword **EXTERNAL** is present, the entity will map to an ***entity reference***. If neither keyword is present, or if the keyword **DYNAMIC** appears, the entity may legally map to either an ***embedded entity*** or an ***entity reference***.

4.4.1 Entities As Internal Attributes

When the keyword **INTERNAL** is present, an entity declared as an attribute will map to an ***embedded entity***. The syntax of an ***embedded entity*** can be found in STEP Document 4.2.1, The STEP File Structure. If the child entity is not a **SUPERTYPE**, then the ***entity type keyword*** is optional. Since the embedded entity must always be of the same type, the ***entity type keyword*** is not required for unambiguous processing of the exchange file. If the child entity is a **SUPERTYPE**, then the ***entity type keyword*** is required because of the select from functionality of EXPRESS's **SUPERTYPE** construct.

The significance of an ***embedded entity*** is that the sending CAD system does not intend for the receiving CAD system to create the ***embedded entity*** as an independent entity within the database of the receiving system. The ***embedded entity*** is present only for the purposes of constructing the parent entity. If the parent entity cannot be constructed within the receiving database, the ***embedded entity*** should not be constructed.

4.4.1.1 Mapping Example

Entity Definition In EXPRESS

```
ENTITY YYY;
x: REAL;
y: REAL;
z: REAL;
END_ENTITY;

ENTITY XXX; <--------- Ⓐ
  p0: INTERNAL YYY ; <--- Ⓑ
  p1: INTERNAL YYY ; <------- Ⓒ
END_ENTITY;
```

Sample Entity Occurrence In DATA Section

$$\texttt{@30 = }\underset{A}{\texttt{XXX}}\texttt{(}\underbrace{\texttt{YYY(0.0, 1.0, 2.0)}}_{B}\texttt{ , }\underbrace{\texttt{YYY(1.0, 2.0, 3.0));}}_{C}$$

Ⓐ The EXPRESS **ENTITY-NAME** "XXX" is mapped to the ***entity-type keyword*** of the DATA Section entity.

Ⓑ p0 is mapped to an embedded YYY entity in this entity occurrence.

Ⓒ p1 is mapped to an embedded YYY entity in this entity occurrence.

Another Sample Entity Occurrence In DATA Section

$$\texttt{@31 = }\underset{D}{\texttt{XXX}}\texttt{(}\underbrace{\texttt{(0.0, 1.0, 2.0)}}_{E}\texttt{ , }\underbrace{\texttt{(1.0, 2.0, 3.0)}}_{F}\texttt{);}$$

Ⓓ The EXPRESS **ENTITY-NAME** "XXX" is mapped to the ***entity-type keyword*** of the DATA Section entity.

Ⓔ p0 is mapped to an embedded YYY entity in this entity occurrence.

Ⓕ p1 is mapped to an embedded YYY entity in this entity occurrence.

4.4.2 Entities As External Attributes

When the keyword **EXTERNAL** is present, an entity declared as an attribute will map to an ***entity reference***. The syntax of an ***entity reference*** can be found in STEP Document Normative ANNEX B, "The STEP File Structure". If the keyword **EXTERNAL** is used, it is illegal for an entity attribute to be embedded in a parent entity.

The significance of an entity reference is that the sending CAD system intends for the receiving CAD system to create the referred entity as an independent, sharable entity within the database of the receiving system.

4.4.2.1 Mapping Example

Entity Definition In EXPRESS

```
ENTITY YYY;
x: REAL;
y: REAL;
z: REAL;
END_ENTITY;

ENTITY XXX; <--------- Ⓐ
p0: EXTERNAL YYY ; <----- Ⓑ
p1: EXTERNAL YYY ; <--------- Ⓒ
END_ENTITY;
```

Sample Entity Occurrences In DATA Section

```
@9 = YYY(4.0, 5.0, 6.0);

@10 = YYY(1.0, 2.0, 3.0);

@11 = XXX(#9, #10);
      |   |    |
      Ⓐ   Ⓑ    Ⓒ
```

Ⓐ The EXPRESS **ENTITY-NAME** "XXX" is mapped to the ***entity-type keyword*** of the DATA Section entity.

Ⓑ p0 is a reference to a YYY entity with an entity identifier of 9.

Ⓒ p1 is a reference to a YYY entity with an entity identifier of 10.

4.4.3 Entities as Dynamic Attributes

When the keyword **DYNAMIC** is present or when neither the keywords **INTERNAL** nor **EXTERNAL** is present, an entity declared as an attribute may legally map to an ***embedded entity*** or an ***entity reference***. The syntax of embedded entities and entity references can be found in STEP Document Normative ANNEX B, "The STEP File Structure".

If the entity that has been declared as an attribute is not a SUPERTYPE, then the ***entity type keyword*** is optional. Since the embedded entity must always be of the same type, the ***entity type keyword*** is not required for unambiguous processing of the exchange file. If the entity that has been declared as an attribute is a SUPERTYPE, then the ***entity type keyword*** is required because of the select from functionality of EXPRESS's SUPERTYPE construct.

The significance of the 2 mappings is specified in Chapters 4.4.1 and 4.4.2.

4.4.3.1 Mapping Example

Entity Definition in EXPRESS

```
ENTITY YYY;
x : REAL;
y : REAL;
z : REAL;
END_ENTITY;

ENTITY XXX <----------- Ⓐ
p0 : DYNAMIC YYY <--------- Ⓑ
p1 : DYNAMIC YYY <------------- Ⓒ
END_ENTITY;
```

Sample Entity Occurence in DATA Section

```
@7 = YYY(3., 4., 5.)
@9 = XXX(YYY(1., 2., 3.), #7);
      |     |              |
      Ⓐ     Ⓑ              Ⓒ
```

Ⓐ The EXPRESS **ENTITY NAME** "XXX" is mapped to the ***entity type keyword*** of the DATA section entity.

Ⓑ The attribute p0 is mapped to an embedded YYY entity in this occurrence.

Ⓒ The attribute p1 is mapped to an entity reference in this entity occurrence.

4.5 ENTITIES AS SUBTYPES

When an EXPRESS entity is labeled as a **SUBTYPE** of some other entity(s) it will inherit the attributes of the **SUPERTYPE** entity(s). The order of the attribute inheritance is as follows:

- o All inherited attributes will appear sequentially prior to the defining attributes of any entity.
- o The attributes of a **SUPERTYPE** entity are inherited in the order they appear in the **SUPERTYPE** entity itself.
- o If the **SUPERTYPE** entity is itself a **SUBTYPE** of another entity, then the attributes of the higher **SUPERTYPE** entity are inherited first.
- o When multiple **SUPERTYPE** entities are listed, the list is processed left to right.

4.5.1 Mapping Example

Entity Definition in EXPRESS

```
ENTITY AAA SUPERTYPE OF (BBB);  <-------------- Ⓐ
tm:  EXTERNAL ZZZ;  <------------------------------ Ⓑ
END_ENTITY;

ENTITY BBB SUBTYPE OF (AAA) SUPERTYPE OF (XXX); <-- Ⓒ
p0:  EXTERNAL YYY;  <-------------------------- Ⓓ
p1:  EXTERNAL YYY;  <------------------------ Ⓔ
END_ENTITY;

ENTITY CCC SUPERTYPE OF (XXX);  <------------ Ⓕ
parameterization : REAL;  <--------------------- Ⓖ
END_ENTITY;

ENTITY XXX SUBTYPE OF (BBB, CCC);  <--------- Ⓗ
midpt:  EXTERNAL YYY;  <------------------------ Ⓘ
END_ENTITY;
```

<u>Sample Entity Occurence in DATA Section</u>

```
@1 = ZZZ(1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 1., 0.);
@2 = YYY(1.0, 2.0, 0.0)
@3 = YYY(2.0, 2.0, 0.0)
@4 = YYY(1.5, 2.5, 0.0)
@5 = XXX(#1, #2, #3, 1.0, #4);
        |    |    |    |    |    |
        H    B    D    E    G    I
```

A Since entity AAA is a **SUPERTYPE**, it will not map to the DATA Section of the exchange format file.

B The attribute tm will map to the DATA Section as an inherited attribute in an entity that is directly or indirectly subtyped to the AAA entity. In this case, tm is represented by the ZZZ entity with the ***entity identifier*** of "@1".

C Since entity BBB is a **SUPERTYPE**, it will not map to the DATA Section of the exchange format file.

D The attribute p0 will map to the DATA Section as an inherited attribute in an entity that is directly or indirectly subtyped to the AAA entity. In this case, p0 is represented by the YYY entity with the ***entity identifier*** "@2".

E The attribute p1 will map to the DATA Section as an inherited attribute in an entity that is directly or indirectly subtyped to the AAA entity. In this case, p1 is represented by the YYY entity with the ***entity identifier*** "@3".

F Since entity CCC is a **SUPERTYPE**, it will not map to the DATA Section of the exchange format file.

G The attribute parameterization will map to the DATA Section as an inherited attribute in an entity that is directly or indirectly subtyped to the AAA entity. In this case, the parameterization value is 1.0.

H The **EXPRESS ENTITY NAME** "XXX" is mapped to the ***entity type keyword*** of the DATA Section entity.

I Attribute midpt is represented by the YYY entity with the ***entity identifier*** of "@4".

4.6 ENTITIES AS SUPERTYPES

Entities that are declared as supertypes of other entities will not map directly to the DATA Section of the exchange format file. The attributes of those supertype entities will be migrated into the subtyped entities. See Section 4.5 for a detailed description of the attribute migration.

4.7 ENTITY WITH WHERE RULES

Only attributes that are explicitly declared are mapped to the DATA section. Therefore, **WHERE** rules do not map to the DATA section. In the example below, note that the **WHERE** rules are not instantiated in the entity occurrence.

The information contained within the **WHERE** rules can be used to validate the information within the entity occurrence. However, the **WHERE** rules themselves are not represented in the exchange format file.

4.7.1 Mapping Example

Entity Definition In EXPRESS

```
ENTITY WIDGET; <-------------- Ⓐ
a: REAL; <----------------------- Ⓑ
b: REAL; <-------------------------- Ⓒ
c: REAL; <------------------- Ⓓ
WHERE
a ** 2 + b ** 2 + c ** 2 = 3.0; <--Ⓔ
END_ENTITY;
```

Sample Entity Occurrence In DATA Section

```
@22 = WIDGET( 1.0, 1.0, 2.0);
           |     |    |    |
           Ⓐ     Ⓑ    |    |
                      Ⓒ    Ⓓ
```

Ⓐ The EXPRESS **ENTITY NAME** "WIDGET" is mapped to the ***entity type keyword*** of the DATA section entity.

Ⓑ Attribute a had a value of 1.0 in the entity occurence.

Ⓒ Attribute b had a value of 1.0 in the entity occurence.

Ⓓ Attribute c had a value of 2.0 in the entity occurence.

Ⓔ The WHERE rule did not map to the DATA section. In this case, the entity is syntactically correct, but semantically incorrect.

CHAPTER 5 - SCHEMA

5.0 SCHEMA

The EXPRESS construct of **SCHEMA** does not map to the DATA Section.

CHAPTER 6 - REMARKS

6.0 REMARKS

Remarks do not map to the DATA section.

Title: Integrated Product Data Semantic Model and Topical Reference Models

Owner: Anthony Day

Date: 31 October 1988

Corresponding ISO Document Number: N288

1.1 Purpose

The purpose of the data model described herein is to provide a fundamental data structure for the shape definition of a product item and its various geometric representations. The data structure is independent of the type of product. Whether it be strictly mechanical, electrical, architectural, construction, or of some other type, the model can satisfy the requirements to provide the shape definition and shape geometric representations.

1.2 Scope

The scope of the Integration Core Model evolves as more PDES topical models become ready to be integrated. The initial scope of the model is focused on models that contain shareable information, such as geometry, Product Structure Configuration Management, Form Feature, Tolerance, etc. The model does not contain information that is specific to an application area, such as Mechanical Product, Electric Product, Architectural Product, etc. The scope of the integration core model will expand to contain integration information necessary for the purpose to indicate how the shareable data is used for an application area.

At any point of time, the Integration Core Model represents a consolidated viewpoint of all models that are addressed. Eventually, the Integration Core Model will represent the viewpoint of PDES total scope.

1.3 Fundamental Concepts and Assumptions

The Integration Core Model was based on a fundamental conceptual idea—that is, the elements of shape that are used to reference the form of a real or conceived object are independent from any specific geometric and topological elements (e.g, face, vertex, point, etc.) that are associated with specific rules of a representation method. A clear distinction was made between referenceable shape elements on a real or conceived object and the mechanism used to represent that shape element.

The structure of the Integration Core Model is very extendible. The separation of the referenceable shape elements from their representations allows expansion of additional representations. The establishment of the referenceable shape elements provides a framework for elements of the descriptive identification of the physical form of any product item. It also allows for future expansion when requirements arise.

For each identified shape element, relationships were established to all of its known possible representations. The following table was used to capture the relationships and guide the development of the Integration Core Model:

Referenceable Shape Element and Representation Geometric Model Relationship Tables

Dimensionality-3 Shape Element Representation Table

Model	Object	Voidless Volume	Object Assembly
Brep	Entire model	Shell	
Facetted Brep	Entire model	Shell	
CSG Solid	Entire model	Entire model	Entire model
CSG Primitive		Entire model	
Surface	Entire model	Entire model	Entire model
Half Space		Entire model	
Wireframe	Entire model	Entire model	Entire model
SOR (Complete)	Entire model	Loop log. struct.	
SOR (Partial)		Entire model	
SOLE		Entire model	
Unstruct. Geom.	Entire model	Entire model	Entire model
Geom. Assembly			Entire model

Dimensionality-2 Shape Element Representation Table

Model	Area	Maximal Area	Nonmaximal Area
Brep	Face		Subface
Facetted Brep	Face		Subface
CSG Solid			
CSG Primitive			
Surface	Face		Subface
Half Space			
Wireframe	Loop		
SOR (Complete)	Edge		Edge (1)
SOR (Partial)	Edge	Face	Subface, Edge (1)
SOLE	Edge	Face	Subface, Edge (1)
Unstruct. Geom.	Geometry		
Geom. Assembly			

Note 1: Edge on subface.

Model	Seam	Perimeter
Brep	Edge	Loop
Facetted Brep		Polyloop
CSG Solid		
CSG Primitive		
Surface	Edge	Loop
Half Space		
Wireframe	Edge	Loop
SOR (Complete)	Vertex	Vertex
SOR (Partial)	Edge, Vertex	Loop, Edge
SOLE	Edge, Vertex	Loop, Edge
Unstruct. Geom.	Geometry	Geometry
Geom. Assembly		

Dimensionality-0 Shape Element Representation Table

Model	Corner	Boundary Location	Interior Location
Brep	Vertex	Vertex (1)	Vertex (1)
Facetted Brep	Point	Point (2)	Point (2)
CSG Solid			
CSG Primitive			
Surface	Vertex	Vertex (1)	Vertex (1)
Half Space			
Wireframe	Vertex	Vertex (1)	Vertex (1)
SOR (Complete)	Vertex		Vertex (1)
SOR (Partial)	Vertex	Vertex (1)	Vertex (1)
SOLE	Vertex	Vertex (1)	Vertex (1)
Unstruct. Geom.	Geometry	Geometry	Geometry
Geom. Assembly			

Note 1: Vertex on nonmax face.
Note 2: Point on nonmax polyloop.

Assumptions were made that the PDES Integrated Product Data Model (IPDM) must address the following issues:

(1) PDES must include various types of geometric models, i.e., Boundary Representation, CSG, Surface, Extrusion, Wireframe, Solid of Revolution, Facetted Boundary Representation, Geometry, and a mixture of several representations.

(2) To describe the same physical form/shape of a product item, many possible representations can be and will be used

(3) It is necessary to identify the correspondences between geometric entities that belong to different geometric models when they represent the same physical form/shape of a product item.

(4) PDES will allow geometry to be exchanged independent of its association with a product item, e.g., standard shape

1.4 Abbreviations and Acronyms

The following abbreviations and acronyms are used throughout this document.

Brep	Boundary Representation
DIM-0	Dimensionality-0
DIM-1	Dimensionality-1
DIM-2	Dimensionality-2
DIM-3	Dimensionality-3
PDES	Product Data Exchange Specification
PI	Product Item
PIV	Product Item Version
PSCM	Product Structure Configuration Management
SE	Shape Element
SML	Structured Modeling Language
SOLE	Solids of Linear Extrusion
SOR	Solids of Revolution

2. INTEGRATION PLANNING MODEL

This section describes the planning model for the Integration model. This planning model serves as a high-level overview of the scope of the model and as a starting point for the development of the detailed reference model.

2.1 Entity Pool

The Integration planning model consists of the following entities, which are defined on subsequent pages:

Entity No.	Entity Name
INT-1	Shape
INT-2	Shape Element

The Integration planning model also contains the following entities, which are (or need to be) defined in other PDES reference models:

Entity No.	Entity Name
PSCM-1	Product Item
PSCM-2	Product Item Version
GEO-84	CSG Primitive Model
GEO-85	CSG Solid Model
GEO-86	Facetted Brep Model
GEO-87	Half Space Model
GEO-88	Manifold Solid Brep Model
GEO-106	Solid of Linear Extrusion Model
GEO-107	Solid of Revolution Model
	Surface Model
	Wireframe Model
	Unstructured Geometry Model
	Geometric Assembly Model

2.2 Planning Model Diagram

planning model goes here

2.3 Entity Glossary

Entity Name: CSG Primitive Model

Entity Number: GEO-84

Entity Definition: Defined in the PDES Geometry reference model.

Business Rules: Every "CSG Primitive Model":
- represents zero, one, or more "Shape Elements".

Entity Name: CSG Solid Model

Entity Number: GEO-85

Entity Definition: Defined in the PDES Geometry reference model.

Business Rules: Every "CSG Solid Model":
- represents zero, one, or more "Shape Elements".

Entity Name: Facetted Brep Model

Entity Number: GEO-86

Entity Definition: Defined in the PDES Geometry reference model.

Business Rules: Every "Facetted Brep Model":
- represents zero, one, or more "Shape Elements".

Entity Name: Geometric Assembly Model

Entity Number: none

Entity Definition: Needs to be defined in some other PDES reference model.

Business Rules: Every "Geometric Assembly Model":
- represents zero, one, or more "Shape Elements".

Entity Name: Half Space Model

Entity Number: GEO-87

Entity Definition: Defined in the PDES Geometry reference model.

Business Rules: Every "Half Space Model":
- represents zero, one, or more "Shape Elements".

Entity Name: Manifold Solid Brep Model

Entity Number: GEO-88

Entity Definition: Defined in the PDES Geometry reference model.

Business Rules: Every "Manifold Solid Brep Model":
- represents zero, one, or more "Shape Elements".

Entity Name: Product Item

Entity Number: PSCM-1

Entity Definition: Defined in the PDES PSCM reference model.

Business Rules: Every "Product Item":
- has one or more "Product Item Versions".

Entity Name: Product Item Version

Entity Number: PSCM-2

Entity Definition: Defined in the PDES PSCM reference model.

Business Rules: Every "Product Item Version":
- is for one, and only one, "Product Item".
- has a primary shape of zero, one, or more "Shapes".

Entity Name:	Shape
Entity Number:	INT-1
Entity Definition:	The size, spatial configuration, and proportions of a real or conceived thing, independent of whether or how it is represented.

Business Rules: Every "Shape":

- is an aggregation zero, one, or more "Shape Elements".
- is the primary shape for zero, one, more "Product Item Versions".

Entity Name:	Shape Element
Entity Number:	INT-2
Entity Definition:	A distinguishable aspect of a "Shape".

Business Rules: Every "Shape Element":

- is part of one, and only one, "Shape".
- is represented by zero, one, or more "CSG Primitive Models".
- is represented by zero, one, or more "CSG Solid Models".
- is represented by zero, one, or more "Facetted Brep Models".
- is represented by zero, one, or more "Geometric Assembly Models".
- is represented by zero, one, or more "Half Space Models".
- is represented by zero, one, or more "Manifold Solid Brep Models".
- is represented by zero, one, or more "Solid of Linear Extrusion Models".
- is represented by zero, one, or more "Solid of Revolution Models".
- is represented by zero, one, or more "Surface Models".
- is represented by zero, one, or more "Unstructured Geometry Models".
- is represented by zero, one, or more "Wireframe Models".

Entity Name: Solid of Linear Extrusion Model

Entity Number: GEO-106

Entity Definition: Defined in the PDES Geometry reference model.

Business Rules: Every "Solid of Linear Extrusion Model":
- represents zero, one, or more "Shape Elements".

Entity Name: Solid of Revolution Model

Entity Number: GEO-107

Entity Definition: Defined in the PDES Geometry reference model.

Business Rules: Every "Solid of Revolution Model":
- represents zero, one, or more "Shape Elements".

Entity Name: Surface Model

Entity Number: none

Entity Definition: Needs to be defined in some other PDES reference model.

Business Rules: Every "Surface Model":
- represents zero, one, or more "Shape Elements".

Entity Name: Unstructured Geometry Model

Entity Number: none

Entity Definition: Needs to be defined in some other PDES reference model.

Business Rules: Every "Unstructured Geometry Model":
- represents zero, one, or more "Shape Elements".

Entity Name: Wireframe Model

Entity Number: none

Entity Definition: Needs to be defined in some other PDES reference model.

Business Rules: Every "Wireframe Model":

- represents zero, one, or more "Shape Elements".

3. INTEGRATION REFERENCE MODEL

This section describes the reference model for the Integration model. This reference model is depicted in 15 individual views:

1. Shape
2. Geometric Models
3. Dimensionality-3
4. Object
5. Voidless Volume
6. Object Assembly
7. Area
8. Maximal Area
9. Nonmaximal Area
10. Seam
11. Perimeter
12. Dimensionality-0
13. Corner
14. Boundary Location
15. Interior Location

3.1 Entity Pool

The Integration reference model consists of the following entities, which are defined on subsequent pages:

Entity No.	Entity Name
INT-1	Shape
INT-2	Shape Element
INT-3	Dimensionality 3 Shape Element
INT-4	Object Shape Element
INT-5	Voidless Volume Shape Element
INT-6	Object Assembly Shape Element
INT-7	Dimensionality 2 Shape Element
INT-8	Area Shape Element
INT-9	Maximal Area Shape Element
INT-10	Nonmaximal Area Shape Element
INT-11	Zone Shape Element
INT-13	Dimensionality 1 Shape Element
INT-14	Seam Shape Element
INT-15	Edge Shape Element
INT-16	Subedge Shape Element
INT-17	Interior Seam Shape Element
INT-18	Perimeter Shape Element
INT-19	Dimensionality 0 Shape Element
INT-20	Corner Shape Element
INT-21	Boundary Location Shape Element
INT-22	Interior Location Shape Element
INT-23	Geometric Model
INT-24	Pair of Equivalent Geometric Models
INT-25	Dim 3 Shape Element Representation
INT-26	CSG Solid Dim 3 SE Rep
INT-27	Surface Dim 3 SE Rep
INT-28	Wireframe Dim 3 SE Rep
INT-29	Unstruct Geometry Dim 3 SE Rep
INT-30	Object Representation
INT-31	Brep Object Rep
INT-32	Facetted Brep Object Rep
INT-33	Full Rev SOR Object Rep
INT-34	Voidless Volume Representation
INT-35	Brep Volume Rep
INT-36	CSG Primitive Volume Rep
INT-37	Half Space Volume Rep
INT-38	Partial Rev SOR Volume Rep
INT-39	Full Rev SOR Volume Rep

INT-40	SOLE Volume Rep
INT-41	Object Assembly Representation
INT-42	Area Representation
INT-43	Brep Area Rep
INT-44	Facetted Brep Area Rep
INT-45	Surface Area Rep
INT-46	Partial Rev SOR Max Area Rep
INT-47	SOLE Max Area Rep
INT-48	Wireframe Area Rep
INT-49	SOR Edge Area Rep
INT-50	SOLE Edge Area Rep
INT-51	Unstruct Geometry Area Rep
INT-52	Nonmaximal Area Representation
INT-53	Brep NM Area Rep
INT-54	Facetted Brep NM Area Rep
INT-55	Surface NM Area Rep
INT-56	Partial Rev SOR Subface NM Area Rep
INT-57	SOLE Subface NM Area Rep
INT-59	SOR Edge NM Area Rep
INT-60	SOLE Edge NM Area Rep
INT-63	Seam Representation
INT-64	Brep Seam Rep
INT-65	Surface Seam Rep
INT-66	Wireframe Seam Rep
INT-67	Partial Rev SOR Edge Seam Rep
INT-68	SOLE Edge Seam Rep
INT-70	SOR Vertex Seam Rep
INT-71	SOLE Vertex Seam Rep
INT-72	Unstruct Geometry Seam Rep
INT-73	Perimeter Representation
INT-74	Brep Perimeter Rep
INT-75	Surface Perimeter Rep
INT-76	Wireframe Perimeter Rep
INT-77	Partial Rev SOR Loop Perimeter Rep
INT-78	SOLE Loop Perimeter Rep
INT-79	Facetted Brep Perimeter Rep
INT-80	Full Rev SOR Vertex Perimeter Rep
INT-81	Partial Rev SOR Edge Perimeter Rep
INT-82	SOLE Edge Perimeter Rep
INT-83	Unstruct Geometry Perimeter Rep
INT-84	Dim 0 Shape Element Representation
INT-85	Brep Dim 0 SE Rep
INT-86	Surface Dim 0 SE Rep
INT-87	Wireframe Dim 0 SE Rep
INT-88	SOLE Dim 0 SE Rep

INT-89	Facetted Brep Dim 0 SE Rep
INT-90	Unstruct Geometry Dim 0 SE Rep
INT-91	Corner Representation
INT-92	Full Rev SOR Corner Rep
INT-93	Partial Rev SOR Corner Rep
INT-97	Partial Rev SOR Bdry Loc Rep
INT-99	Interior Location Representation
INT-100	Full Rev SOR Int Loc Rep
INT-101	Partial Rev SOR Int Loc Rep
INT-103	Zone Shape Element Component
INT-104	Facetted Brep Volume Rep
INT-105	Maximal Area Representation

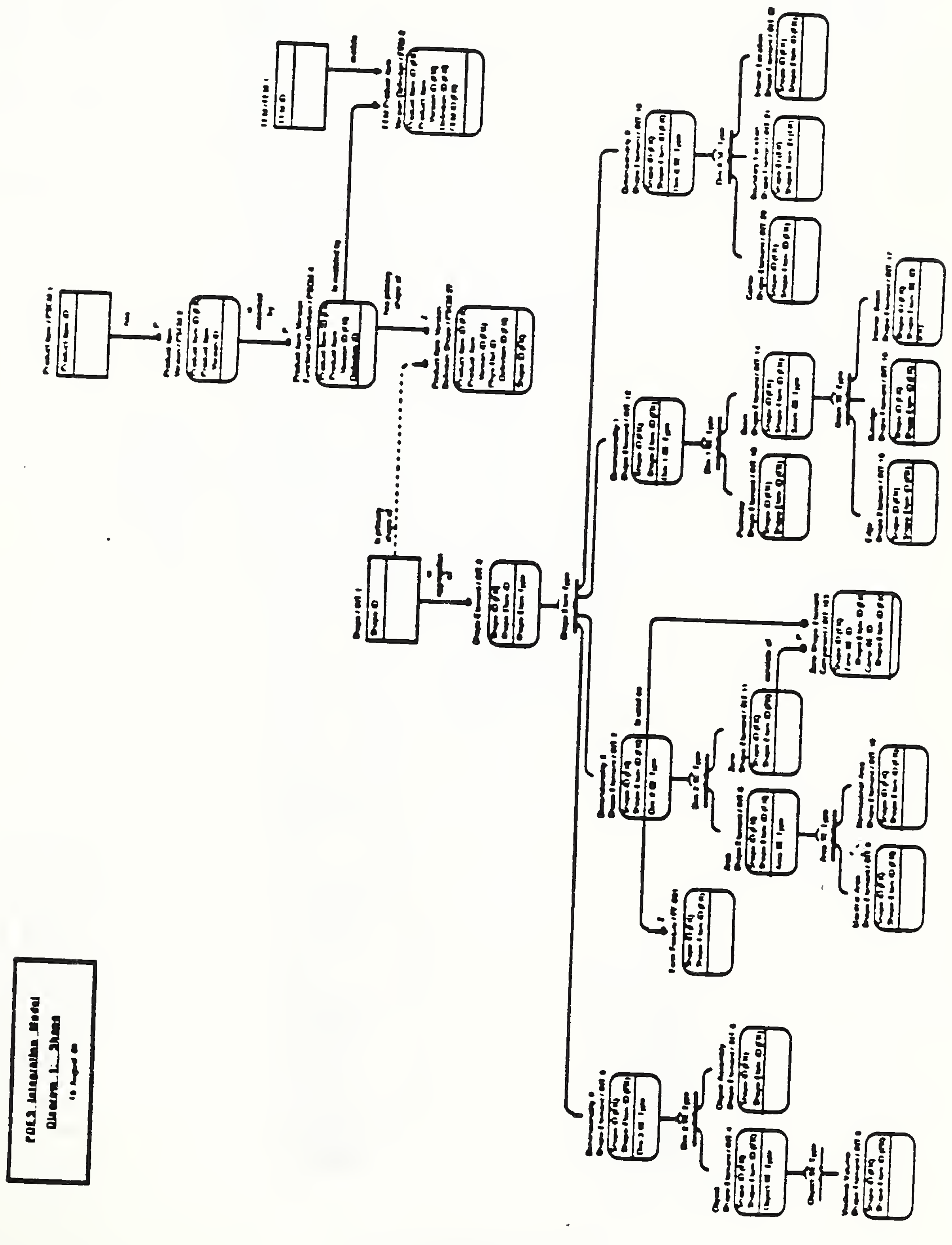
The Integration reference model also contains the following entities, which are (or need to be) defined in other PDES reference models:

Entity No.	Entity Name
FF-001	Form Feature
TOP-2	Vertex
TOP-3	Edge
TOP-4	Loop
TOP-5	Face
TOP-6	Shell
TOP-8	Subface
TOP-11	Polyloop
TOP-25	Loop Logical Structure
GEO-1	Geometry
GEO-2	Point
GEO-84	CSG Primitive Model
GEO-85	CSG Solid Model
GEO-86	Facetted Brep Model
GEO-87	Half Space Model
GEO-88	Manifold Solid Brep Model
GEO-106	Solid of Linear Extrusion Model
GEO-107	Solid of Revolution Model
	Surface Model
	Wireframe Model
	Unstructured Geometry Model
	Geometric Assembly Model

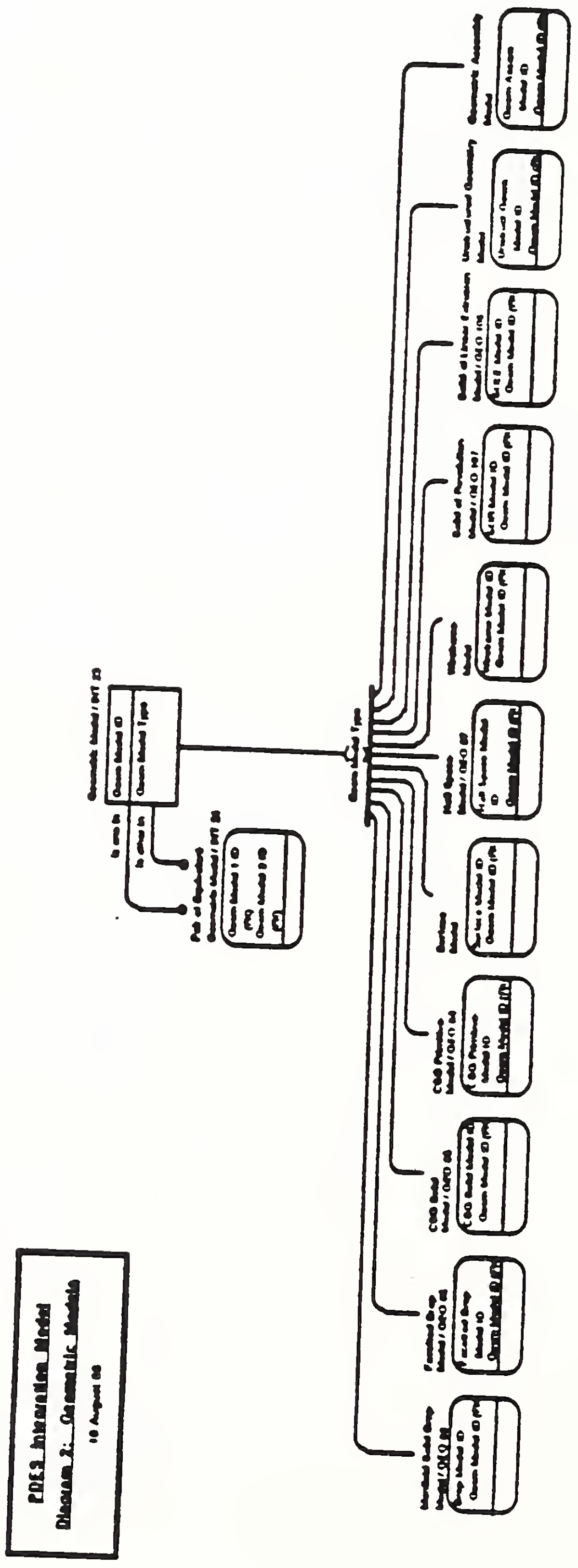
Section 1: INTEGRATION CORE MODEL

PSCM-1	Product Item
PSCM-2	Product Item Version
PSCM-4	Product Item Version Functional Definition
PSCM-27	Product Item Version Definition Shape
FEM-1	FEM
FEM-2	FEM Product Item Version Definition

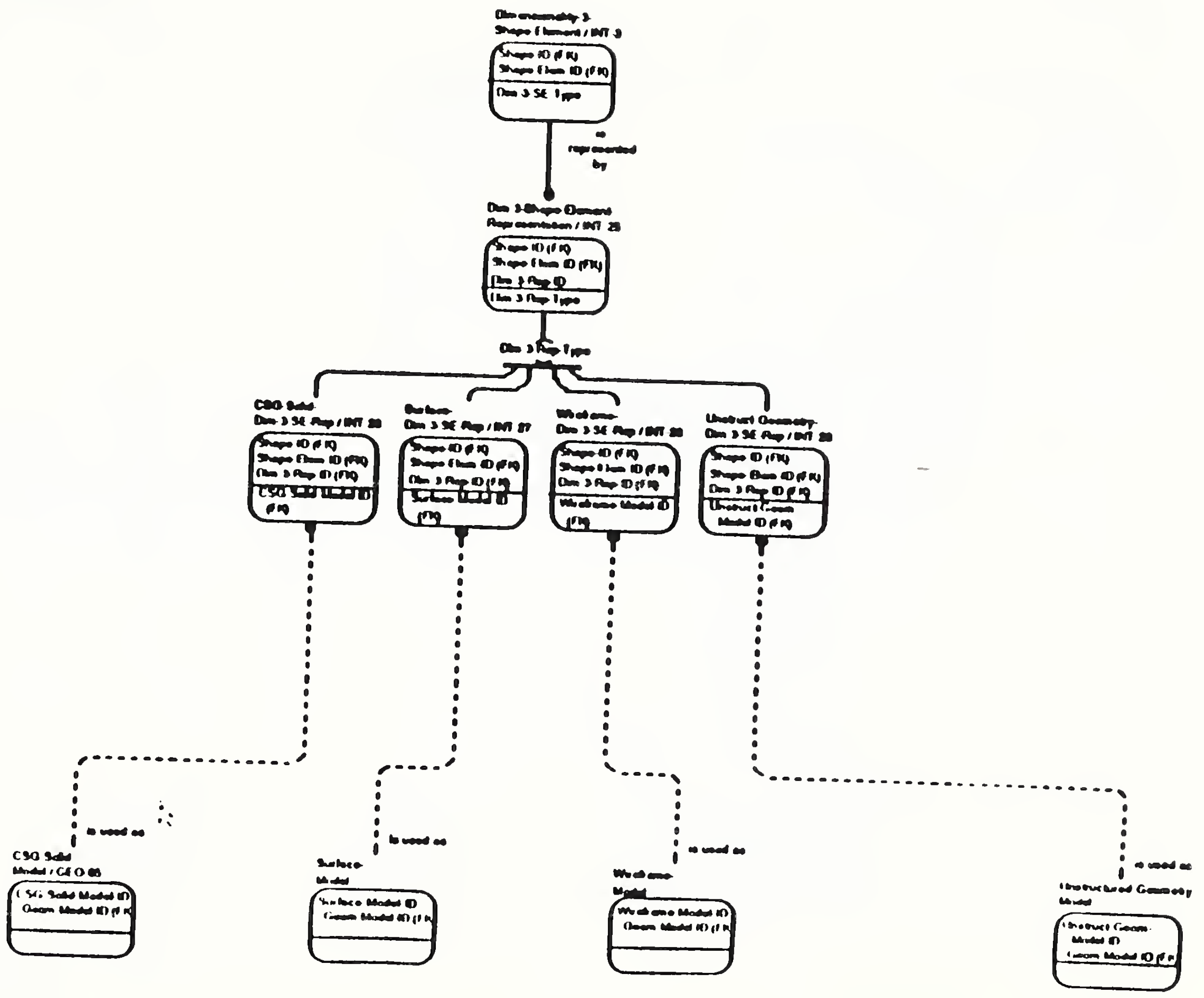
3.2 Reference Model Diagrams



Section 1: *INTEGRATION CORE MODEL*



PDES Integration Model
Diagram 3: Dimensionality-3
18 August 88

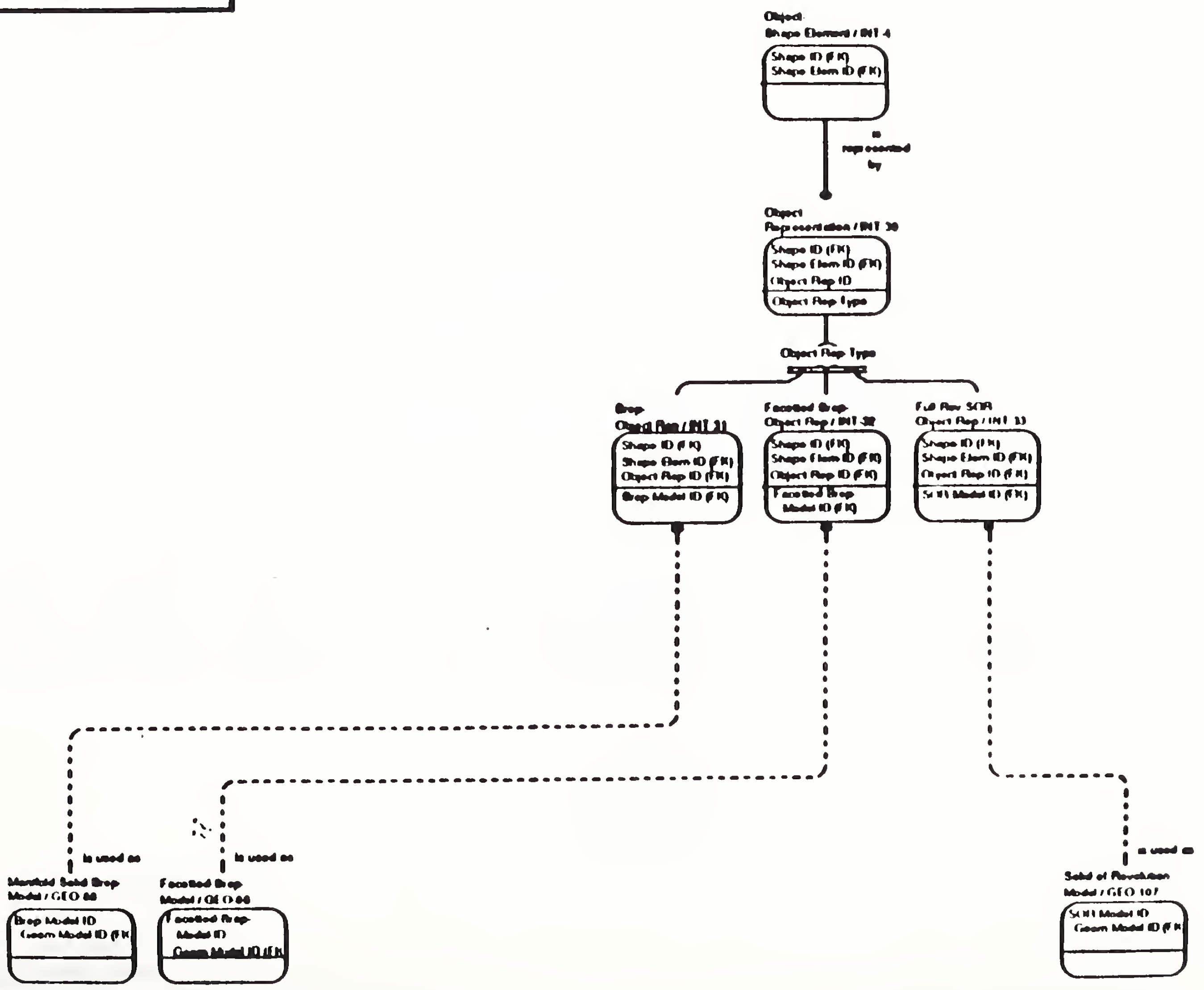


Section 1: INTEGRATION CORE MODEL

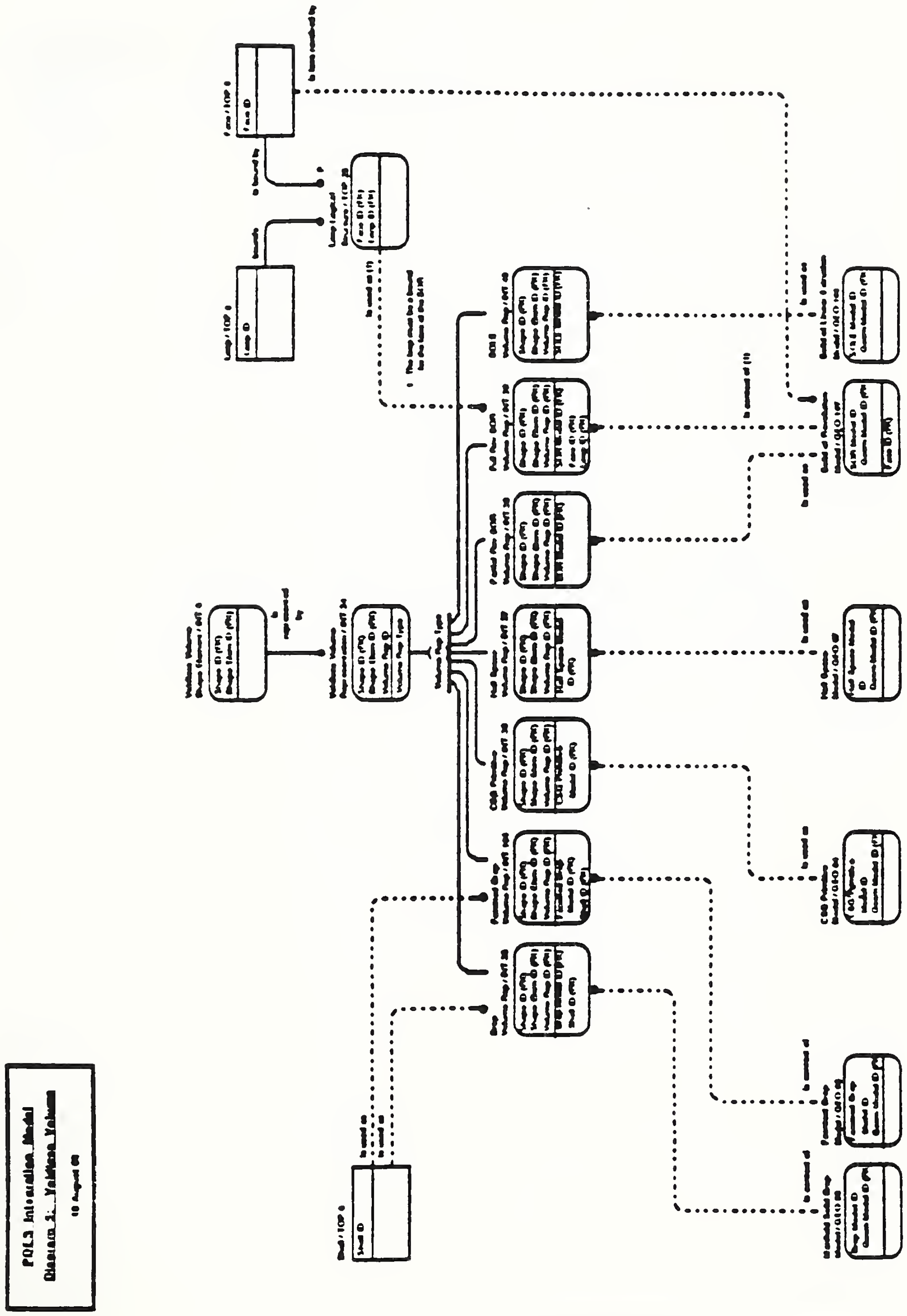
PDES Integration Model

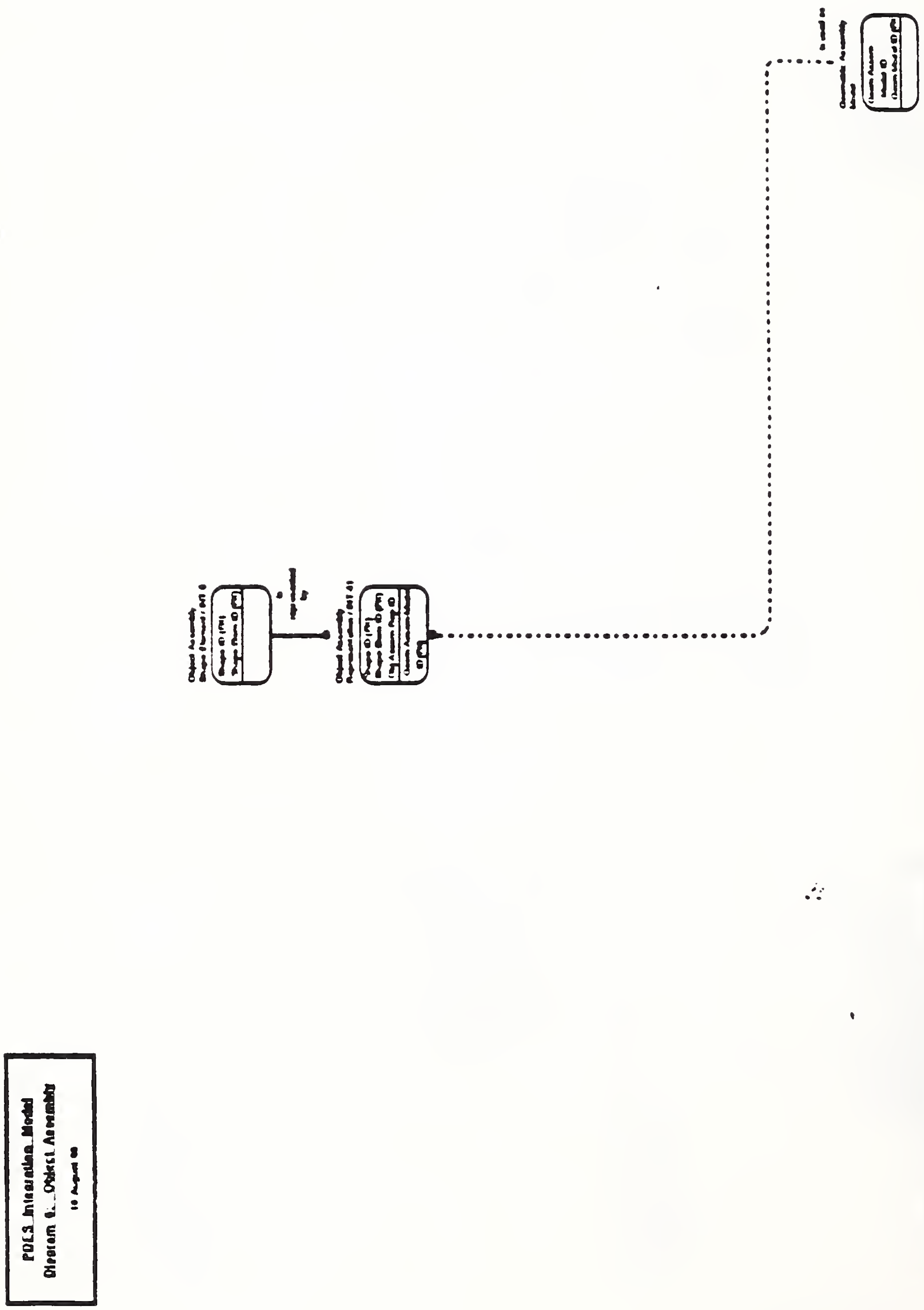
Diagram 4: Object

18 August 88



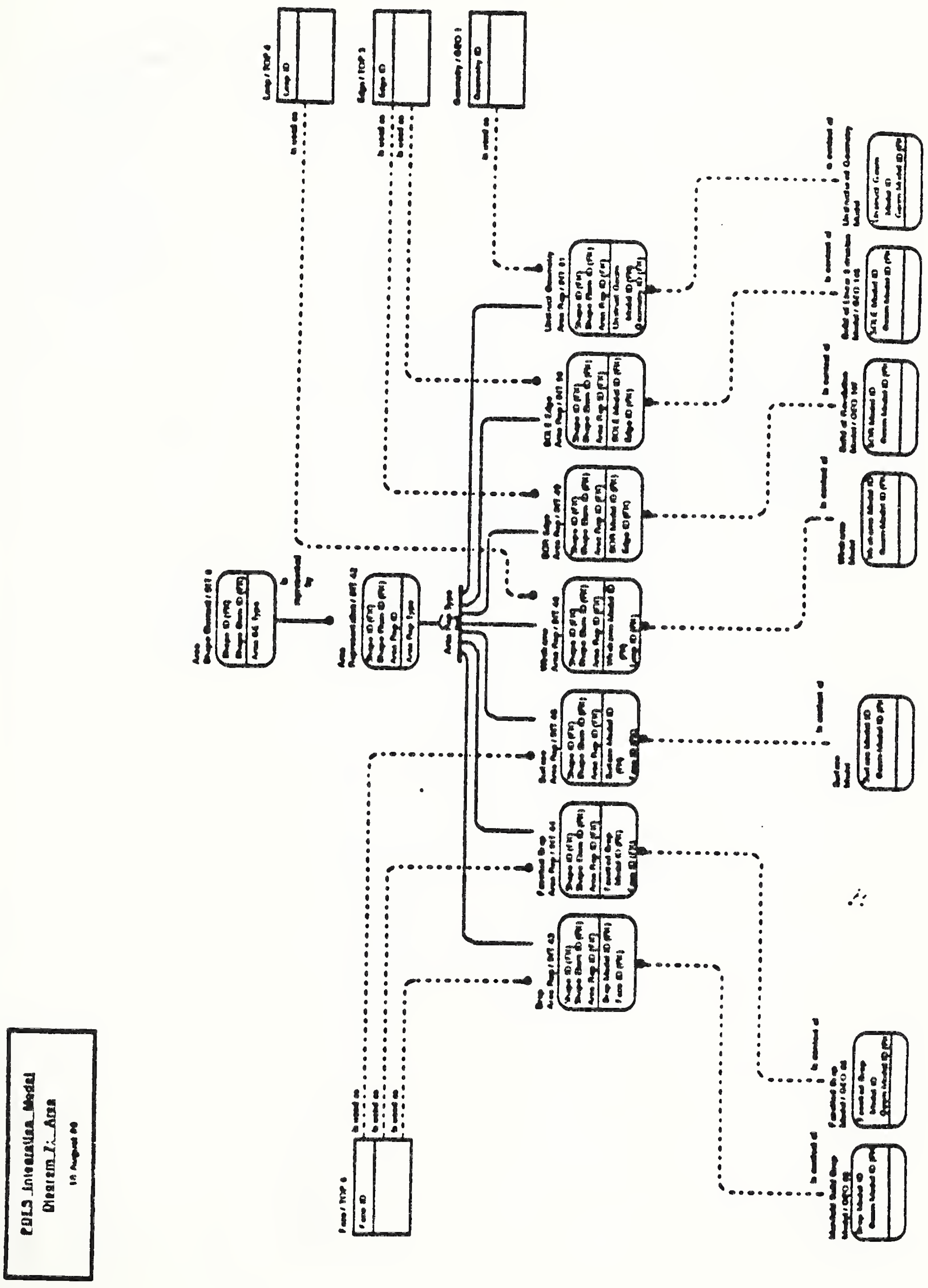
Section 1: INTEGRATION CORE MODEL





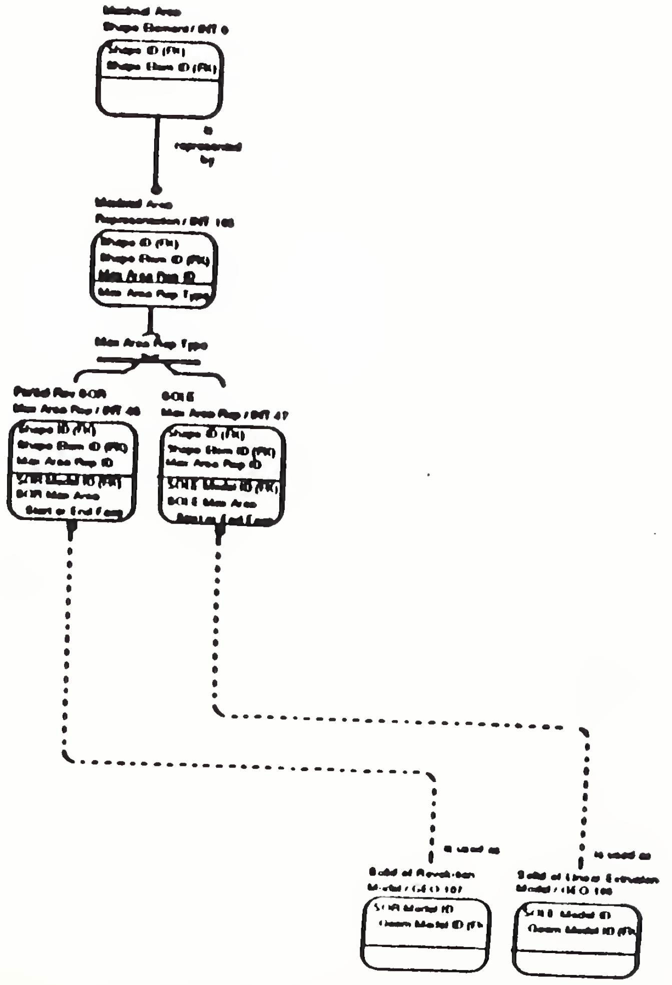
PDES_Integration_Model
Diagram 6._Object Assembly
10 August 88

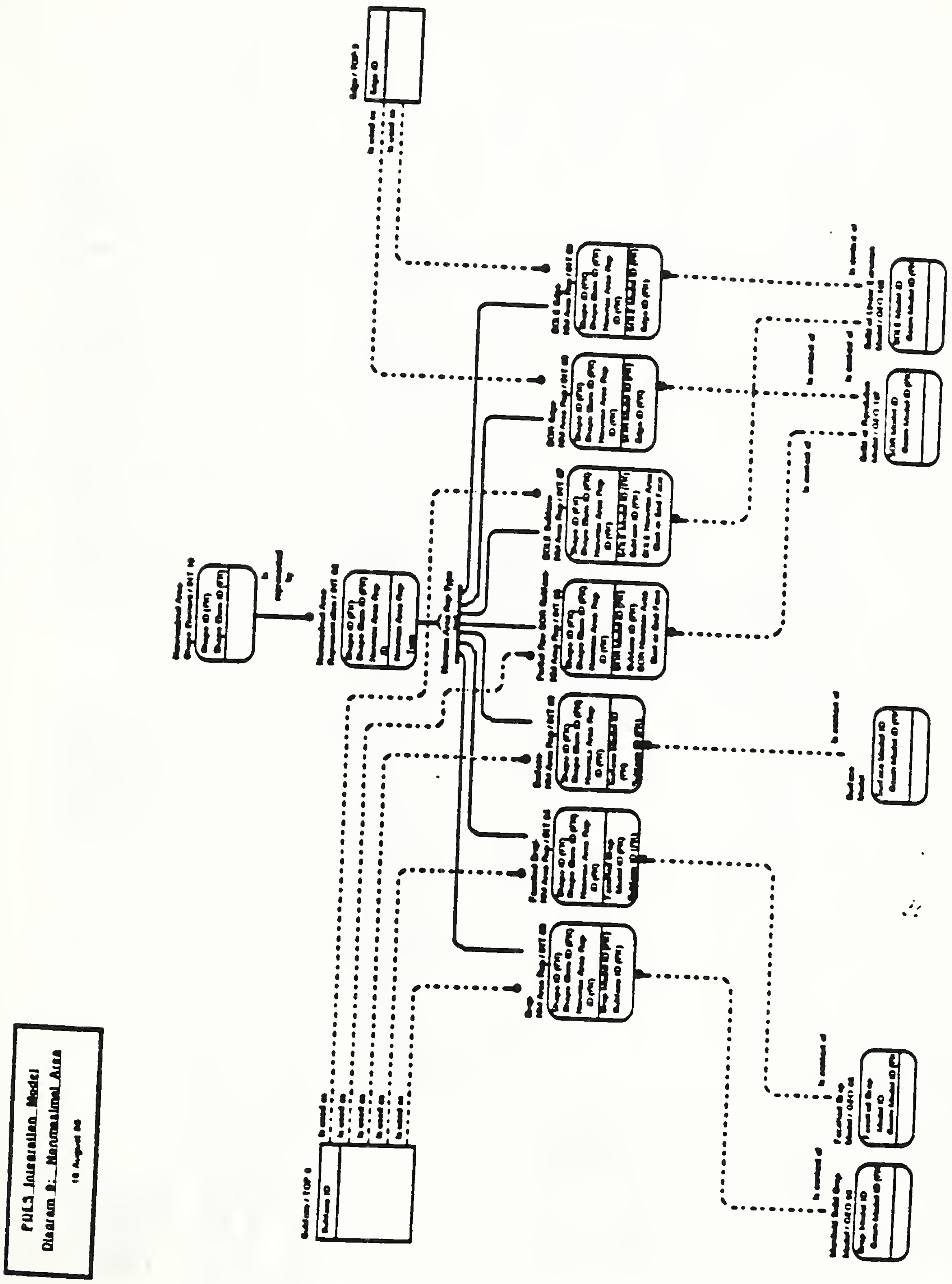
Section 1: INTEGRATION CORE MODEL



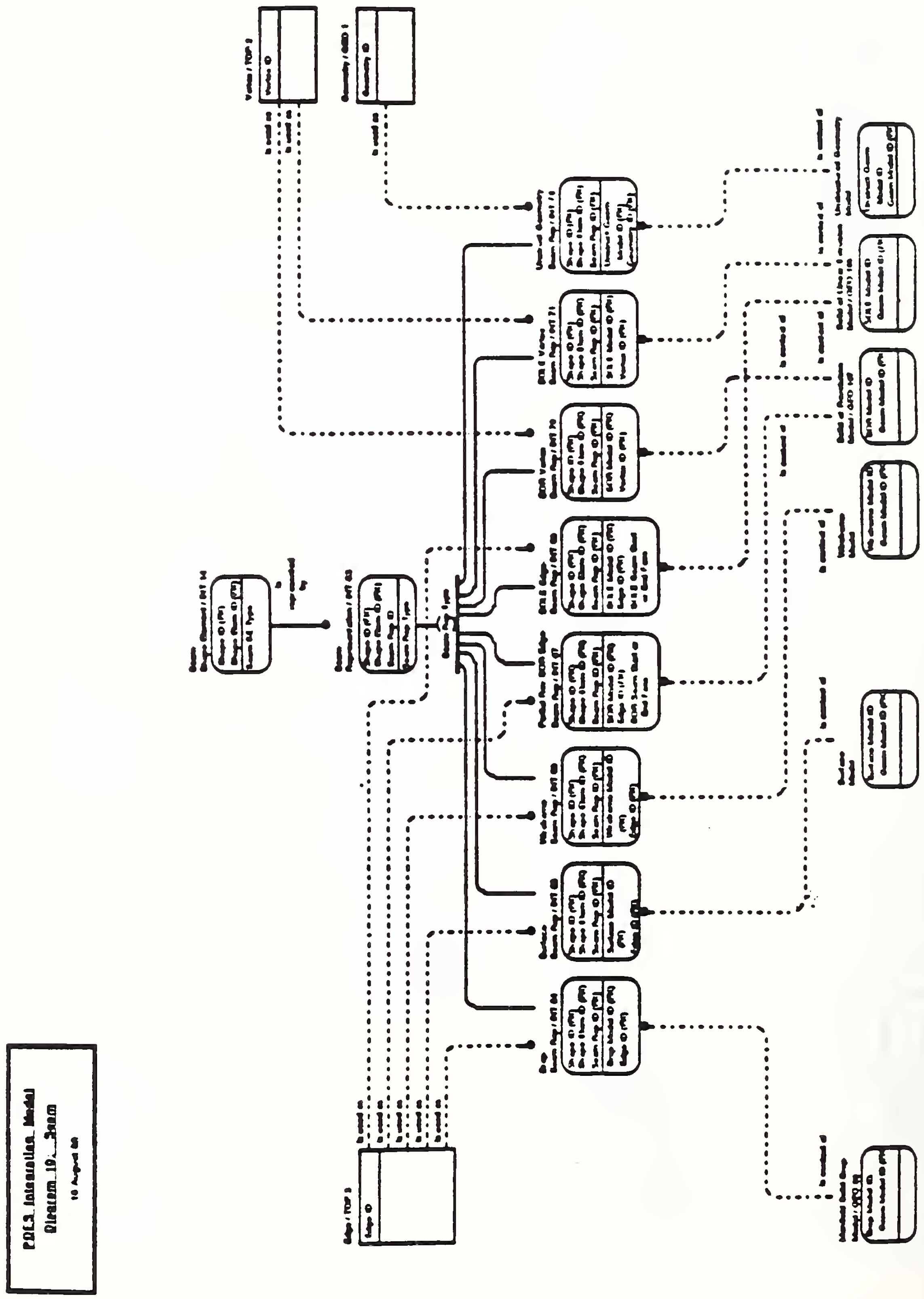
Section 1: INTEGRATION CORE MODEL

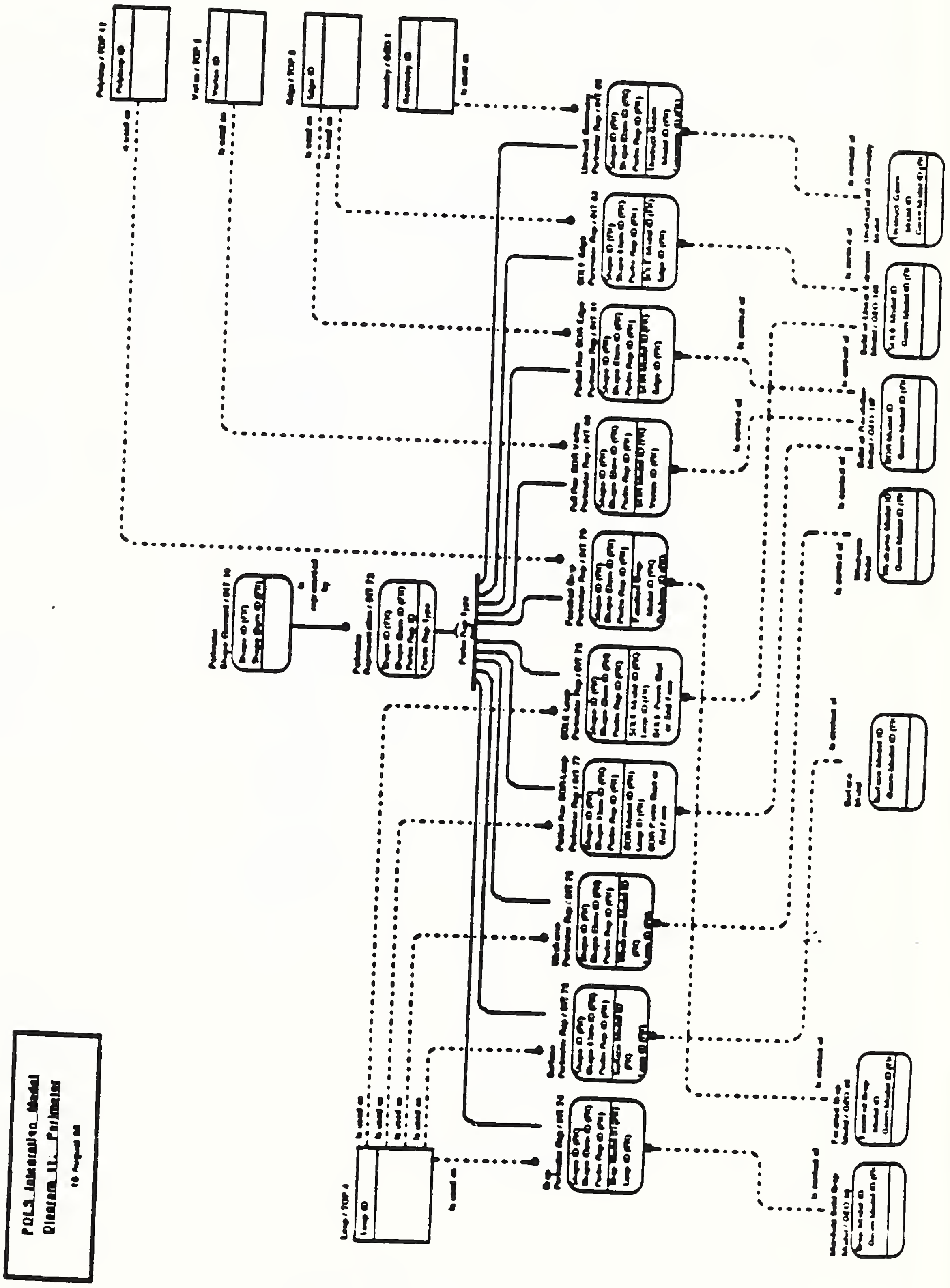
PDLS Integration Model
Diagram 6: Maximal Area
10 August 88



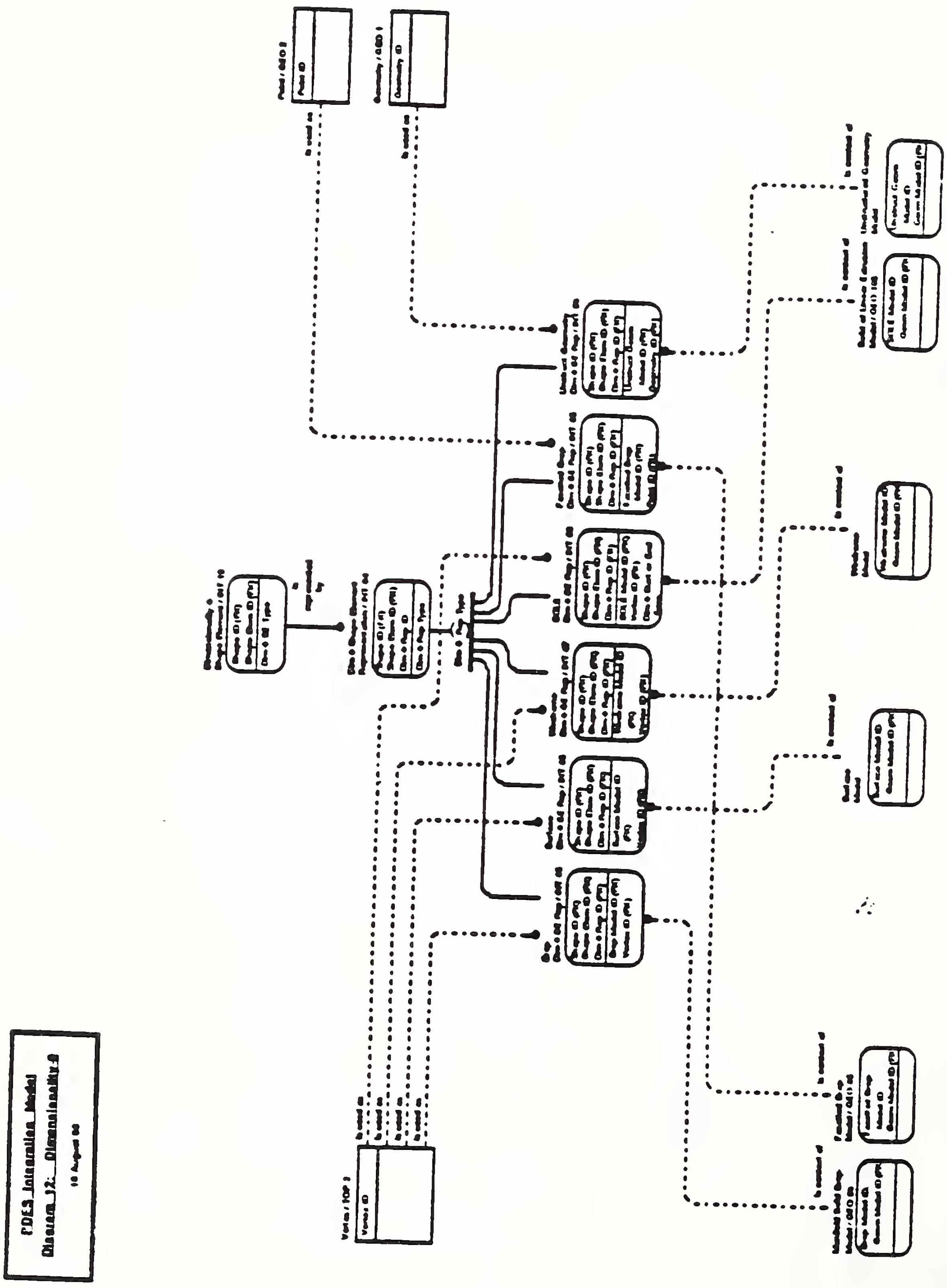

PDES Integration Model
Diagram 8: Nonmaximal Area
10 August 88

Section 1: INTEGRATION CORE MODEL

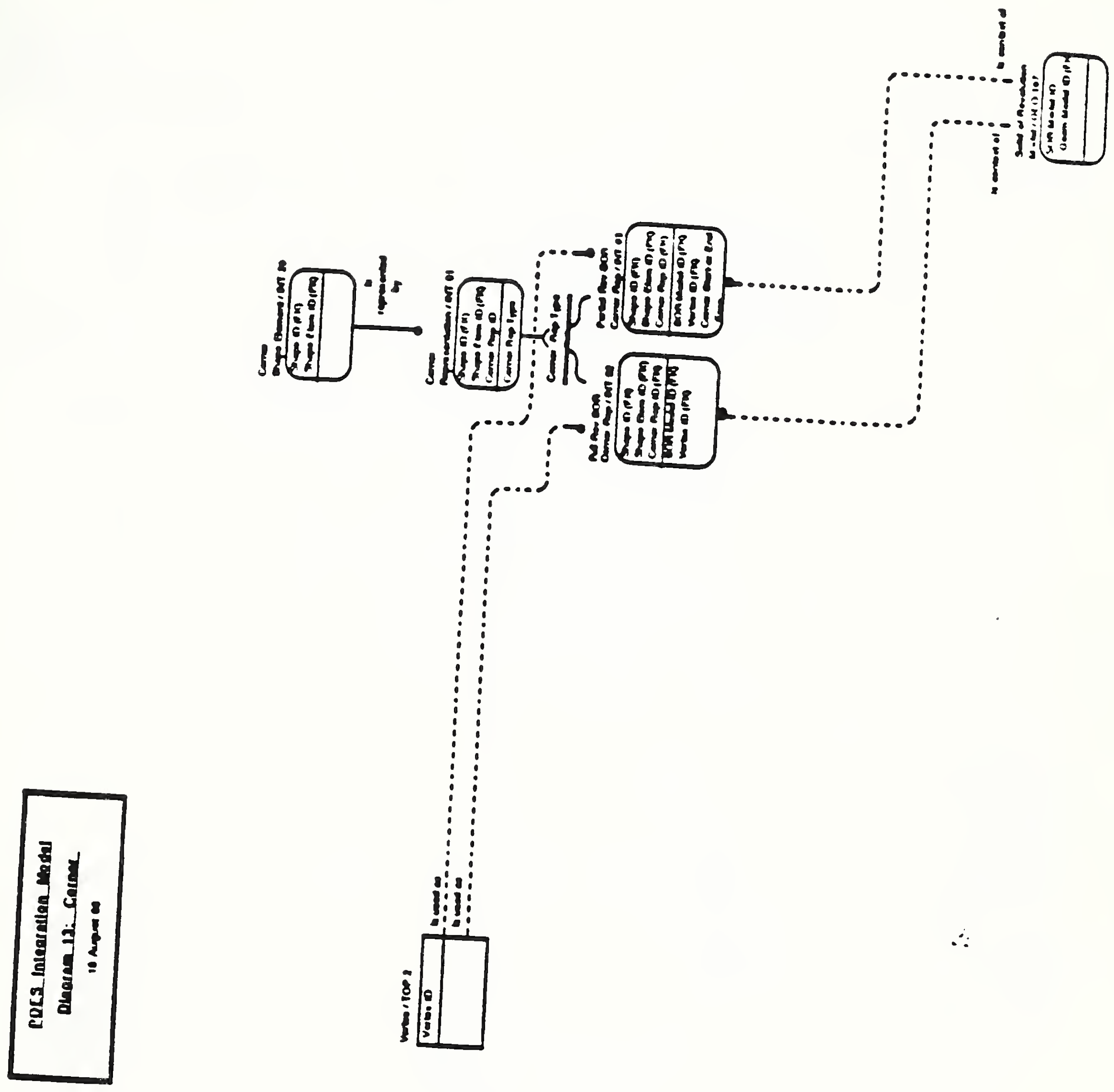


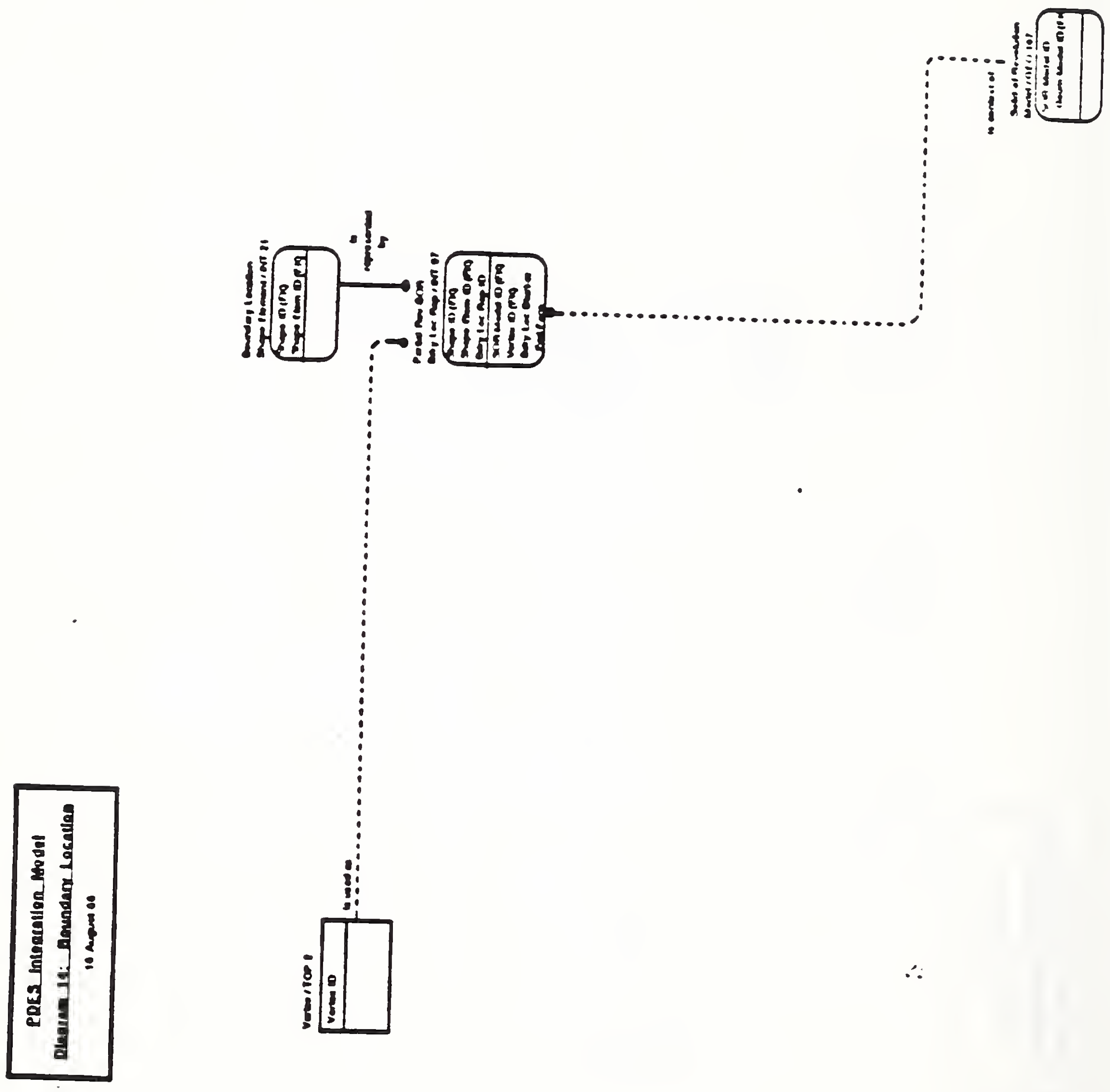

PDLS Integration Model
Diagram 11: Perimeter
10 August 88

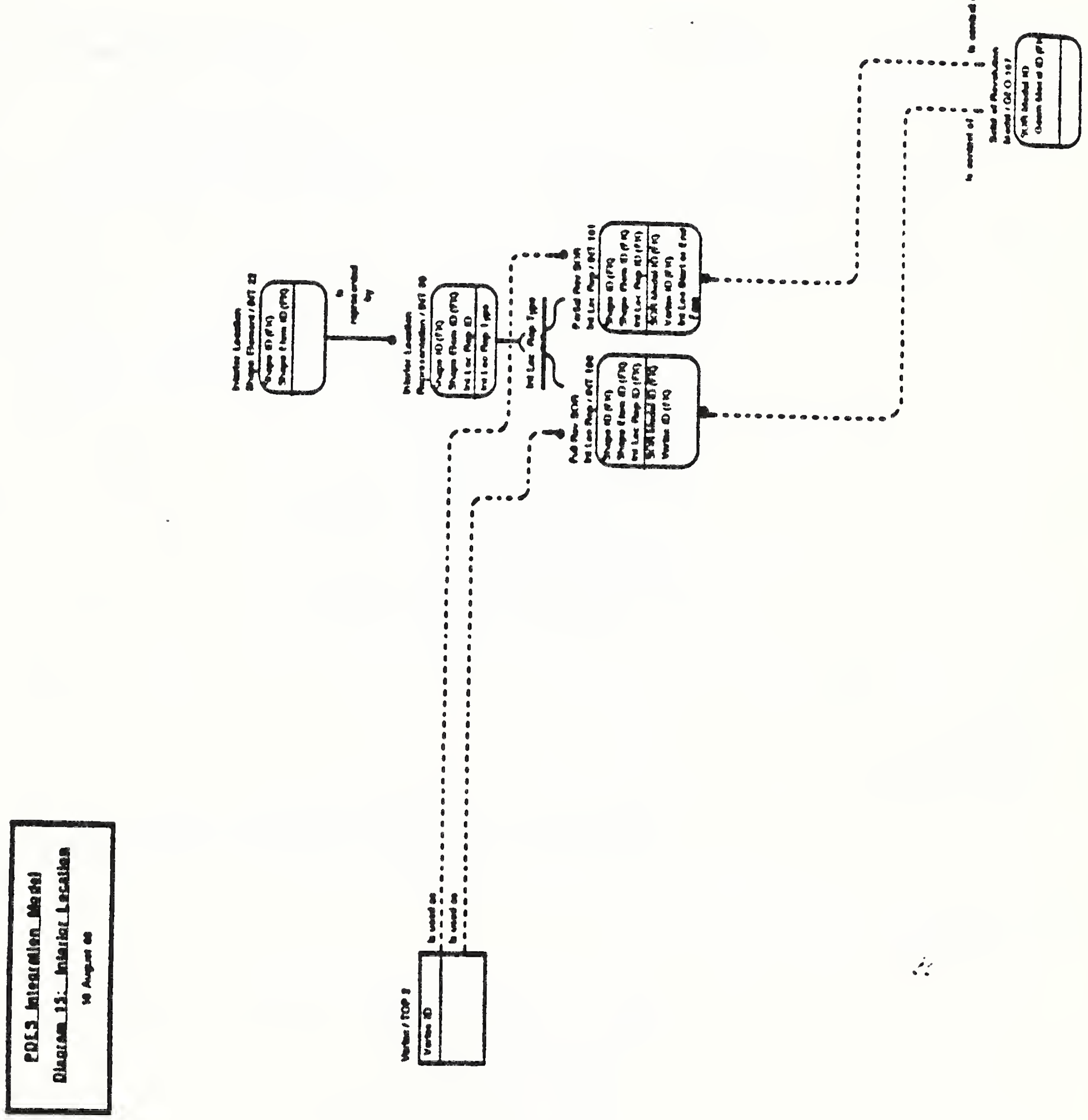
Section 1: *INTEGRATION CORE MODEL*



Section 1: *INTEGRATION CORE MODEL*




PDES Integration Model
Diagram 14: Boundary Location
10 August 88
Boundary Location
Shape ID (FK)
is represented by
Vertex / TOP 1
Vertex ID
is used as
is member of


PDES Integration Model
Diagram 15: Interior Location
Vertex / TOP 2
Vertex ID
is used as
is used as
Int Loc Prop Type

3.3 Entity and Attribute Glossary

Entity Name:	Area Representation
Entity Number:	INT-42
Entity Definition:	The symbolic description of an "Area Shape Element" in a "Geometric Model".

Business Rules: Every "Area Representation":

- represents one, and only one, "Area Shape Element".
- must be one, and only one, of the following:
  "Brep Area Rep"
  "Facetted Brep Area Rep"
  "SOLE Edge Area Rep"
  "SOLE Max Area Rep"
  "SOR Edge Area Rep"
  "Partial Rev SOR Max Area Rep"
  "Surface Area Rep"
  "Unstruct Geometry Area Rep"
  "Wireframe Area Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	The means of distinguishing each "Area Representation" from all the others for the same "Area Shape Element".

Other Attributes:

Area Rep Type	The means of determining whether an "Area Representation" is a(n): "Brep Area Rep", "Facetted Brep Area Rep", "SOLE Edge Area Rep", "SOLE Max Area Rep", "SOR Edge Area Rep", "Partial Rev SOR Max Area Rep", "Surface Area Rep", "Unstruct Geometry Area Rep", or "Wireframe Area Rep".

SML:

```
ENTITY Area-Representation
   KEY
      Area-Shape-Element "is represented by"
      Area-Rep-ID
   ENDK
   Area-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Area_Representation
   SUPERTYPE    OF ( Brep_Area_Rep
                OR   Facetted_Brep_Area_Rep
                OR   SOLE_Edge_Area_Rep
                OR   SOLE_Max_Area_Rep
                OR   SOR_Edge_Area_Rep
                OR   Partial_Rev_SOR_Max_Area_Rep
                OR   Surface_Area_Rep
                OR   Unstruct_Geometry_Area_Rep
                OR   Wireframe_Area_Rep   );
END_ENTITY;
```

Entity Name: Area Shape Element

Entity Number: INT-8

Entity Definition: A "Dimensionality 2 Shape Element" that is arcwise connected and has a uniform underlying mathematical surface.

Business Rules: Every "Area Shape Element":
- is a "Dimensionality 2 Shape Element".
- must be one, and only one, of the following:
  "Maximal Area Shape Element"
  "Nonmaximal Area Shape Element"
- is represented by zero, one, or more "Area Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes:

Area SE Type	The means of determining whether an "Area Shape Element" is a(n): "Maximal Area Shape Element" or "Nonmaximal Area Shape Element".

SML:

```
ENTITY Area-Shape-Element
   CATEGORY BY Dim-2-SE-Type OF Dimensionality-2-Shape-Element
   Area-SE-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Area_Shape_Element
   SUPERTYPE    OF  ( Maximal_Area_Shape_Element
                OR    Nonmaximal_Area_Shape-Element   )
   SUBTYPE      OF  ( Dimensionality_2_Shape_Element   );
   Representations : LIST OF [ 0 : # ] OF Area_Representation;
END_ENTITY;
```

Entity Name: Boundary Location Shape Element

Entity Number: INT-21

Entity Definition: A "Dimensionality 0 Shape Element" that is on an "Edge Shape Element", but that is not an end point.

Business Rules: Every "Boundary Location Shape Element":
- is a "Dimensionality 0 Shape Element".
- is represented by zero, one, or more "Partial Rev SOR Bdry Loc Reps".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Boundary-Location-Shape-Element
   CATEGORY BY Dim-0-SE-Type OF Dimensionality-0-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Boundary_Location_Shape_Element
   SUBTYPE       OF  ( Dimensionality_0_Shape_Element   );
   Representations : LIST OF [ 0 : # ] OF Partial_Rev_SOR_Bdry_Loc_Rep;
END_ENTITY;
```

Entity Name: Brep Area Rep

Entity Number: INT-43

Entity Definition: The use of a "Face" in a "Manifold Solid Brep Model" to represent an "Area Shape Element". In a manifold solid Brep, a face represents a portion of a solid's surface area that (i) has a uniform underlying surface and (ii) is arcwise connected. If there is an adjacent face with the same underlying surface, the area is nonmaximal; otherwise, it is maximal.

Business Rules: Every "Brep Area Rep":

- is an "Area Representation".
- is in one, and only one, "Manifold Solid Brep Model".
- is one, and only one, "Face".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	(FK)

Other Attributes:

Brep Model ID	(FK)
Face ID	(FK)

SML:

```
ENTITY Brep-Area-Rep
   CATEGORY BY Area-Rep-Type OF Area-Representation
   Face "is used as" NONULL
   Manifold-Solid-Brep-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Brep_Area_Rep
   SUBTYPE      OF ( Area_Representation );
   Definition : Face;
   Context : Manifold_Solid_Brep_Model;
END_ENTITY;
```

Entity Name: Brep Dim 0 SE Rep

Entity Number: INT-85

Entity Definition: The use of a "Vertex" in a "Manifold Solid Brep Model" to represent a "Dimensionality 0 Shape Element". In a manifold solid Brep, vertices are employed in maximal faces, nonmaximal faces, subfaces, and vertex loops. In the first three cases, the edges that meet at the vertex may have the same underlying curve. So, a vertex may represent any of the three categories of "Dimensionality 0 Shape Element" -- corner, boundary location, or interior location.

Business Rules: Every "Brep Dim 0 SE Rep":

- is a "Dim 0 Shape Element Representation".
- is in one, and only one, "Manifold Solid Brep Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 0 Rep ID	(FK)

Other Attributes:

Brep Model ID	(FK)
Vertex ID	(FK)

SML:

```
ENTITY Brep-Dim-0-SE-Rep
    CATEGORY BY Dim-0-Rep-Type OF Dim-0-Shape-Element-Representation
    Vertex "is used as" NONULL
    Manifold-Solid-Brep-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY  Brep_Dim_0_SE_Rep
    SUBTYPE      OF  ( Dim_0_Shape_Element_Representation   );
    Definition : Vertex;
    Context : Manifold_Solid_Brep_Model;
END_ENTITY;
```

Entity Name:	Brep NM Area Rep
Entity Number:	INT-53
Entity Definition:	The use of a "Subface" in a "Manifold Solid Brep Model" to represent a "Nonmaximal Area Shape Element". In a manifold solid Brep, a subface represents a portion of surface area that is necessarily nonmaximal because the subface is a subset of a face with a uniform underlying surface. (Note: The IPIM does not require that a subface be a proper subset of the containing face, but it seems pointless to have a subface identical to its containing face. For this reason, no provision is made here for representing a "Maximal Area Shape Element" with a subface.)

Business Rules: Every "Brep NM Area Rep":

- is a "Nonmaximal Area Representation".
- is in one, and only one, "Manifold Solid Brep Model".
- is one, and only one, "Subface".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Nonmax Area Rep ID	(FK)

Other Attributes:

Brep Model ID	(FK)
Subface ID	(FK)

SML:

```
ENTITY Brep-NM-Area-Rep
    CATEGORY BY Nonmax-Area-Rep-Type
        OF Nonmaximal-Area-Representation
    Subface "is used as" NONULL
    Manifold-Solid-Brep-Model "is context of" NONULL
ENDE
```

```
ENTITY Brep_NM_Area_Rep
   SUBTYPE      OF ( Nonmaximal_Area_Representation   );
   Definition : Subface;
   Context : Manifold_Solid_Brep_Model;
END_ENTITY;
```

Entity Name: Brep Object Rep

Entity Number: INT-31

Entity Definition: The use of a "Manifold Solid Brep Model" to represent an "Object Shape Element". A manifold solid Brep represents a volume that has an arcwise-connected interior, but that may include voids.

Business Rules: Every "Brep Object Rep":

- is an "Object Representation".
- is one, and only one, "Manifold Solid Brep Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Object Rep ID	(FK)

Other Attributes:

Brep Model ID	(FK)

SML:

```
ENTITY Brep-Object-Rep
    CATEGORY BY Object-Rep-Type OF Object-Representation
    Manifold-Solid-Brep-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY Brep_Object_Rep
    SUBTYPE       OF ( Object_Representation  );
    Definition : Manifold_Solid_Brep_Model;
END_ENTITY;
```

Entity Name:	Brep Perimeter Rep
Entity Number:	INT-74
Entity Definition:	The use of a "Loop" in a "Manifold Solid Brep Model" to represent a "Perimeter Shape Element". In a manifold solid Brep, a loop occurs as a boundary of a maximal face. Hence, a loop may represent the perimeter of an "Area Shape Element".

Business Rules: Every "Brep Perimeter Rep":
- is a "Perimeter Representation".
- is in one, and only one, "Manifold Solid Brep Model".
- is one, and only one, "Loop".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

Other Attributes:

Brep Model ID	(FK)
Loop ID	(FK)

SML:

```
ENTITY Brep-Perimeter-Rep
    CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
    Loop "is used as" NONULL
    Manifold-Solid-Brep-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Brep_Perimeter_Rep
    SUBTYPE      OF ( Perimeter_Representation  );
    Definition : Loop;
    Context : Manifold_Solid_Brep_Model;
END_ENTITY;
```

Entity Name:	Brep Seam Rep
Entity Number:	INT-64
Entity Definition:	The use of an "Edge" in a "Manifold Solid Brep Model" to represent a "Seam Shape Element". In a manifold solid Brep, an edge may occur as a boundary element of a maximal or nonmaximal face and/or as an edge of a subface of a maximal or nonmaximal face. Even if the parent face is maximal, the edge may be nonmaximal; i.e., the edge may have an adjacent edge with the same underlying curve. Hence, an edge may represent a full "natural" edge, a portion of a full "natural" edge, or a curve in the interior of a "natural" face. So, an edge may represent any of the three categories of "Seam Shape Element" -- edge, subedge, or interior seam.

Business Rules: Every "Brep Seam Rep":

- is a "Seam Representation".
- is in one, and only one, "Manifold Solid Brep Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Seam Rep ID	(FK)

Other Attributes:

Brep Model ID	(FK)
Edge ID	(FK)

SML:

```
ENTITY Brep-Seam-Rep
    CATEGORY BY Seam-Rep-Type OF Seam-Representation
    Edge "is used as" NONULL
    Manifold-Solid-Brep-Model "is context of" NONULL
ENDE
```

<u>EXPRESS:</u>

```
ENTITY Brep_Seam_Rep
   SUBTYPE      OF ( Seam_Representation  );
   Definition : Edge;
   Context  : Manifold_Solid_Brep_Model;
END_ENTITY;
```

Entity Name:	Brep Volume Rep
Entity Number:	INT-35
Entity Definition:	The use of a "Shell" in a "Manifold Solid Brep Model" to represent a "Voidless Volume Shape Element". In a manifold solid Brep, a shell represents a voidless volume. This may be the peripheral volume of the represented solid or a void within the solid.

Business Rules: Every "Brep Volume Rep":
- is a "Voidless Volume Representation".
- is in one, and only one, "Manifold Solid Brep Model".
- is one, and only one, "Shell".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Volume Rep ID	(FK)

Other Attributes:

Brep Model ID	(FK)
Shell ID	(FK)

SML:

```
ENTITY Brep-Volume-Rep
   CATEGORY BY Volume-Rep-Type OF Voidless-Volume-Representation
   Shell "is used as" NONULL
   Manifold-Solid-Brep-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Brep_Volume_Rep
   SUBTYPE     OF ( Voidless_Volume_Representation  );
   Definition : Shell;
   Context : Manifold_Solid_Brep_Model;
END_ENTITY;
```

Entity Name: Corner Representation

Entity Number: INT-91

Entity Definition: The symbolic description of a "Corner Shape Element" in a "Geometric Model".

Business Rules: Every "Corner Representation":
- represents one, and only one, "Corner Shape Element".
- must be one, and only one, of the following:
  "Full Rev SOR Corner Rep"
  "Partial Rev SOR Corner Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Corner Rep ID	The means of distinguishing each "Corner Representation" from all the others for the same "Corner Shape Element".

Other Attributes:

Corner Rep Type	The means of determining whether a "Corner Representation" is a(n): "Full Rev SOR Corner Rep" or "Partial Rev SOR Corner Rep".

SML:

```
ENTITY Corner-Representation
   KEY
      Corner-Shape-Element "is represented by"
      Corner-Rep-ID
   ENDK
   Corner-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Corner_Representation
   SUPERTYPE    OF ( Full_Rev_SOR_Corner_Rep
                OR   Partial_Rev_SOR_Corner_Rep  );
END_ENTITY;
```

Entity Name: Corner Shape Element

Entity Number: INT-20

Entity Definition: A "Dimensionality 0 Shape Element" that is the intersection of three or more "Area Shape Elements" or that is the apex of a cone-like shape.

Business Rules: Every "Corner Shape Element":
- is a "Dimensionality 0 Shape Element".
- is represented by zero, one, or more "Corner Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Corner-Shape-Element
   CATEGORY BY Dim-0-SE-Type OF Dimensionality-0-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Corner_Shape_Element
   SUBTYPE        OF  ( Dimensionality_0_Shape_Element   );
   Representations : LIST OF [ 0 : # ] OF Corner_Representation;
END_ENTITY;
```

Entity Name:	CSG Primitive Model
Entity Number:	GEO-84
Entity Definition:	Defined in the PDES Geometry reference model.
Business Rules:	Every "CSG Primitive Model": • is a "Geometric Model". • is used as zero, one, or more "CSG Primitive Volume Reps".

Entity Name:	CSG Primitive Volume Rep
Entity Number:	INT-36
Entity Definition:	The use of a "CSG Primitive Model" to represent a "Voidless Volume Shape Element".

Business Rules: Every "CSG Primitive Volume Rep":

- is a "Voidless Volume Representation".
- is one, and only one, "CSG Primitive Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Volume Rep ID	(FK)

Other Attributes:

CSG Primitive Model ID	(FK)

SML:

```
ENTITY CSG-Primitive-Volume-Rep
   CATEGORY BY Volume-Rep-Type OF Voidless-Volume-Representation
   CSG-Primitive-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY CSG_Primitive_Volume_Rep
   SUBTYPE      OF ( Volume_Representation  );
   Definition : CSG_Primitive_Model;
END_ENTITY;
```

Entity Name: CSG Solid Dim 3 SE Rep

Entity Number: INT-26

Entity Definition: The use of a "CSG Solid Model" to represent a "Dimensionality 3 Shape Element".

Business Rules: Every "CSG Solid Dim 3 SE Rep":

- is a "Dim 3 Shape Element Representation".
- is one, and only one, "CSG Solid Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 3 Rep ID	(FK)

Other Attributes:

CSG Solid Model ID	(FK)

SML:

```
ENTITY CSG-Solid-Dim-3-SE-Rep
   CATEGORY BY Dim-3-Rep-Type OF Dim-3-Shape-Element-Representation
   CSG-Solid-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY  CSG_Solid_Dim_3_SE_Rep
   SUBTYPE      OF  ( Dim_3_Shape_Element_Representation   );
   Definition : CSG_Solid_Model;
END_ENTITY;
```

Entity Name: CSG Solid Model

Entity Number: GEO-85

Entity Definition: Defined in the PDES Geometry reference model.

Business Rules: Every "CSG Solid Model":
- is a "Geometric Model".
- is used as zero, one, or more "CSG Solid Dim 3 SE Reps".

Entity Name:	Dim 0 Shape Element Representation
Entity Number:	INT-84
Entity Definition:	The symbolic description of a "Dimensionality 0 Shape Element" in a "Geometric Model".

Business Rules: Every "Dim 0 Shape Element Representation":

- represents one, and only one, "Dimensionality 0 Shape Element".
- must be one, and only one, of the following:
  "Brep Dim 0 SE Rep"
  "Facetted Brep Dim 0 SE Rep"
  "SOLE Dim 0 SE Rep"
  "Surface Dim 0 SE Rep"
  "Unstruct Geometry Dim 0 SE Rep"
  "Wireframe Dim 0 SE Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 0 Rep ID	The means of distinguishing each "Dim 0 Shape Element Representation" from all the others for the same "Dimensionality 0 Shape Element".

Other Attributes:

Dim 0 Rep Type	The means of determining whether a "Dim 0 Shape Element Representation" is a(n): "Brep Dim 0 SE Rep", "Facetted Brep Dim 0 SE Rep", "SOLE Dim 0 SE Rep", "Surface Dim 0 SE Rep", "Unstruct Geometry Dim 0 SE Rep", or "Wireframe Dim 0 SE Rep".

SML:

```
ENTITY Dim-0-Shape-Element-Representation
   KEY
      Dimensionality-0-Shape-Element "is represented by"
      Dim-0-Rep-ID
   ENDK
   Dim-0-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Dim_0_Shape_Element_Representation
   SUPERTYPE   OF ( Brep_Dim_0_SE_Rep
               OR   Facetted_Brep_Dim_0_SE_Rep
               OR   SOLE_Dim_0_SE_Rep
               OR   Surface_Dim_0_SE_Rep
               OR   Unstruct_Geometry_Dim_0_SE_Rep
               OR   Wireframe_Dim_0_SE_Rep   );
END_ENTITY;
```

Entity Name:	Dim 3 Shape Element Representation
Entity Number:	INT-25
Entity Definition:	The symbolic description of a "Dimensionality 3 Shape Element" in a "Geometric Model".

Business Rules: Every "Dim 3 Shape Element Representation":

- represents one, and only one, "Dimensionality 3 Shape Element".
- must be one, and only one, of the following:
  "CSG Solid Dim 3 SE Rep"
  "Surface Dim 3 SE Rep"
  "Unstruct Geometry Dim 3 SE Rep"
  "Wireframe Dim 3 SE Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 3 Rep ID	The means of distinguishing each "Dim 3 Shape Element Representation" from all the others for the same "Dimensionality 3 Shape Element".

Other Attributes:

Dim 3 Rep Type	The means of determining whether a "Dim 3 Shape Element Representation" is a(n): "CSG Solid Dim 3 SE Rep", "Surface Dim 3 SE Rep", "Unstruct Geometry Dim 3 SE Rep", or "Wireframe Dim 3 SE Rep".

SML:

```
ENTITY Dim-3-Shape-Element-Representation
    KEY
        Dimensionality-3-Shape-Element "is represented by"
        Dim-3-Rep-ID
    ENDK
    Dim-3-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Dim_3_Shape_Element_Representation
   SUPERTYPE    OF ( CSG_Solid_Dim_3_SE_Rep
                OR   Surface_Dim_3_SE_Rep
                OR   Unstruct_Geometry_Dim_3_SE_Rep
                OR   Wireframe_Dim_3_SE_Rep   );
END_ENTITY;
```

Entity Name:	Dimensionality 0 Shape Element
Entity Number:	INT-19
Entity Definition:	A "Shape Element" that has dimensionality zero, i.e., that is a location on the surface area of a shape.

Business Rules: Every "Dimensionality 0 Shape Element":

- is a "Shape Element".
- must be one, and only one, of the following:
  "Boundary Location Shape Element"
  "Corner Shape Element"
  "Interior Location Shape Element"
- is represented by zero, one, or more "Dim 0 Shape Element Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes:

Dim 0 SE Type	The means of determining whether a "Dimensionality 0 Shape Element" is a(n): "Boundary Location Shape Element", "Corner Shape Element", or "Interior Location Shape Element".

SML:

```
ENTITY Dimensionality-0-Shape-Element
    CATEGORY BY Shape-Elem-Type OF Shape-Element
    Dim-0-SE-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Dimensionality_0_Shape_Element
   SUPERTYPE    OF ( Corner_Shape_Element
                OR   Boundary_Location_Shape_Element
                OR   Interior_Location_Shape_Element  )
   SUBTYPE      OF ( Shape_Element  );
   Representations : LIST OF [ 0 : # ] OF
      Dim_0_Shape_Element_Representation;
END_ENTITY;
```

Entity Name:	Dimensionality 1 Shape Element
Entity Number:	INT-13
Entity Definition:	A "Shape Element" that has no discontinuity and has dimensionality one, i.e., that is a path on the surface area of a shape.

Business Rules: Every "Dimensionality 1 Shape Element":

- is a "Shape Element".
- must be one, and only one, of the following:
  "Perimeter Shape Element"
  "Seam Shape Element"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes:

Dim 1 SE Type	The means of determining whether a "Dimensionality 1 Shape Element" is a(n): "Perimeter Shape Element" or "Seam Shape Element".

SML:

```
ENTITY Dimensionality-1-Shape-Element
    CATEGORY BY Shape-Elem-Type OF Shape-Element
    Dim-1-SE-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY  Dimensionality_1_Shape_Element
    SUPERTYPE     OF  ( Seam_Shape_Element
                  OR    Perimeter_Shape_Element   )
    SUBTYPE       OF  ( Shape_Element  );
END_ENTITY;
```

Entity Name:	Dimensionality 2 Shape Element
Entity Number:	INT-7
Entity Definition:	A "Shape Element" that has dimensionality two, i.e., that is a portion of the surface area of a shape.

Business Rules: Every "Dimensionality 2 Shape Element":

- is a "Shape Element".
- must be one, and only one, of the following:
  "Area Shape Element"
  "Zone Shape Element"
- is zero or one "Form Feature".
- is used as zero, one, or more "Zone Shape Element Components".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes:

Dim 2 SE Type	The means of determining whether a "Dimensionality 2 Shape Element" is a(n): "Area Shape Element" or "Zone Shape Element".

SML:

```
ENTITY Dimensionality-2-Shape-Element
    CATEGORY BY Shape-Elem-Type OF Shape-Element
    Dim-2-SE-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Dimensionality_2_Shape_Element
    SUPERTYPE     OF ( Area_Shape_Element
                  OR   Zone_Shape_Element  )
    SUBTYPE       OF ( Shape_Element  );
    Form_Feature_Shape_Element : OPTIONAL Form_Feature;
    Use_As_Zone_Comp : LIST OF [ 0 : # ] Zone_Shape_Element_Component;
END_ENTITY;
```

Entity Name:	Dimensionality 3 Shape Element
Entity Number:	INT-3
Entity Definition:	A "Shape Element" that has dimensionality three, i.e., that is a volume.

Business Rules: Every "Dimensionality 3 Shape Element":

- is a "Shape Element".
- must be one, and only one, of the following:
  "Object Assembly Shape Element"
  "Object Shape Element"
- is represented by zero, one, or more "Dim 3 Shape Element Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes:

Dim 3 SE Type	The means of determining whether a "Dimensionality 3 Shape Element" is a(n): "Object Assembly Shape Element" or "Object Shape Element".

SML:

```
ENTITY Dimensionality-3-Shape-Element
    CATEGORY BY Shape-Elem-Type OF Shape-Element
    Dim-3-SE-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Dimensionality_3_Shape_Element
    SUPERTYPE    OF ( Object_Shape_Element
                 OR   Object_Assembly_Shape_Element  )
    SUBTYPE      OF ( Shape_Element  );
    Representations : LIST OF [ 0 : # ] OF
        Dim_3_Shape_Element_Representation;
END_ENTITY;
```

Entity Name: Edge

Entity Number: TOP-3

Entity Definition: Defined in the PDES Topology reference model.

Business Rules: Every "Edge":

- is used as zero, one, or more "Brep Seam Reps".
- is used as zero, one, or more "SOLE Edge Area Reps".
- is used as zero, one, or more "SOLE Edge NM Area Reps".
- is used as zero, one, or more "SOLE Edge Perimeter Reps".
- is used as zero, one, or more "SOLE Edge Seam Reps".
- is used as zero, one, or more "SOR Edge Area Reps".
- is used as zero, one, or more "SOR Edge NM Area Reps".
- is used as zero, one, or more "Partial Rev SOR Edge Perimeter Reps".
- is used as zero, one, or more "Partial Rev SOR Edge Seam Reps".
- is used as zero, one, or more "Surface Seam Reps".
- is used as zero, one, or more "Wireframe Seam Reps".

Entity Name:	Edge Shape Element
Entity Number:	INT-15
Entity Definition:	A "Seam Shape Element" that is the intersection of two "Maximal Area Shape Elements". Due to the continuity requirement on "Dimensionality 1 Shape Elements", a "Seam Shape Element" does not have to be the entire intersection of the pair of "Maximal Area Shape Elements", but it must be a maximal continuous portion of their intersection.
Business Rules:	Every "Edge Shape Element" is a "Seam Shape Element".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Edge-Shape-Element
   CATEGORY BY Seam-SE-Type OF Seam-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Edge_Shape_Element
   SUBTYPE      OF ( Seam_Shape_Element  );
END_ENTITY;
```

Entity Name: Face

Entity Number: TOP-5

Entity Definition: Defined in the PDES Topology reference model.

Business Rules: Every "Face":

- is the face revolved by zero, one, or more "Solid of Revolution Models".
- is bound by one or more "Loop Logical Structures".
- is used as zero, one, or more "Brep Area Reps".
- is used as zero, one, or more "Facetted Brep Area Reps".
- is used as zero, one, or more "Surface Area Reps".

Entity Name: Facetted Brep Area Rep

Entity Number: INT-44

Entity Definition: The use of a "Face" in a "Facetted Brep Model" to represent an "Area Shape Element".

Business Rules: Every "Facetted Brep Area Rep":

- is an "Area Representation".
- is in one, and only one, "Facetted Brep Model".
- is one, and only one, "Face".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	(FK)

Other Attributes:

Facetted Brep Model ID	(FK)
Face ID	(FK)

SML:

```
ENTITY Facetted-Brep-Area-Rep
    CATEGORY BY Area-Rep-Type OF Area-Representation
    Face "is used as" NONULL
    Facetted-Brep-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Facetted_Brep_Area_Rep
    SUBTYPE      OF ( Area_Representation  );
    Definition : Face;
    Context : Facetted_Brep_Model;
END_ENTITY;
```

Entity Name:	Facetted Brep Dim 0 SE Rep
Entity Number:	INT-89
Entity Definition:	The use of a "Point" in a "Facetted Brep Model" to represent a "Dimensionality 0 Shape Element".

Business Rules: Every "Facetted Brep Dim 0 SE Rep":

- is a "Dim 0 Shape Element Representation".
- is in one, and only one, "Facetted Brep Model".
- is one, and only one, "Point".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 0 Rep ID	(FK)

Other Attributes:

Facetted Brep Model ID	(FK)
Point ID	(FK)

SML:

```
ENTITY Facetted-Brep-Dim-0-SE-Rep
    CATEGORY BY Dim-0-Rep-Type OF Dim-0-Shape-Element-Representation
    Point "is used as" NONULL
    Facetted-Brep-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY  Facetted_Brep_Dim_0_SE_Rep
    SUBTYPE       OF  ( Dim_0_Shape_Element_Representation   );
    Definition : Point;
    Context : Facetted_Brep_Model;
END_ENTITY;
```

Entity Name:	Facetted Brep Model
Entity Number:	GEO-86
Entity Definition:	Defined in the PDES Geometry reference model.

Business Rules: Every "Facetted Brep Model":

- is a "Geometric Model".
- is the context for zero, one, or more "Facetted Brep Area Reps".
- is the context for zero, one, or more "Facetted Brep Dim 0 SE Reps".
- is the context for zero, one, or more "Facetted Brep NM Area Reps".
- is used as zero, one, or more "Facetted Brep Object Reps".
- is the context for zero, one, or more "Facetted Brep Perimeter Reps".
- is the context of zero, one, or more "Facetted Brep Volume Reps".

Entity Name:	Facetted Brep NM Area Rep
Entity Number:	INT-54
Entity Definition:	The use of a "Subface" in a "Facetted Brep Model" to represent a "Nonmaximal Area Shape Element".

Business Rules: Every "Facetted Brep NM Area Rep":

- is a "Nonmaximal Area Representation".
- is in one, and only one, "Facetted Brep Model".
- is one, and only one, "Subface".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Nonmax Area Rep ID	(FK)

Other Attributes:

Facetted Brep Model ID	(FK)
Subface ID	(FK)

SML:

```
ENTITY Facetted-Brep-NM-Area-Rep
    CATEGORY BY Nonmax-Area-Rep-Type
        OF Nonmaximal-Area-Representation
    Subface "is used as" NONULL
    Facetted-Brep-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY  Facetted_Brep_NM_Area_Rep
    SUBTYPE       OF  ( Nonmaximal_Area_Representation   );
    Definition : Subface;
    Context : Facetted_Brep_Model;
END_ENTITY;
```

Entity Name: Facetted Brep Object Rep

Entity Number: INT-32

Entity Definition: The use of a "Facetted Brep Model" to represent an "Object Shape Element".

Business Rules: Every "Facetted Brep Object Rep":

- is an "Object Representation".
- is one, and only one, "Facetted Brep Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Object Rep ID	(FK)

Other Attributes:

Facetted Brep Model ID	(FK)

SML:

```
ENTITY Facetted-Brep-Object-Rep
    CATEGORY BY Object-Rep-Type OF Object-Representation
    Facetted-Brep-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY Facetted_Brep_Object_Rep
    SUBTYPE      OF ( Object_Representation  );
    Definition : Facetted_Brep_Model;
END_ENTITY;
```

<u>Entity Name:</u> Facetted Brep Perimeter Rep

<u>Entity Number:</u> INT-79

<u>Entity Definition:</u> The use of a "Polyloop" in a "Facetted Brep Model" to represent a "Perimeter Shape Element".

<u>Business Rules:</u> Every "Facetted Brep Perimeter Rep":
- is a "Perimeter Representation".
- is in one, and only one, "Facetted Brep Model".
- is one, and only one, "Polyloop".

<u>Primary Key Attributes:</u>

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

<u>Other Attributes:</u>

Facetted Brep Model ID	(FK)
Polyloop ID	(FK)

<u>SML:</u>

```
ENTITY Facetted-Brep-Perimeter-Rep
    CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
    Polyloop "is used as" NONULL
    Facetted-Brep-Model "is context of" NONULL
ENDE
```

<u>EXPRESS:</u>

```
ENTITY Facetted_Brep_Perimeter_Rep
    SUBTYPE      OF  ( Perimeter_Representation  );
    Definition : Polyloop;
    Context : Facetted_Brep_Model;
END_ENTITY;
```

Entity Name:	Facetted Brep Volume Rep
Entity Number:	INT-104
Entity Definition:	The use of a "Shell" in a "Facetted Brep Model" to represent a "Voidless Volume Shape Element".

Business Rules: Every "Facetted Brep Volume Rep":

- is a "Voidless Volume Representation".
- is in one, and only one, "Facetted Brep Model".
- is one, and only one, "Shell".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Volume Rep ID	(FK)

Other Attributes:

Facetted Brep Model ID	(FK)
Shell ID	(FK)

SML:

```
ENTITY Facetted-Brep-Volume-Rep
    CATEGORY BY Volume-Rep-Type OF Voidless-Volume-Representation
    Shell "is used as" NONULL
    Facetted-Brep-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Facetted_Brep_Volume_Rep
    SUBTYPE     OF ( Voidless_Volume_Representation   );
    Definition : Shell;
    Context : Facetted_Brep_Model;
END_ENTITY;
```

Entity Name: FEM

Entity Number: FEM-1

Entity Definition: Defined in the PDES FEM reference model.

Business Rules: Every "FEM" models zero, one, or more "FEM Product Item Version Definitions".

Entity Name: FEM Product Item Version Definition

Entity Number: FEM-2

Entity Definition: Defined in the PDES FEM reference model.

Business Rules: Every "FEM Product Item Version Definition":

- is modeled by one, and only one, "FEM".
- models one, and only one, "Product Item Version Functional Definition".

<u>Entity Name:</u>	Form Feature
<u>Entity Number:</u>	FF-001
<u>Entity Definition:</u>	Defined in the PDES Form Feature reference model.
<u>Business Rules:</u>	Every "Form Feature" is a "Dimensionality 2 Shape Element".

Entity Name:	Full Rev SOR Corner Rep
Entity Number:	INT-92
Entity Definition:	The use of a "Vertex" in a "Solid of Revolution Model" that is revolved through 360° to represent a "Corner Shape Element".

Business Rules: Every "Full Rev SOR Corner Rep":

- is a "Corner Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Corner Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Vertex ID	(FK)

SML:

```
ENTITY Full-Rev-SOR-Corner-Rep
    CATEGORY BY Corner-Rep-Type OF Corner-Representation
    Vertex "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY  Full_Rev_SOR_Corner_Rep
    SUBTYPE       OF  ( Corner_Representation  );
    Definition : Vertex;
    Context  : Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Number: INT-100

Entity Definition: The use of a "Vertex" in a "Solid of Revolution Model" that is revolved through 360° to represent an "Interior Location Shape Element".

Business Rules: Every "Full Rev SOR Int Loc Rep":

- is a "Interior Location Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Int Loc Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Vertex ID	(FK)

SML:

```
ENTITY Full-Rev-SOR-Int-Loc-Rep
    CATEGORY BY Int-Loc-Rep-Type OF Interior-Location-Representation
    Vertex "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY  Full_Rev_SOR_Int_Loc_Rep
    SUBTYPE      OF  ( Interior_Location_Representation  );
    Definition : Vertex;
    Context  : Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Name: Full Rev SOR Object Rep

Entity Number: INT-33

Entity Definition: The use of a "Solid of Revolution Model" that is revolved through 360° to represent an "Object Shape Element".

Business Rules: Every "Full Rev SOR Object Rep":
- is an "Object Representation".
- is one, and only one, "Solid of Revolution Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Object Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)

SML:

```
ENTITY Full-Rev-SOR-Object-Rep
   CATEGORY BY Object-Rep-Type OF Object-Representation
   Solid-of-Revolution-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY Full_Rev_SOR_Object_Rep
   SUBTYPE      OF ( Object_Representation );
   Definition : Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Name:	Full Rev SOR Vertex Perimeter Rep
Entity Number:	INT-80
Entity Definition:	The use of a "Vertex" in a complete "Solid of Revolution Model" that is revolved through 360° to represent a "Perimeter Shape Element".

Business Rules: Every "Full Rev SOR Vertex Perimeter Rep":

- is a "Perimeter Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Vertex ID	(FK)

SML:

```
ENTITY Full-Rev-SOR-Vertex-Perimeter-Rep
    CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
    Vertex "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Full_Rev_SOR_Vertex_Perimeter_Rep
    SUBTYPE      OF ( Perimeter_Representation  );
    Definition : Vertex;
    Context : Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Name:	Full Rev SOR Volume Rep
Entity Number:	INT-39
Entity Definition:	The use of a "Loop Logical Structure" in a "Solid of Revolution Model" that is revolved through 360° to represent a "Voidless Volume Shape Element".

Business Rules: Every "Full Rev SOR Volume Rep":

- is a "Voidless Volume Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Loop Logical Structure".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Volume Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Face ID	(FK)
Loop ID	(FK)

SML:

```
ENTITY Full-Rev-SOR-Volume-Rep
    CATEGORY BY Volume-Rep-Type OF Voidless-Volume-Representation
    Loop-Logical-Structure "is used as" (1) NONULL
    Solid-of-Revolution-Model "is context of" (1) NONULL
ENDE
```

EXPRESS:

```
ENTITY Full_Rev_SOR_Volume_Rep
    SUBTYPE      OF ( Voidless_Volume_Representation  );
    Definition : Loop_Logical_Structure;
    Context : Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Name: Geometric Assembly Model

Entity Number: none

Entity Definition: Needs to be defined in some other PDES reference model.

Business Rules: Every "Geometric Assembly Model"

- is a "Geometric Model".
- is used as zero, one, or more "Object Assembly Representations".

Entity Name: Geometric Model

Entity Number: INT-23

Entity Definition: A formal logical/mathematical representation of a shape.

Business Rules: Every "Geometric Model":

- must be one, and only one, of the following:
  "CSG Primitive Model"
  "CSG Solid Model"
  "Facetted Brep Model"
  "Geometric Assembly Model"
  "Half Space Model"
  "Manifold Solid Brep Model"
  "Solid of Linear Extrusion Model"
  "Solid of Revolution Model"
  "Surface Model"
  "Unstructured Geometry Model"
  "Wireframe Model"
- is one in zero, one, or more "Pairs of Equivalent Geometric Models".
- is the other in zero, one, or more "Pairs of Equivalent Geometric Models".

Primary Key Attributes:

Geom Model ID	The means of distinguishing each "Geometric Model" from all others.

Other Attributes:

Geom Model Type	The means of determining whether a "Geometric Model" is a(n): "CSG Primitive Model", "CSG Solid Model", "Facetted Brep Model", "Geometric Assembly Model", "Half Space Model", "Manifold Solid Brep Model", "Solid of Linear Extrusion Model", "Solid of Revolution Model", "Surface Model", "Unstructured Geometry Model", or "Wireframe Model".

SML:

```
ENTITY Geometric-Model
   KEY
      Geom-Model-ID
   ENDK
   Geom-Model-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Geometric_Model
   SUPERTYPE    OF ( CSG_Primitive_Model
                OR   CSG_Solid_Model
                OR   Facetted_Brep_Model
                OR   Geometric_Assembly_Model
                OR   Half_Space_Model
                OR   Manifold_Solid_Brep_Model
                OR   Solid_of_Linear_Extrusion_Model
                OR   Solid_of_Revolution_Model
                OR   Surface_Model
                OR   Unstructured_Geometry_Model
                OR   Wireframe_Model  );
END_ENTITY;
```

Entity Name:	Geometry
Entity Number:	GEO-1
Entity Definition:	Defined in the PDES Geometry reference model.

Business Rules: Every "Geometry":

- is used as zero, one, or more "Unstruct Geometry Area Reps".
- is used as zero, one, or more "Unstruct Geometry Dim 0 SE Reps".
- is used as zero, one, or more "Unstruct Geometry NM Area Reps".
- is used as zero, one, or more "Unstruct Geometry Perimeter Reps".
- is used as zero, one, or more "Unstruct Geometry Seam Reps".

Entity Name:	Half Space Model
Entity Number:	GEO-87
Entity Definition:	Defined in the PDES Geometry reference model.

Business Rules: Every "Half Space Model":

- is a "Geometric Model".
- is used as zero, one, or more "Half Space Volume Reps".

Entity Name:	Half Space Volume Rep
Entity Number:	INT-37
Entity Definition:	The use of a "Half Space Model" to represent a "Voidless Volume Shape Element".

Business Rules: Every "Half Space Volume Rep":
- is a "Voidless Volume Representation".
- is one, and only one, "Half Space Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Volume Rep ID	(FK)

Other Attributes:

Half Space Model ID	(FK)

SML:

```
ENTITY Half-Space-Volume-Rep
   CATEGORY BY Volume-Rep-Type OF Voidless-Volume-Representation
   Half-Space-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY Half_Space_Volume_Rep
   SUBTYPE     OF ( Voidless_Volume_Representation   );
   Definition : Half_Space_Model;
END_ENTITY;
```

Entity Name: Interior Location Representation

Entity Number: INT-99

Entity Definition: The symbolic description of an "Interior Location Shape Element" in a "Geometric Model".

Business Rules: Every "Interior Location Representation":

- represents one, and only one, "Interior Location Shape Element".
- must be one, and only one, of the following:
  "Full Rev SOR Int Loc Rep"
  "Partial Rev SOR Int Loc Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Int Loc Rep ID	The means of distinguishing each "Interior Location Representation" from all the others for the same "Interior Location Shape Element".

Other Attributes:

Int Loc Rep Type	The means of determining whether an "Interior Location Representation" is a(n): "Full Rev SOR Int Loc Rep" or "Partial Rev SOR Int Loc Rep".

SML:

```
ENTITY Interior-Location-Representation
   KEY
      Interior-Location-Shape-Element "is represented by"
      Int-Loc-Rep-ID
   ENDK
   Int-Loc-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Interior_Location_Representation
   SUPERTYPE    OF ( Full_Rev_SOR_Int_Loc_Rep
                OR   Partial_Rev_SOR_Int_Loc_Rep   );
END_ENTITY;
```

Entity Name: Interior Location Shape Element

Entity Number: INT-22

Entity Definition: A "Dimensionality 0 Shape Element" that is in the interior of an "Area Shape Element".

Business Rules: Every "Interior Location Shape Element":

- is a "Dimensionality 0 Shape Element".
- is represented by zero, one, or more "Interior Location Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Interior-Location-Shape-Element
    CATEGORY BY Dim-0-SE-Type OF Dimensionality-0-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Interior_Location_Shape_Element
    SUBTYPE      OF ( Dimensionality_0_Shape_Element   );
    Representations : LIST OF [ 0 : # ] OF Interior_Location_Representation;
END_ENTITY;
```

Entity Name: Interior Seam Shape Element

Entity Number: INT-17

Entity Definition: A "Seam Shape Element" that, with the possible exception of one or both of its end points, lies in the interior of an "Area Shape Element".

Business Rules: Every "Interior Seam Shape Element" is a "Seam Shape Element".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Interior-Seam-Shape-Element
   CATEGORY BY Seam-SE-Type OF Seam-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Interior_Seam_Shape_Element
   SUBTYPE      OF ( Seam_Shape_Element  );
END_ENTITY;
```

Entity Name: Loop

Entity Number: TOP-4

Entity Definition: Defined in the PDES Topology reference model.

Business Rules: Every "Loop":

- bounds zero, one, or more "Loop Logical Structures".
- is used as zero, one, or more "Brep Perimeter Reps".
- is used as zero, one, or more "SOLE Loop Perimeter Reps".
- is used as zero, one, or more "Partial Rev SOR Loop Perimeter Reps".
- is used as zero, one, or more "Surface Perimeter Reps".
- is used as zero, one, or more "Wireframe Area Reps".
- is used as zero, one, or more "Wireframe NM Area Reps".
- is used as zero, one, or more "Wireframe Perimeter Reps".

Entity Name: Loop Logical Structure

Entity Number: TOP-25

Entity Definition: Defined in the PDES Topology reference model.

Business Rules: Every "Loop Logical Structure":

- is used as zero, one, or more "Full Rev SOR Volume Reps".
- is bound by one, and only one, "Loop".
- bounds one, and only one, "Face".

<u>Entity Name:</u> Manifold Solid Brep Model

<u>Entity Number:</u> GEO-88

<u>Entity Definition:</u> Defined in the PDES Geometry reference model.

<u>Business Rules:</u> Every "Manifold Solid Brep Model":
- is a "Geometric Model".
- is the context of zero, one, or more "Brep Area Reps".
- is the context of zero, one, or more "Brep Dim 0 SE Reps".
- is the context of zero, one, or more "Brep NM Area Reps".
- is used as zero, one, or more "Brep Object Reps".
- is the context of zero, one, or more "Brep Perimeter Reps".
- is the context of zero, one, or more "Brep Seam Reps".
- is the context of zero, one, or more "Brep Volume Reps".

Entity Name:	Maximal Area Representation
Entity Number:	INT-105
Entity Definition:	The symbolic description of a "Maximal Area Shape Element" in a "Geometric Model".

Business Rules: Every "Maximal Area Representation":

- represents one, and only one, "Maximal Area Shape Element".
- must be one, and only one, of the following:
  "SOLE Max Area Rep"
  "Partial Rev SOR Max Area Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Max Area Rep ID	The means of distinguishing each "Maximal Area Representation" from all the others for the same "Maximal Area Shape Element".

Other Attributes:

Maximal Area Rep Type	The means of determining whether a "Maximal Area Representation" is a(n): "SOLE Max Area Rep", "Partial Rev SOR Max Area Rep",

SML:

```
ENTITY Maximal-Area-Representation
   KEY
      Maximal-Area-Shape-Element "is represented by"
      Max-Area-Rep-ID
   ENDK
   Max-Area-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Maximal_Area_Representation
   SUPERTYPE   OF ( SOLE_Max_Area_Rep
               OR   Partial_Rev_SOR_Max_Area_Rep   );
END_ENTITY;
```

Entity Name:	Maximal Area Shape Element
Entity Number:	INT-9
Entity Definition:	An "Area Shape Element" that has no adjacent "Area Shape Element" with the same underlying mathematical surface.
Business Rules:	Every "Maximal Area Shape Element" is an "Area Shape Element".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Maximal-Area-Shape-Element
   CATEGORY BY Area-SE-Type OF Area-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Maximal_Area_Shape_Element
   SUBTYPE      OF ( Area_Shape_Element  );
END_ENTITY;
```

Entity Name: Nonmaximal Area Representation

Entity Number: INT-52

Entity Definition: The symbolic description of a "Nonmaximal Area Shape Element" in a "Geometric Model".

Business Rules: Every "Nonmaximal Area Representation":

- represents one, and only one, "Nonmaximal Area Shape Element".
- must be one, and only one, of the following:
  "Brep NM Area Rep"
  "Facetted Brep NM Area Rep"
  "SOLE Edge NM Area Rep"
  "SOLE Subface NM Area Rep"
  "SOR Edge NM Area Rep"
  "Partial Rev SOR Subface NM Area Rep"
  "Surface NM Area Rep"
  "Unstruct Geometry NM Area Rep"
  "Wireframe NM Area Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Nonmax Area Rep ID	The means of distinguishing each "Nonmaximal Area Representation" from all the others for the same "Nonmaximal Area Shape Element".

Other Attributes:

Nonmax Area Rep Type	The means of determining whether a "Nonmaximal Area Representation" is a(n): "Brep NM Area Rep", "Facetted Brep NM Area Rep", "SOLE Edge NM Area Rep", "SOLE Subface NM Area Rep", "SOR Edge NM Area Rep", "Partial Rev SOR Subface NM Area Rep", "Surface NM Area Rep", "Unstruct Geometry NM Area Rep", or "Wireframe NM Area Rep".

SML:

```
ENTITY Nonmaximal-Area-Representation
   KEY
      Nonmaximal-Area-Shape-Element "is represented by"
      Nonmax-Area-Rep-ID
   ENDK
   Nonmax-Area-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Nonmaximal_Area_Representation
   SUPERTYPE    OF ( Brep_NM_Area_Rep
                OR   Facetted_Brep_NM_Area_Rep
                OR   SOLE_Edge_NM_Area_Rep
                OR   SOLE_Subface_NM_Area_Rep
                OR   SOR_Edge_NM_Area_Rep
                OR   Partial_Rev_SOR_Subface_NM_Area_Rep
                OR   Surface_NM_Area_Rep
                OR   Unstruct_Geometry_NM_Area_Rep
                OR   Wireframe_NM_Area_Rep   );
END_ENTITY;
```

Entity Name:	Nonmaximal Area Shape Element
Entity Number:	INT-10
Entity Definition:	An "Area Shape Element" that has at least one adjacent "Area Shape Element" with the same underlying mathematical surface.

Business Rules: Every "Nonmaximal Area Shape Element":

- is an "Area Shape Element".
- is represented by zero, one, or more "Nonmaximal Area Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Nonmaximal-Area-Shape-Element
    CATEGORY BY Area-SE-Type OF Area-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Nonmaximal_Area_Shape_Element
    SUBTYPE      OF  ( Area_Shape_Element  );
    Representations : LIST OF [ 0 : # ] OF Nonmaximal_Area_Representation;
END_ENTITY;
```

Entity Name:	Object Assembly Representation
Entity Number:	INT-41
Entity Definition:	The symbolic description of an "Object Assembly Shape Element" in a "Geometric Model".

Business Rules: Every "Object Assembly Representation":
- represents one, and only one, "Object Assembly Shape Element".
- is one, and only one, "Geometric Assembly Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Obj Assem Rep ID	The means of distinguishing each "Object Assembly Representation" from all the others for the same "Object Assembly Shape Element".

Other Attributes:

Geom Assem Model ID	(FK)

SML:

```
ENTITY Object-Assembly-Representation
    KEY
        Object-Assembly-Shape-Element "is represented by"
        Obj-Assem-Rep-ID
    ENDK
    Geometric-Assembly-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY Object_Assembly_Representation;
    Definition : Geometric_Assembly_Model;
END_ENTITY;
```

Entity Name: Object Assembly Shape Element

Entity Number: INT-6

Entity Definition: A "Dimensionality 3 Shape Element" that is a collection of two or more positioned "Object Shape Elements".

Business Rules: Every "Object Assembly Shape Element":

- is a "Dimensionality 3 Shape Element".
- is represented by zero, one, or more "Object Assembly Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Object-Assembly-Shape-Element
   CATEGORY BY Dim-3-SE-Type OF Dimensionality-3-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Object_Assembly_Shape_Element
   SUBTYPE      OF  ( Dimensionality_3_Shape_Element   );
   Representations : LIST OF [ 0 : # ] OF Object_Assembly_Representation;
END_ENTITY;
```

Entity Name:	Object Representation
Entity Number:	INT-30
Entity Definition:	The symbolic description of an "Object Shape Element" in a "Geometric Model".

Business Rules: Every "Object Representation":
- represents one, and only one, "Object Shape Element".
- must be one, and only one, of the following:
  "Brep Object Rep"
  "Full Rev SOR Object Rep"
  "Facetted Brep Object Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Object Rep ID	The means of distinguishing each "Object Representation" from all the others for the same "Object Shape Element".

Other Attributes:

Object Rep Type	The means of determining whether an "Object Representation" is a(n): "Brep Object Rep", "Full Rev SOR Object Rep", or "Facetted Brep Object Rep".

SML:

```
ENTITY Object-Representation
    KEY
        Object-Shape-Element "is represented by"
        Object-Rep-ID
    ENDK
    Object-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Object_Representation
   SUPERTYPE    OF  ( Brep_Object_Rep
                OR    Full_Rev_SOR_Object_Rep
                OR    Facetted_Brep_Object_Rep  );
END_ENTITY;
```

Entity Name: Object Shape Element

Entity Number: INT-4

Entity Definition: A "Dimensionality 3 Shape Element" that is arcwise connected. It may have interior voids.

Business Rules: Every "Object Shape Element":

- is a "Dimensionality 3 Shape Element".
- is zero or one "Voidless Volume Shape Element".
- is represented by zero, one, or more "Object Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes:

Object SE Type	The means of determining whether an "Object Shape Element" is a "Voidless Volume Shape Element" or not.

SML:

```
ENTITY Object-Shape-Element
   CATEGORY BY Dim-3-SE-Type OF Dimensionality-3-Shape-Element
   Object-SE-Type
ENDE
```

EXPRESS:

```
ENTITY Object_Shape_Element
   SUBTYPE      OF  ( Dimensionality_3_Shape_Element   );
   Voidless_Volume  : OPTIONAL  Voidless_Volume_Shape_Element;
   Representations : LIST OF [ 0 : # ] OF Object_Representation;
END_ENTITY;
```

Entity Name:	Pair of Equivalent Geometric Models
Entity Number:	INT-24
Entity Definition:	Identifies alternative representations of shape.

Business Rules: Every "Pair of Equivalent Geometric Models":
- includes one, and only one, first "Geometric Model".
- includes one, and only one, second "Geometric Model".

Primary Key Attributes:

Geom Model 1 ID	(FK) – The role name for the Geom Model ID of one "Geometric Model" in the pair of equivalent models.
Geom Model 2 ID	(FK) – The role name for the Geom Model ID of the other "Geometric Model" in the pair of equivalent models.

Other Attributes: none

SML:

```
ENTITY Pair-of-Equivalent-Geometric-Models
    KEY
        Geometric-Model "is one in"
            ROLE Geom-Model-1-ID FOR Geom-Model-ID
        Geometric-Model "is other in"
            ROLE Geom-Model-2-ID FOR Geom-Model-ID
    ENDK
ENDE
```

EXPRESS:

```
ENTITY Pair_of_Equivalent_Geometric_Models;
    First_Model : Geometric_Model;
    Second_Model : Geometric_Model;
END_ENTITY;
```

Entity Name:	Partial Rev SOR Bdry Loc Rep
Entity Number:	INT-97
Entity Definition:	The use of a "Vertex" in a "Solid of Revolution Model" that is revolved through less than 360° to represent a "Boundary Location Shape Element".

Business Rules: Every "Partial Rev SOR Bdry Loc Rep":

- represents one, and only one, "Boundary Location Shape Element".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Bdry Loc Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Vertex ID	(FK)
Bdry Loc Start or End Face	Indicates whether the "Partial Rev SOR Bdry Loc Rep" is on the starting or ending face in the partially revolved "Solid of Revolution Model".

SML:

```
ENTITY Partial-Rev-SOR-Bdry-Loc-Rep
    KEY
        Boundary-Location-Shape-Element "is represented by"
        Bdry-Loc-Rep-ID
    ENDK
    Vertex "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
    Bdry-Loc-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
TYPE
    Partial_Rev_SOR_Face_Types =
        ENUMERATION OF ( Starting_SOR_Face, Ending_SOR_Face );
END_TYPE;

ENTITY Partial_Rev_SOR_Bdry_Loc_Rep;
    Definition : Vertex;
    Context : Solid_of_Revolution_Model;
    Face : Partial_Rev_SOR_Face_Types;
END_ENTITY;
```

Entity Name:	Partial Rev SOR Corner Rep
Entity Number:	INT-93
Entity Definition:	The use of a "Vertex" in a "Solid of Revolution Model" that is revolved through less than 360° to represent a "Corner Shape Element".

Business Rules: Every "Partial Rev SOR Corner Rep":

- is a "Corner Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Corner Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Vertex ID	(FK)
Corner Start or End Face	Indicates whether the "Partial Rev SOR Corner Rep" is on the starting or ending face in the partially revolved "Solid of Revolution Model".

SML:

```
ENTITY Partial-Rev-SOR-Corner-Rep
    CATEGORY BY Corner-Rep-Type OF Corner-Representation
    Vertex "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
    Corner-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
ENTITY  Partial_Rev_SOR_Corner_Rep
    SUBTYPE      OF  ( Corner_Representation  );
    Definition : Vertex;
    Context : Solid_of_Revolution_Model;
    Face : Partial_Rev_SOR_Face_Types;
END_ENTITY;
```

Entity Name: Partial Rev SOR Edge Perimeter Rep

Entity Number: INT-81

Entity Definition: The use of an "Edge" in a "Solid of Revolution Model" that is revolved through less than 360° to represent a "Perimeter Shape Element".

Business Rules: Every "Partial Rev SOR Edge Perimeter Rep":

- is a "Perimeter Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Edge ID	(FK)

SML:

```
ENTITY Partial-Rev-SOR-Edge-Perimeter-Rep
    CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
    Edge "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Partial_Rev_SOR_Edge_Perimeter_Rep
    SUBTYPE      OF ( Perimeter_Representation );
    Definition : Edge;
    Context : Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Name: Partial Rev SOR Edge Seam Rep

Entity Number: INT-67

Entity Definition: The use of an "Edge" in a "Solid of Revolution Model" that is revolved through less than 360° to represent a "Seam Shape Element".

Business Rules: Every "Partial Rev SOR Edge Seam Rep":
- is a "Seam Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Seam Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Edge ID	(FK)
SOR Seam Start or End Face	Indicates whether the "Partial Rev SOR Edge Seam Rep" is on the starting or ending face in the partially revolved "Solid of Revolution Model".

SML:

```
ENTITY Partial-Rev-SOR-Edge-Seam-Rep
    CATEGORY BY Seam-Rep-Type OF Seam-Representation
    Edge "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
    SOR-Seam-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
ENTITY Partial_Rev_SOR_Edge_Seam_Rep
    SUBTYPE      OF ( Seam_Representation  );
    Definition : Edge;
    Context  : Solid_of_Revolution_Model;
    Face  : Partial_Rev_SOR_Face_Types;
END_ENTITY;
```

Entity Name: Partial Rev SOR Int Loc Rep

Entity Number: INT-101

Entity Definition: The use of a "Vertex" in a "Solid of Revolution Model" that is revolved through less than 360° to represent an "Interior Location Shape Element".

Business Rules: Every "Partial Rev SOR Int Loc Rep":
- is a "Interior Location Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Int Loc Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Vertex ID	(FK)
Int Loc Start or End Face	Indicates whether the "Partial Rev SOR Int Loc Rep" is on the starting or ending face in the partially revolved "Solid of Revolution Model".

SML:

```
ENTITY Partial-Rev-SOR-Int-Loc-Rep
    CATEGORY BY Int-Loc-Rep-Type OF Interior-Location-Representation
    Vertex "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
    Int-Loc-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
ENTITY  Partial_Rev_SOR_Int_Loc_Rep
    SUBTYPE       OF  ( Interior_Location_Representation   );
    Definition : Vertex;
    Context  :  Solid_of_Revolution_Model;
    Face  :  Partial_Rev_SOR_Face_Types;
END_ENTITY;
```

Entity Name:	Partial Rev SOR Loop Perimeter Rep
Entity Number:	INT-77
Entity Definition:	The use of a "Loop" in a "Solid of Revolution Model" that is revolved through less than 360° to represent a "Perimeter Shape Element".

Business Rules: Every "Partial Rev SOR Loop Perimeter Rep":

- is a "Perimeter Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Loop".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Loop ID	(FK)
SOR Perim Start or End Face	Indicates whether the "Partial Rev SOR Loop Perimeter Rep" is on the starting or ending face in the partially revolved "Solid of Revolution Model".

SML:

```
ENTITY Partial-Rev-SOR-Loop-Perimeter-Rep
    CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
    Loop "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
    SOR-Perim-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
ENTITY Partial_Rev_SOR_Loop_Perimeter_Rep
   SUBTYPE      OF ( Perimeter_Representation );
   Definition : Loop;
   Context : Solid_of_Revolution_Model;
   Face : Partial_Rev_SOR_Face_Types;
END_ENTITY;
```

Entity Name:	Partial Rev SOR Max Area Rep
Entity Number:	INT-46
Entity Definition:	The use of a "Solid of Revolution Model" that is revolved through less than 360° to represent a "Maximal Area Shape Element".

Business Rules: Every "Partial Rev SOR Max Area Rep":
- is an "Maximal Area Representation".
- is one, and only one, "Solid of Revolution Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
SOR Max Area Start or End Face	Indicates whether the "Partial Rev SOR Max Area Rep" is on the starting or ending face in the partially revolved "Solid of Revolution Model".

SML:

```
ENTITY Partial-Rev-SOR-Max-Area-Rep
    CATEGORY BY Max-Area-Rep-Type OF Maximal-Area-Representation
    Solid-of-Revolution-Model "is used as" NONULL
    SOR-Max-Area-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
ENTITY  Partial_Rev_SOR_Max_Area_Rep
    SUBTYPE       OF  ( Maximal_Area_Representation  );
    Definition  :  Solid_of_Revolution_Model;
    Face  :  Partial_Rev_SOR_Face_Types;
END_ENTITY;
```

Entity Name:	Partial Rev SOR Subface NM Area Rep
Entity Number:	INT-56
Entity Definition:	The use of a "Subface" in a "Solid of Revolution Model" that is revolved through less than 360° to represent a "Nonmaximal Area Shape Element".

Business Rules: Every "Partial Rev SOR Subface NM Area Rep":

- is a "Nonmaximal Area Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Subface".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Nonmax Area Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Subface ID	(FK)
SOR Nonmax Area Start or End Face	Indicates whether the "Partial Rev SOR Subface NM Area Rep" is on the starting or ending face in the partially revolved "Solid of Revolution Model".

SML:

```
ENTITY Partial-Rev-SOR-Subface-NM-Area-Rep
    CATEGORY BY Nonmax-Area-Rep-Type
        OF Nonmaximal-Area-Representation
    Subface "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
    SOR-Nonmax-Area-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
ENTITY Partial_Rev_SOR_Subface_NM_Area_Rep
   SUBTYPE      OF ( Nonmaximal_Area_Representation  );
   Definition : Subface;
   Context : Solid_of_Revolution_Model;
   Face : Partial_Rev_SOR_Face_Types;
END_ENTITY;
```

Entity Name:	Partial Rev SOR Volume Rep
Entity Number:	INT-38
Entity Definition:	The use of a "Solid of Revolution Model" that is revolved through less than 360° to represent a "Voidless Volume Shape Element".

Business Rules: Every "Partial Rev SOR Volume Rep":

- is a "Voidless Volume Representation".
- is one, and only one, "Solid of Revolution Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Volume Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)

SML:

```
ENTITY Partial-Rev-SOR-Volume-Rep
   CATEGORY BY Volume-Rep-Type OF Voidless-Volume-Representation
   Solid-of-Revolution-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY Partial_Rev_SOR_Volume_Rep
   SUBTYPE       OF ( Voidless_Volume_Representation   );
   Definition : Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Name:	Perimeter Representation
Entity Number:	INT-73
Entity Definition:	The symbolic description of a "Perimeter Shape Element" in a "Geometric Model".

Business Rules: Every "Perimeter Representation":

- represents one, and only one, "Perimeter Shape Element".
- must be one, and only one, of the following:
  "Brep Perimeter Rep"
  "Facetted Brep Perimeter Rep"
  "SOLE Edge Perimeter Rep"
  "SOLE Loop Perimeter Rep"
  "Partial Rev SOR Edge Perimeter Rep"
  "Partial Rev SOR Loop Perimeter Rep"
  "Full Rev SOR Vertex Perimeter Rep"
  "Surface Perimeter Rep"
  "Unstruct Geometry Perimeter Rep"
  "Wireframe Perimeter Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	The means of distinguishing each "Perimeter Representation" from all the others for the same "Perimeter Shape Element".

Other Attributes:

Perim Rep Type	The means of determining whether a "Perimeter Representation" is a(n): "Brep Perimeter Rep", "Facetted Brep Perimeter Rep", "SOLE Edge Perimeter Rep", "SOLE Loop Perimeter Rep", "Partial Rev SOR Edge Perimeter Rep", "Partial Rev SOR Loop Perimeter Rep", "Full Rev SOR Vertex Perimeter Rep", "Surface Perimeter Rep", "Unstruct Geometry Perimeter Rep", or "Wireframe Perimeter Rep".

SML:

```
ENTITY Perimeter-Representation
   KEY
      Perimeter-Shape-Element "is represented by"
      Perim-Rep-ID
   ENDK
   Perim-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Perimeter_Representation
   SUPERTYPE    OF ( Brep_Perimeter_Rep
                OR   Facetted_Brep_Perimeter_Rep
                OR   SOLE_Edge_Perimeter_Rep
                OR   SOLE_Loop_Perimeter_Rep
                OR   Partial_Rev_SOR_Edge_Perimeter_Rep
                OR   Partial_Rev_SOR_Loop_Perimeter_Rep
                OR   Full_Rev_SOR_Vertex_Perimeter_Rep
                OR   Surface_Perimeter_Rep
                OR   Unstruct_Geometry_Perimeter_Rep
                OR   Wireframe_Perimeter_Rep   );
END_ENTITY;
```

Entity Name:	Perimeter Shape Element
Entity Number:	INT-18
Entity Definition:	A "Dimensionality 1 Shape Element" that is a closed boundary of a "Maximal Area Shape Element".

Business Rules: Every "Perimeter Shape Element":
- is a "Dimensionality 1 Shape Element".
- is represented by zero, one, or more "Perimeter Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Perimeter-Shape-Element
   CATEGORY BY Dim-1-SE-Type OF Dimensionality-1-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Perimeter_Shape_Element
   SUBTYPE      OF  ( Dimensionality_1_Shape_Element   );
   Representations : LIST OF [ 0 : # ] OF Perimeter_Representation;
END_ENTITY;
```

Entity Name:	Point
Entity Number:	GEO-2
Entity Definition:	Defined in the PDES Geometry reference model.
Business Rules:	Every "Point" is used as zero, one, or more "Facetted Brep Dim 0 SE Reps".

Entity Name:	Polyloop
Entity Number:	TOP-11
Entity Definition:	Defined in the PDES Topology reference model.
Business Rules:	Every "Polyloop" is used as zero, one, or more "Facetted Brep Perimeter Reps".

Entity Name:	Product Item
Entity Number:	PSCM-1
Entity Definition:	Defined in the PDES PSCM reference model.
Business Rules:	Every "Product Item" has one or more "Product Item Versions".

Entity Name:	Product Item Version
Entity Number:	PSCM-2
Entity Definition:	Defined in the PDES PSCM reference model.

Business Rules: Every "Product Item Version":

- is for one, and only one, "Product Item".
- is described by one or more "Product Item Version Functional Definitions".

Entity Name: Product Item Version Definition Shape

Entity Number: PSCM-27

Entity Definition: Defined in the PDES PSCM reference model.

Business Rules: Every "Product Item Version Definition Shape":

- is the primary shape for one, and only one, "Product Item Version Functional Definition".
- is one, and only one, "Shape".

Entity Name:	Product Item Version Functional Definition
Entity Number:	PSCM-4
Entity Definition:	Defined in the PDES PSCM reference model.

Business Rules: Every "Product Item Version Functional Definition":

- describes one, and only one, "Product Item Version".
- has a primary shape of zero or one "Product Item Version Definition Shape".
- is modeled by zero, one, or more "FEM Product Item Version Definitions".

Entity Name:	Seam Representation
Entity Number:	INT-63
Entity Definition:	The symbolic description of a "Seam Shape Element" in a "Geometric Model".

Business Rules: Every "Seam Representation":

- represents one, and only one, "Seam Shape Element".
- must be one, and only one, of the following:
  "Brep Seam Rep"
  "SOLE Edge Seam Rep"
  "SOLE Vertex Seam Rep"
  "Partial Rev SOR Edge Seam Rep"
  "SOR Vertex Seam Rep"
  "Surface Seam Rep"
  "Unstruct Geometry Seam Rep"
  "Wireframe Seam Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Seam Rep ID	The means of distinguishing each "Seam Representation" from all the others for the same "Seam Shape Element".

Other Attributes:

Seam Rep Type	The means of determining whether a "Seam Representation" is a(n): "Brep Seam Rep", "SOLE Edge Seam Rep", "SOLE Vertex Seam Rep", "Partial Rev SOR Edge Seam Rep", "SOR Vertex Seam Rep", "Surface Seam Rep", "Unstruct Geometry Seam Rep", or "Wireframe Seam Rep".

SML:

```
ENTITY Seam-Representation
   KEY
      Seam-Shape-Element "is represented by"
      Seam-Rep-ID
   ENDK
   Seam-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Seam_Representation
   SUPERTYPE    OF  ( Brep_Seam_Rep
                OR    SOLE_Edge_Seam_Rep
                OR    SOLE_Vertex_Seam_Rep
                OR    Partial_Rev_SOR_Edge_Seam_Rep
                OR    SOR_Vertex_Seam_Rep
                OR    Surface_Seam_Rep
                OR    Unstruct_Geometry_Seam_Rep
                OR    Wireframe_Seam_Rep   );
END_ENTITY;
```

Entity Name:	Seam Shape Element
Entity Number:	INT-14
Entity Definition:	A "Dimensionality 1 Shape Element" that has a uniform underlying mathematical curve.

Business Rules: Every "Seam Shape Element":

- is a "Dimensionality 1 Shape Element".
- must be one, and only one, of the following:
  "Edge Shape Element"
  "Interior Seam Shape Element"
  "Subedge Shape Element"
- is represented by zero, one, or more "Seam Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes:

Seam SE Type	The means of determining whether a "Seam Shape Element" is a(n): "Edge Shape Element", "Interior Seam Shape Element", or "Subedge Shape Element".

SML:

```
ENTITY Seam-Shape-Element
   CATEGORY BY Dim-1-SE-Type OF Dimensionality-1-Shape-Element
   Seam-SE-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Seam_Shape_Element
   SUPERTYPE     OF ( Edge_Shape_Element
                 OR   Subedge_Shape-Element
                 OR   Interior_Seam_Shape-Element  )
   SUBTYPE       OF ( Dimensionality_1_Shape_Element  );
   Representations : LIST OF [ 0 : # ] OF Seam_Representation;
END_ENTITY;
```

Entity Name:	Shape
Entity Number:	INT-1
Entity Definition:	The size, spatial configuration, and proportions of a real or conceived thing, independent of whether or how it is represented.

Business Rules: Every "Shape":

- is an aggregation zero, one, or more "Shape Elements".
- is the primary shape for zero, one, more "Product Item Version Definition Shapes".

Primary Key Attributes:

Shape ID	The means of distinguishing each "Shape" from all others.

Other Attributes: none

SML:

```
ENTITY Shape
    KEY
        Shape-ID
    ENDK
ENDE
```

EXPRESS:

```
ENTITY Shape;
    Elements : LIST OF [ 0 : # ] Shape_Element;
END_ENTITY;
```

Entity Name:	Shape Element
Entity Number:	INT-2
Entity Definition:	A distinguishable aspect of a "Shape".

Business Rules: Every "Shape Element":

- is part of one, and only one, "Shape".
- must be one, and only one, of the following:
  "Dimensionality 0 Shape Element"
  "Dimensionality 1 Shape Element"
  "Dimensionality 2 Shape Element"
  "Dimensionality 3 Shape Element"

Primary Key Attributes:

Shape ID	(FK)
Shape Element ID	The means of distinguishing each "Shape Element" from all the others belonging to the same "Shape".

Other Attributes:

Shape Element Type	The means of determining whether a "Shape Element" is a(n): "Dimensionality 0 Shape Element", "Dimensionality 1 Shape Element", "Dimensionality 2 Shape Element", or "Dimensionality 3 Shape Element".

SML:

```
ENTITY Shape-Element
    KEY
        Shape "is aggregation of"
        Shape-Elem-ID
    ENDK
    Shape-Elem-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Shape_Element
   SUPERTYPE    OF ( Dimensionality_0_Shape_Element
                OR   Dimensionality_1_Shape_Element
                OR   Dimensionality_2_Shape_Element
                OR   Dimensionality_3_Shape_Element  );
END_ENTITY;
```

Entity Name: Shell

Entity Number: TOP-6

Entity Definition: Defined in the PDES Topology reference model.

Business Rules: Every "Shell":

- is used as zero, one, or more "Brep Volume Reps".
- is used as zero, one, or more "Facetted Brep Volume Reps".

Entity Name: SOLE Dim 0 SE Rep

Entity Number: INT-88

Entity Definition: The use of a "Vertex" in a "Solid of Linear Extrusion Model" to represent a "Dimensionality 0 Shape Element".

Business Rules: Every "SOLE Dim 0 SE Rep":
- is a "Dim 0 Shape Element Representation".
- is in one, and only one, "Solid of Linear Extrusion Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 0 Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)
Vertex ID	(FK)
Dim 0 Start or End Face	Indicates whether the "SOLE Dim 0 SE Rep" is on the starting or ending face in the "Solid of Linear Extrusion Model".

SML:

```
ENTITY SOLE-Dim-0-SE-Rep
    CATEGORY BY Dim-0-Rep-Type OF Dim-0-Shape-Element-Representation
    Vertex "is used as" NONULL
    Solid-of-Linear-Extrusion-Model "is context of" NONULL
    Dim-0-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
TYPE
   SOLE_Face_Types =
      ENUMERATION OF ( Starting_SOLE_Face, Ending_SOLE_Face );
END_TYPE;

ENTITY SOLE_Dim_0_SE_Rep
   SUBTYPE      OF ( Dim_0_Shape_Element_Representation   );
   Definition : Vertex;
   Context : Solid_of_Linear_Extrusion_Model;
   Face : SOLE_Face_Types;
END_ENTITY;
```

Entity Name:	SOLE Edge Area Rep
Entity Number:	INT-50
Entity Definition:	The use of an "Edge" in a "Solid of Linear Extrusion Model" to represent an "Area Shape Element". An edge of the swept face sweeps a surface area of the prismatic solid. If the edge has an adjacent edge with the same underlying curve, the area is nonmaximal; otherwise, the area is maximal.

Business Rules: Every "SOLE Edge Area Rep":

- is an "Area Representation".
- is in one, and only one, "Solid of Linear Extrusion Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)
Edge ID	(FK)

SML:

```
ENTITY SOLE-Edge-Area-Rep
    CATEGORY BY Area-Rep-Type OF Area-Representation
    Edge "is used as" NONULL
    Solid-of-Linear-Extrusion-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY SOLE_Edge_Area_Rep
    SUBTYPE      OF ( Area_Representation );
    Definition : Edge;
    Context : Solid_of_Linear_Extrusion_Model;
END_ENTITY;
```

Entity Name:	SOLE Edge NM Area Rep
Entity Number:	INT-60
Entity Definition:	The use of an "Edge" in a "Solid of Linear Extrusion Model" to represent a "Nonmaximal Area Shape Element". An edge of a subface of the face swept by an SOLE sweeps a portion of the surface area of the solid, provided that the edge is a portion of an edge of the swept face. If, in addition, the subface edge is a proper subset of the swept face edge, the edge sweeps a nonmaximal area. (If the subface edge is an entire edge of the swept face, it seems pointless to regard the subface edge as the representation of the swept area; the swept face edge is available and more natural. Therefore, it is considered that only a nonmaximal area can be represented by an edge of a subface of the swept face.)

Business Rules: Every "SOLE Edge NM Area Rep":
- is a "Nonmaximal Area Representation".
- is in one, and only one, "Solid of Linear Extrusion Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Nonmax Area Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)
Edge ID	(FK)

SML:

```
ENTITY SOLE-Edge-NM-Area-Rep
    CATEGORY BY Nonmax-Area-Rep-Type
        OF Nonmaximal-Area-Representation
    Edge "is used as" NONULL
    Solid-of-Linear-Extrusion-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY SOLE_Edge_NM_Area_Rep
   SUBTYPE      OF ( Nonmaximal_Area_Representation  );
   Definition : Edge;
   Context  : Solid_of_Linear_Extrusion_Model;
END_ENTITY;
```

Entity Name:	SOLE Edge Perimeter Rep
Entity Number:	INT-82
Entity Definition:	The use of an "Edge" in a "Solid of Linear Extrusion Model" to represent a "Perimeter Shape Element".

Business Rules: Every "SOLE Edge Perimeter Rep":

- is a "Perimeter Representation".
- is in one, and only one, "Solid of Linear Extrusion Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)
Edge ID	(FK)

SML:

```
ENTITY SOLE-Edge-Perimeter-Rep
    CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
    Edge "is used as" NONULL
    Solid-of-Linear-Extrusion-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY SOLE_Edge_Perimeter_Rep
    SUBTYPE      OF  ( Perimeter_Representation  );
    Definition : Edge;
    Context  : Solid_of_Linear_Extrusion_Model;
END_ENTITY;
```

Entity Name:	SOLE Edge Seam Rep
Entity Number:	INT-68
Entity Definition:	The use of an "Edge" in a "Solid of Linear Extrusion Model" to represent a "Seam Shape Element". An edge of the face swept by an SOLE corresponds to some or all of a seam between the "base" or "cap" of the prismatic solid and a side area of the solid. If the edge has no adjacent face with the same underlying curve, the seam is an "Edge Shape Element", i.e., the intersection of maximal areas. If there is an adjacent face with the same underlying curve, the seam is a "Subedge Shape Element". An "Interior Seam Shape Element" cannot be represented in this way.

Business Rules: Every "SOLE Edge Seam Rep":

- is a "Seam Representation".
- is in one, and only one, "Solid of Linear Extrusion Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Seam Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)
Edge ID	(FK)
SOLE Seam Start or End Face	Indicates whether the "SOLE Edge Seam Rep" is on the starting or ending face in the "Solid of Linear Extrusion Model".

SML:

```
ENTITY SOLE-Edge-Seam-Rep
    CATEGORY BY Seam-Rep-Type OF Seam-Representation
    Edge "is used as" NONULL
    Solid-of-Linear-Extrusion-Model "is context of" NONULL
    SOLE-Seam-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
ENTITY SOLE_Edge_Seam_Rep
   SUBTYPE      OF ( Seam_Representation  );
   Definition : Edge;
   Context  :  Solid_of_Linear_Extrusion_Model;
   Face : SOLE_Face_Types;
END_ENTITY;
```

Entity Name:	SOLE Loop Perimeter Rep
Entity Number:	INT-78
Entity Definition:	The use of a "Loop" in a "Solid of Linear Extrusion Model" to represent a "Perimeter Shape Element".

Business Rules: Every "SOLE Loop Perimeter Rep":

- is a "Perimeter Representation".
- is in one, and only one, "Solid of Linear Extrusion Model".
- is one, and only one, "Loop".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)
Loop ID	(FK)
SOLE Perim Start or End Face	Indicates whether the "SOLE Loop Perimeter Rep" is on the starting or ending face in the "Solid of Linear Extrusion Model".

SML:

```
ENTITY SOLE-Loop-Perimeter-Rep
    CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
    Loop "is used as" NONULL
    Solid-of-Linear-Extrusion-Model "is context of" NONULL
    SOLE-Perim-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
ENTITY SOLE_Loop_Perimeter_Rep
    SUBTYPE      OF  ( Perimeter_Representation  );
    Definition : Loop;
    Context : Solid_of_Linear_Extrusion_Model;
    Face : SOLE_Face_Types;
END_ENTITY;
```

Entity Name:	SOLE Max Area Rep
Entity Number:	INT-47
Entity Definition:	The use of a "Solid of Linear Extrusion Model" to represent an "Maximal Area Shape Element". The swept face of an SOLE corresponds to two surface areas of the solid: the "base" and the "cap" of the prism. By the nature of an SOLE, these two areas are necessarily maximal.

Business Rules: Every "SOLE Max Area Rep":

- is a "Maximal Area Representation".
- is one, and only one, "Solid of Linear Extrusion Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)
SOLE Max Area Start or End Face	Indicates whether the "SOLE Max Area Rep" is on the starting or ending face in the "Solid of Linear Extrusion Model".

SML:

```
ENTITY SOLE-Max-Area-Rep
    CATEGORY BY Max-Area-Rep-Type OF Maximal-Area-Representation
    Solid-of-Linear-Extrusion-Model "is used as" NONULL
    SOLE-Max-Area-Start-or-End-Face NONULL
ENDE
```

EXPRESS:

```
ENTITY SOLE_Max_Area_Rep
    SUBTYPE      OF ( Maximal_Area_Representation  );
    Definition : Solid_of_Linear_Extrusion_Model;
    Face : SOLE_Face_Types;
END_ENTITY;
```

Entity Name:	SOLE Subface NM Area Rep
Entity Number:	INT-57
Entity Definition:	The use of a "Subface" in a "Solid of Linear Extrusion Model" to represent a "Nonmaximal Area Shape Element". A subface of the face swept of an SOLE corresponds to two surface areas of the solid. These are nonmaximal areas: one being a subset of the "base" of the prismatic solid; the other, a subset of the "cap".

Business Rules: Every "SOLE Subface NM Area Rep":

- is a "Nonmaximal Area Representation".
- is in one, and only one, "Solid of Linear Extrusion Model".
- is one, and only one, "Subface".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Nonmax Area Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)
Subface ID	(FK)
SOLE Nonmax Area Start or End Face	Indicates whether the "SOLE Subface NM Area Rep" is on the starting or ending face in the "Solid of Linear Extrusion Model".

SML:

```
ENTITY SOLE-Subface-NM-Area-Rep
    CATEGORY BY Nonmax-Area-Rep-Type
        OF Nonmaximal-Area-Representation
    Subface "is used as" NONULL
    Solid-of-Linear-Extrusion-Model "is context of" NONULL
    SOLE-Nonmax-Area-Start-or-End-Face NONULL
ENDE
```

<u>EXPRESS:</u>

```
ENTITY SOLE_Subface_NM_Area_Rep
   SUBTYPE       OF ( Nonmaximal_Area_Representation   );
   Definition : Subface;
   Context : Solid_of_Linear_Extrusion_Model;
   Face : SOLE_Face_Types;
END_ENTITY;
```

Entity Name:	SOLE Vertex Seam Rep
Entity Number:	INT-71
Entity Definition:	The use of a "Vertex" in a "Solid of Linear Extrusion Model" to represent a "Seam Shape Element".

Business Rules: Every "SOLE Vertex Seam Rep":
- is a "Seam Representation".
- is in one, and only one, "Solid of Linear Extrusion Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Seam Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)
Vertex ID	(FK)

SML:

```
ENTITY SOLE-Vertex-Seam-Rep
    CATEGORY BY Seam-Rep-Type OF Seam-Representation
    Vertex "is used as" NONULL
    Solid-of-Linear-Extrusion-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY SOLE_Vertex_Seam_Rep
    SUBTYPE      OF  ( Seam_Representation  );
    Definition : Vertex;
    Context : Solid_of_Linear_Extrusion_Model;
END_ENTITY;
```

Entity Name:	SOLE Volume Rep
Entity Number:	INT-40
Entity Definition:	The use of a "Solid of Linear Extrusion Model" to represent a "Voidless Volume Shape Element". An SOLE is a solid model. Since an SOLE is a sweep of a single face, the solid must have a connected interior. The nature of the representation makes it impossible for the solid to have any voids.

Business Rules: Every "SOLE Volume Rep":

- is a "Voidless Volume Representation".
- is one, and only one, "Solid of Linear Extrusion Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Volume Rep ID	(FK)

Other Attributes:

SOLE Model ID	(FK)

SML:

```
ENTITY SOLE-Volume-Rep
   CATEGORY BY Volume-Rep-Type OF Voidless-Volume-Representation
   Solid-of-Linear-Extrusion-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY SOLE_Volume_Rep
   SUBTYPE      OF ( Voidless_Volume_Representation   );
   Definition : Solid_of_Linear_Extrusion_Model;
END_ENTITY;
```

Entity Name:	Solid of Linear Extrusion Model
Entity Number:	GEO-106
Entity Definition:	Defined in the PDES Geometry reference model.

Business Rules: Every "Solid of Linear Extrusion Model":

- is a "Geometric Model".
- is the context of zero, one, or more "SOLE Dim 0 SE Reps".
- is the context of zero, one, or more "SOLE Edge Area Reps".
- is the context of zero, one, or more "SOLE Edge NM Area Reps".
- is the context of zero, one, or more "SOLE Edge Perimeter Reps".
- is the context of zero, one, or more "SOLE Edge Seam Reps".
- is used as zero, one, or more "SOLE Max Area Reps".
- is the context of zero, one, or more "SOLE Loop Perimeter Reps".
- is the context of zero, one, or more "SOLE Subface NM Area Reps".
- is the context of zero, one, or more "SOLE Vertex Seam Reps".
- is used as zero, one, or more "SOLE Volume Reps".

Entity Name:	Solid of Revolution Model
Entity Number:	GEO-107
Entity Definition:	Defined in the PDES Geometry reference model.

Business Rules: Every "Solid of Revolution Model":

- is a "Geometric Model".
- revolves one, and only one, "Face".
- is the context of zero, one, or more "Full Rev SOR Corner Reps".
- is the context of zero, one, or more "Full Rev SOR Int Loc Reps".
- is used as zero, one, or more "Full Rev SOR Object Reps".
- is the context of zero, one, or more "Full Rev SOR Volume Reps".
- is the context of zero, one, or more "Partial Rev SOR Bdry Loc Reps".
- is the context of zero, one, or more "Partial Rev SOR Corner Reps".
- is the context of zero, one, or more "Partial Rev SOR Int Loc Reps".
- is used as zero, one, or more "Partial Rev SOR Volume Reps".
- is the context of zero, one, or more "SOR Edge Area Reps".
- is the context of zero, one, or more "SOR Edge NM Area Reps".
- is the context of zero, one, or more "Partial Rev SOR Edge Perimeter Reps".
- is the context of zero, one, or more "Partial Rev SOR Edge Seam Reps".
- is used as zero, one, or more "Partial Rev SOR Max Area Reps".
- is the context of zero, one, or more "Partial Rev SOR Loop Perimeter Reps".
- is the context of zero, one, or more "Partial Rev SOR Subface NM Area Reps".
- is the context of zero, one, or more "Full Rev SOR Vertex Perimeter Reps".
- is the context of zero, one, or more "SOR Vertex Seam Reps".

Entity Name: SOR Edge Area Rep

Entity Number: INT-49

Entity Definition: The use of an "Edge" in a "Solid of Revolution Model" to represent an "Area Shape Element".

Business Rules: Every "SOR Edge Area Rep":

- is an "Area Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Edge ID	(FK)

SML:

```
ENTITY SOR-Edge-Area-Rep
    CATEGORY BY Area-Rep-Type OF Area-Representation
    Edge "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY SOR_Edge_Area_Rep
    SUBTYPE     OF ( Area_Representation );
    Definition : Edge;
    Context : Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Name: SOR Edge NM Area Rep

Entity Number: INT-59

Entity Definition: The use of an "Edge" in a "Solid of Revolution Model" to represent a "Nonmaximal Area Shape Element".

Business Rules: Every "SOR Edge NM Area Rep":
- is a "Nonmaximal Area Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Nonmax Area Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Edge ID	(FK)

SML:

```
ENTITY SOR-Edge-NM-Area-Rep
    CATEGORY BY Nonmax-Area-Rep-Type
        OF Nonmaximal-Area-Representation
    Edge "is used as" NONULL
    Solid-of-Revolution-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY  SOR_Edge_NM_Area_Rep
    SUBTYPE       OF  ( Nonmaximal_Area_Representation   );
    Definition : Edge;
    Context  :  Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Name:	SOR Vertex Seam Rep
Entity Number:	INT-70
Entity Definition:	The use of a "Vertex" in a "Solid of Revolution Model" to represent a "Seam Shape Element".

Business Rules: Every "SOR Vertex Seam Rep":

- is a "Seam Representation".
- is in one, and only one, "Solid of Revolution Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Seam Rep ID	(FK)

Other Attributes:

SOR Model ID	(FK)
Vertex ID	(FK)

SML:

```
ENTITY SOR-Vertex-Seam-Rep
   CATEGORY BY Seam-Rep-Type OF Seam-Representation
   Vertex "is used as" NONULL
   Solid-of-Revolution-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY SOR_Vertex_Seam_Rep
   SUBTYPE      OF ( Seam_Representation  );
   Definition : Vertex;
   Context  : Solid_of_Revolution_Model;
END_ENTITY;
```

Entity Name:	Subedge Shape Element
Entity Number:	INT-16
Entity Definition:	A "Seam Shape Element" that is a proper subset of an "Edge Shape Element".
Business Rules:	Every "Subedge Shape Element" is a "Seam Shape Element".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Subedge-Shape-Element
   CATEGORY BY Seam-SE-Type OF Seam-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Subedge_Shape_Element
   SUBTYPE      OF  ( Seam_Shape_Element   );
END_ENTITY;
```

Entity Name:	Subface
Entity Number:	TOP-8
Entity Definition:	Defined in the PDES Topology reference model.

Business Rules: Every "Subface":

- is used as zero, one, or more "Brep NM Area Reps".
- is used as zero, one, or more "Facetted Brep NM Area Reps".
- is used as zero, one, or more "SOLE Subface NM Area Reps".
- is used as zero, one, or more "Partial Rev SOR Subface NM Area Reps".
- is used as zero, one, or more "Surface NM Area Reps".

Entity Name:	Surface Area Rep
Entity Number:	INT-45
Entity Definition:	The use of a "Face" in a "Surface Model" to represent an "Area Shape Element". In a surface model, a face is typically employed to represent a portion of surface area that (i) has a uniform underlying surface and (ii) is arcwise connected. If there is an adjacent face with the same underlying surface, the area is not maximal; otherwise, it is maximal.

Business Rules: Every "Surface Area Rep":

- is an "Area Representation".
- is in one, and only one, "Surface Model".
- is one, and only one, "Face".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	(FK)

Other Attributes:

Surface Model ID	(FK)
Face ID	(FK)

SML:

```
ENTITY Surface-Area-Rep
   CATEGORY BY Area-Rep-Type OF Area-Representation
   Face "is used as" NONULL
   Surface-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Surface_Area_Rep
   SUBTYPE      OF  ( Area_Representation  );
   Definition : Face;
   Context : Surface_Model;
END_ENTITY;
```

Entity Name: Surface Dim 0 SE Rep

Entity Number: INT-86

Entity Definition: The use of a "Vertex" in a "Surface Model" to represent a "Dimensionality 0 Shape Element". In a surface model, vertices are employed in maximal faces, nonmaximal faces, subfaces, and vertex loops. In the first three cases, the edges that meet at the vertex may have the same underlying curve. So, a vertex may represent any of the three categories of "Dimensionality 0 Shape Element" – corner, boundary location, or interior location.

Business Rules: Every "Surface Dim 0 SE Rep":
- is a "Dim 0 Shape Element Representation".
- is in one, and only one, "Surface Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 0 Rep ID	(FK)

Other Attributes:

Surface Model ID	(FK)
Vertex ID	(FK)

SML:

```
ENTITY Surface-Dim-0-SE-Rep
    CATEGORY BY Dim-0-Rep-Type OF Dim-0-Shape-Element-Representation
    Vertex "is used as" NONULL
    Surface-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY  Surface_Dim_0_SE_Rep
    SUBTYPE       OF  ( Dim_0_Shape_Element_Representation   );
    Definition : Vertex;
    Context : Surface_Model;
END_ENTITY;
```

Entity Name:	Surface Dim 3 SE Rep
Entity Number:	INT-27
Entity Definition:	The use of a "Surface Model" to represent a "Dimensionality 3 Shape Element". A surface model has no information for structuring its component shells into solids. So, representation of a "Dimensionality 3 Shape Element" by a surface model is a matter of human interpretation, rather than indigenous content, of the data. With this attitude, a surface model may represent any category of "Dimensionality 3 Shape Element".

Business Rules: Every "Surface Dim 3 SE Rep":

- is a "Dim 3 Shape Element Representation".
- is one, and only one, "Surface Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 3 Rep ID	(FK)

Other Attributes:

Surface Model ID	(FK)

SML:

```
ENTITY Surface-Dim-3-SE-Rep
   CATEGORY BY Dim-3-Rep-Type OF Dim-3-Shape-Element-Representation
   Surface-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY  Surface_Dim_3_SE_Rep
   SUBTYPE       OF  ( Dim_3_Shape_Element_Representation   );
   Definition : Surface_Model;
END_ENTITY;
```

Entity Name: Surface Model

Entity Number: none

Entity Definition: Needs to be defined in some other PDES reference model.

Business Rules: Every "Surface Model":
- is a "Geometric Model".
- is the context of zero, one, or more "Surface Area Reps".
- is the context of zero, one, or more "Surface Dim 0 SE Reps".
- is used as zero, one, or more "Surface Dim 3 SE Reps".
- is the context of zero, one, or more "Surface NM Area Reps".
- is the context of zero, one, or more "Surface Perimeter Reps".
- is the context of zero, one, or more "Surface Seam Reps".

Entity Name: Surface NM Area Rep

Entity Number: INT-55

Entity Definition: The use of a "Subface" in a "Surface Model" to represent a "Nonmaximal Area Shape Element". In a surface model, a subface represents a portion of surface area that is necessarily nonmaximal because the subface is a subset of a face with a uniform underlying surface. (Note: The IPIM does not require that a subface be a proper subset of the containing face, but it seems pointless to have a subface identical to its containing face. For this reason, no provision is made here for representing a "Maximal Area Shape Element" with a subface.)

Business Rules: Every "Surface NM Area Rep":

- is a "Nonmaximal Area Representation".
- is in one, and only one, "Surface Model".
- is one, and only one, "Subface".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Nonmax Area Rep ID	(FK)

Other Attributes:

Surface Model ID	(FK)
Subface ID	(FK)

SML:

```
ENTITY Surface-NM-Area-Rep
    CATEGORY BY Nonmax-Area-Rep-Type
        OF Nonmaximal-Area-Representation
    Subface "is used as" NONULL
    Surface-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
   ENTITY Surface_NM_Area_Rep
      SUBTYPE       OF ( Nonmaximal_Area_Representation   );
      Definition : Subface;
      Context : Surface_Model;
   END_ENTITY;
```

Entity Name:	Surface Perimeter Rep
Entity Number:	INT-75
Entity Definition:	The use of a "Loop" in a "Surface Model" to represent a "Perimeter Shape Element". In a surface model, a loop is employed as a boundary of a maximal face. Hence, a loop may represent the perimeter of an "Area Shape Element".

Business Rules: Every "Surface Perimeter Rep":

- is a "Perimeter Representation".
- is in one, and only one, "Surface Model".
- is one, and only one, "Loop".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

Other Attributes:

Surface Model ID	(FK)
Loop ID	(FK)

SML:

```
ENTITY Surface-Perimeter-Rep
   CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
   Loop "is used as" NONULL
   Surface-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Surface_Perimeter_Rep
   SUBTYPE      OF  ( Perimeter_Representation  );
   Definition : Loop;
   Context : Surface_Model;
END_ENTITY;
```

Entity Name:	Surface Seam Rep
Entity Number:	INT-65
Entity Definition:	The use of an "Edge" in a "Surface Model" to represent a "Seam Shape Element". In a surface model, an edge is employed as a boundary element of a maximal or nonmaximal face and/or as an edge of a subface of a maximal or nonmaximal face. Even if the parent face is maximal, the edge may be nonmaximal; i.e., the edge may have an adjacent edge with the same underlying curve. So, an edge may represent any of the three categories of "Seam Shape Element" -- edge, subedge, or interior seam.
Business Rules:	Every "Surface Seam Rep":

- is a "Seam Representation".
- is in one, and only one, "Surface Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Seam Rep ID	(FK)

Other Attributes:

Surface Model ID	(FK)
Edge ID	(FK)

SML:

```
ENTITY Surface-Seam-Rep
    CATEGORY BY Seam-Rep-Type OF Seam-Representation
    Edge "is used as" NONULL
    Surface-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Surface_Seam_Rep
    SUBTYPE       OF  ( Seam_Representation  );
    Definition : Edge;
    Context : Surface_Model;
END_ENTITY;
```

Entity Name:	Unstruct Geometry Area Rep
Entity Number:	INT-51
Entity Definition:	The use of a "Geometry" in an "Unstructured Geometry Model" to represent an "Area Shape Element".

Business Rules: Every "Unstruct Geometry Area Rep":

- is an "Area Representation".
- is in one, and only one, "Unstructured Geometry Model".
- is one, and only one, "Geometry".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	(FK)

Other Attributes:

Unstruct Geom Model ID	(FK)
Geometry ID	(FK)

SML:

```
ENTITY Unstruct-Geometry-Area-Rep
    CATEGORY BY Area-Rep-Type OF Area-Representation
    Geometry "is used as" NONULL
    Unstructured-Geometry-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Unstruct_Geometry_Area_Rep
    SUBTYPE      OF ( Area_Representation );
    Definition : Geometry;
    Context': Unstructured_Geometry_Model;
END_ENTITY;
```

Entity Name: Unstruct Geometry Dim 0 SE Rep

Entity Number: INT-90

Entity Definition: The use of a "Geometry" in an "Unstructured Geometry Model" to represent a "Dimensionality 0 Shape Element".

Business Rules: Every "Unstruct Geometry Dim 0 SE Rep":
- is a "Dim 0 Shape Element Representation".
- is in one, and only one, "Unstructured Geometry Model".
- is one, and only one, "Geometry".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 0 Rep ID	(FK)

Other Attributes:

Unstruct Geom Model ID	(FK)
Geometry ID	(FK)

SML:

```
ENTITY Unstruct-Geometry-Dim-0-SE-Rep
   CATEGORY BY Dim-0-Rep-Type OF Dim-0-Shape-Element-Representation
   Geometry "is used as" NONULL
   Unstructured-Geometry-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Unstruct_Geometry_Dim_0_SE_Rep
   SUBTYPE      OF ( Dim_0_Shape_Element_Representation   );
   Definition : Geometry;
   Context : Unstructured_Geometry_Model;
END_ENTITY;
```

Entity Name: Unstruct Geometry Dim 3 SE Rep

Entity Number: INT-29

Entity Definition: The use of a "Geometry" in an "Unstructured Geometry Model" to represent a "Dimensionality 3 Shape Element".

Business Rules: Every "Unstruct Geometry Dim 3 SE Rep":

- is a "Dim 3 Shape Element Representation".
- is one, and only one, "Unstructured Geometry Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 3 Rep ID	(FK)

Other Attributes:

Unstruct Geom Model ID	(FK)

SML:

```
ENTITY Unstruct-Geometry-Dim-3-SE-Rep
   CATEGORY BY Dim-3-Rep-Type OF Dim-3-Shape-Element-Representation
   Unstructured-Geometry-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY  Unstruct_Geometry_Dim_3_SE_Rep
   SUBTYPE       OF  ( Dim_3_Shape_Element_Representation   );
   Definition  :  Unstructured_Geometry_Model;
END_ENTITY;
```

Entity Name: Unstruct Geometry Perimeter Rep

Entity Number: INT-83

Entity Definition: The use of a "Geometry" in an "Unstructured Geometry Model" to represent a "Perimeter Shape Element".

Business Rules: Every "Unstruct Geometry Perimeter Rep":

- is a "Perimeter Representation".
- is in one, and only one, "Unstructured Geometry Model".
- is one, and only one, "Geometry".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

Other Attributes:

Unstruct Geom Model ID	(FK)
Geometry ID	(FK)

SML:

```
ENTITY Unstruct-Geometry-Perimeter-Rep
    CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
    Geometry "is used as" NONULL
    Unstructured-Geometry-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Unstruct_Geometry_Perimeter_Rep
    SUBTYPE     OF ( Perimeter_Representation );
    Definition : Geometry;
    Context : Unstructured_Geometry_Model;
END_ENTITY;
```

Entity Name:	Unstruct Geometry Seam Rep
Entity Number:	INT-72
Entity Definition:	The use of a "Geometry" in an "Unstructured Geometry Model" to represent a "Seam Shape Element".

Business Rules: Every "Unstruct Geometry Seam Rep":

- is a "Seam Representation".
- is in one, and only one, "Unstructured Geometry Model".
- is one, and only one, "Geometry".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Seam Rep ID	(FK)

Other Attributes:

Unstruct Geom Model ID	(FK)
Geometry ID	(FK)

SML:

```
ENTITY Unstruct-Geometry-Seam-Rep
    CATEGORY BY Seam-Rep-Type OF Seam-Representation
    Geometry "is used as" NONULL
    Unstructured-Geometry-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Unstruct_Geometry_Seam_Rep
    SUBTYPE      OF ( Seam_Representation  );
    Definition : Geometry;
    Context : Unstructured_Geometry_Model;
END_ENTITY;
```

Entity Name: Unstructured Geometry Model

Entity Number: none

Entity Definition: Needs to be defined in some other PDES reference model.

Business Rules: Every "Unstructured Geometry Model":

- is a "Geometric Model".
- is the context of zero, one, or more "Unstruct Geometry Area Reps".
- is the context of zero, one, or more "Unstruct Geometry Dim 0 SE Reps".
- is used as zero, one, or more "Unstruct Geometry Dim 3 SE Reps".
- is the context of zero, one, or more "Unstruct Geometry NM Area Reps".
- is the context of zero, one, or more "Unstruct Geometry Perimeter Reps".
- is the context of zero, one, or more "Unstruct Geometry Seam Reps".

Entity Name:	Vertex
Entity Number:	TOP-2
Entity Definition:	Defined in the PDES Topology reference model.

Business Rules: Every "Vertex":

- is used as zero, one, or more "Brep Dim 0 SE Reps".
- is used as zero, one, or more "Full Rev SOR Corner Reps".
- is used as zero, one, or more "Full Rev SOR Int Loc Reps".
- is used as zero, one, or more "Partial Rev SOR Bdry Loc Reps".
- is used as zero, one, or more "Partial Rev SOR Corner Reps".
- is used as zero, one, or more "Partial Rev SOR Int Loc Reps".
- is used as zero, one, or more "SOLE Dim 0 SE Reps".
- is used as zero, one, or more "SOLE Vertex Seam Reps".
- is used as zero, one, or more "Full Rev SOR Vertex Perimeter Reps".
- is used as zero, one, or more "SOR Vertex Seam Reps".
- is used as zero, one, or more "Surface Dim 0 SE Reps".
- is used as zero, one, or more "Wireframe Dim 0 SE Reps".

Entity Name:	Voidless Volume Representation
Entity Number:	INT-34
Entity Definition:	The symbolic description of a "Voidless Volume Shape Element" in a "Geometric Model".

Business Rules: Every "Voidless Volume Representation":

- represents one, and only one, "Voidless Volume Shape Element".
- must be one, and only one, of the following:
  "Brep Volume Rep"
  "Full Rev SOR Volume Rep"
  "CSG Primitive Volume Rep"
  "Facetted Brep Volume Rep"
  "Half Space Volume Rep"
  "Partial Rev SOR Volume Rep"
  "SOLE Volume Rep"

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Volume Rep ID	The means of distinguishing each "Voidless Volume Representation" from all the others for the same "Voidless Volume Shape Element".

Other Attributes:

Volume Rep Type	The means of determining whether a "Voidless Volume Representation" is a(n): "Brep Volume Rep", "Full Rev SOR Volume Rep", "CSG Primitive Volume Rep", "Facetted Brep Volume Rep", "Half Space Volume Rep", "Partial Rev SOR Volume Rep", or "SOLE Volume Rep".

SML:

```
ENTITY Voidless-Volume-Representation
   KEY
      Voidless-Volume-Shape-Element "is represented by"
      Volume-Rep-ID
   ENDK
   Volume-Rep-Type NONULL
ENDE
```

EXPRESS:

```
ENTITY Voidless_Volume_Representation
   SUPERTYPE   OF ( Brep_Volume_Rep
               OR   Full_Rev_SOR_Volume_Rep
               OR   CSG_Primitive_Volume_Rep
               OR   Facetted_Brep_Volume_Rep
               OR   Half_Space_Volume_Rep
               OR   Partial_Rev_SOR_Volume_Rep
               OR   SOLE_Volume_Rep  );
END_ENTITY;
```

Entity Name: Voidless Volume Shape Element

Entity Number: INT-5

Entity Definition: An "Object Shape Element" that contains no voids.

Business Rules: Every "Voidless Volume Shape Element":

- is an "Object Shape Element".
- is represented by zero, one, or more "Voidless Volume Representations".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY  Voidless-Volume-Shape-Element
    CATEGORY BY Object-SE-Type OF Object-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY  Voidless_Volume_Shape_Element;
    Representations : LIST OF [ 0 : # ] OF Voidless_Volume_Representation;
END_ENTITY;
```

Entity Name: Wireframe Area Rep

Entity Number: INT-48

Entity Definition: The use of a "Loop" in a "Wireframe Model" to represent an "Area Shape Element".

Business Rules: Every "Wireframe Area Rep":
- is an "Area Representation".
- is in one, and only one, "Wireframe Model".
- is one, and only one, "Loop".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Area Rep ID	(FK)

Other Attributes:

Wireframe Model ID	(FK)
Loop ID	(FK)

SML:

```
ENTITY Wireframe-Area-Rep
    CATEGORY BY Area-Rep-Type OF Area-Representation
    Loop "is used as" NONULL
    Wireframe-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Wireframe_Area_Rep
    SUBTYPE      OF ( Area_Representation );
    Definition : Loop;
    Context : Wireframe_Model;
END_ENTITY;
```

Entity Name:	Wireframe Dim 0 SE Rep
Entity Number:	INT-87
Entity Definition:	The use of a "Vertex" in a "Wireframe Model" to represent a "Dimensionality 0 Shape Element".

Business Rules: Every "Wireframe Dim 0 SE Rep":

- is a "Dim 0 Shape Element Representation".
- is in one, and only one, "Wireframe Model".
- is one, and only one, "Vertex".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 0 Rep ID	(FK)

Other Attributes:

Wireframe Model ID	(FK)
Vertex ID	(FK)

SML:

```
ENTITY Wireframe-Dim-0-SE-Rep
    CATEGORY BY Dim-0-Rep-Type OF Dim-0-Shape-Element-Representation
    Vertex "is used as" NONULL
    Wireframe-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Wireframe_Dim_0_SE_Rep
    SUBTYPE       OF ( Dim_0_Shape_Element_Representation   );
    Definition : Vertex;
    Context : Wireframe_Model;
END_ENTITY;
```

Entity Name: Wireframe Dim 3 SE Rep

Entity Number: INT-28

Entity Definition: The use of a "Wireframe Model" to represent a "Dimensionality 3 Shape Element".

Business Rules: Every "Wireframe Dim 3 SE Rep":

- is a "Dim 3 Shape Element Representation".
- is one, and only one, "Wireframe Model".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Dim 3 Rep ID	(FK)

Other Attributes:

Wireframe Model ID	(FK)

SML:

```
ENTITY Wireframe-Dim-3-SE-Rep
   CATEGORY BY Dim-3-Rep-Type OF Dim-3-Shape-Element-Representation
   Wireframe-Model "is used as" NONULL
ENDE
```

EXPRESS:

```
ENTITY Wireframe_Dim_3_SE_Rep
   SUBTYPE      OF ( Dim_3_Shape_Element_Representation   );
   Definition : Wireframe_Model;
END_ENTITY;
```

Entity Name:	Wireframe Model
Entity Number:	none
Entity Definition:	Needs to be defined in some other PDES reference model.

Business Rules: Every "Wireframe Model":

- is a "Geometric Model".
- is the context of zero, one, or more "Wireframe Area Reps".
- is the context of zero, one, or more "Wireframe Dim 0 SE Reps".
- is used as zero, one, or more "Wireframe Dim 3 SE Reps".
- is the context of zero, one, or more "Wireframe NM Area Reps".
- is the context of zero, one, or more "Wireframe Perimeter Reps".
- is the context of zero, one, or more "Wireframe Seam Reps".

Entity Name:	Wireframe Perimeter Rep
Entity Number:	INT-76
Entity Definition:	The use of a "Loop" in a "Wireframe Model" to represent a "Perimeter Shape Element".

Business Rules: Every "Wireframe Perimeter Rep":

- is a "Perimeter Representation".
- is in one, and only one, "Wireframe Model".
- is one, and only one, "Loop".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Perim Rep ID	(FK)

Other Attributes:

Wireframe Model ID	(FK)
Loop ID	(FK)

SML:

```
ENTITY Wireframe-Perimeter-Rep
   CATEGORY BY Perim-Rep-Type OF Perimeter-Representation
   Loop "is used as" NONULL
   Wireframe-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Wireframe_Perimeter_Rep
   SUBTYPE      OF ( Perimeter_Representation  );
   Definition : Loop;
   Context : Wireframe_Model;
END_ENTITY;
```

Entity Name: Wireframe Seam Rep

Entity Number: INT-66

Entity Definition: The use of an "Edge" in a "Wireframe Model" to represent a "Seam Shape Element".

Business Rules: Every "Wireframe Seam Rep":

- is a "Seam Representation".
- is in one, and only one, "Wireframe Model".
- is one, and only one, "Edge".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)
Seam Rep ID	(FK)

Other Attributes:

Wireframe Model ID	(FK)
Edge ID	(FK)

SML:

```
ENTITY Wireframe-Seam-Rep
   CATEGORY BY Seam-Rep-Type OF Seam-Representation
   Edge "is used as" NONULL
   Wireframe-Model "is context of" NONULL
ENDE
```

EXPRESS:

```
ENTITY Wireframe_Seam_Rep
   SUBTYPE      OF ( Seam_Representation  );
   Definition : Edge;
   Context : Wireframe_Model;
END_ENTITY;
```

Entity Name: Zone Shape Element

Entity Number: INT-11

Entity Definition: A "Dimensionality 2 Shape Element" that is the union of other "Dimensionality 2 Shape Elements".

Business Rules: Every "Zone Shape Element":

- is a "Dimensionality 2 Shape Element".
- consists of one or more "Zone Shape Element Components".

Primary Key Attributes:

Shape ID	(FK)
Shape Elem ID	(FK)

Other Attributes: none

SML:

```
ENTITY Zone-Shape-Element
   CATEGORY BY Dim-2-SE-Type OF Dimensionality-2-Shape-Element
ENDE
```

EXPRESS:

```
ENTITY Zone_Shape_Element
   SUBTYPE     OF ( Dimensionality_2_Shape_Element  );
   Components : LIST OF [ 1 : # ] Zone_Shape_Element_Component;
END_ENTITY;
```

Entity Name:	Zone Shape Element Component
Entity Number:	INT-103
Entity Definition:	A "Dimensionality 2 Shape Element" that is part of a "Zone Shape Element".

Business Rules: Every "Zone Shape Element Component":

- is one, and only one, "Dimensionality 2 Shape Element".
- is part of one, and only one, "Zone Shape Element".

Primary Key Attributes:

Shape ID	(FK)
Zone SE ID	(FK) -- The role name for the Shape Elem ID of the "Zone Shape Element" that includes the "Zone Shape Element Component".
Comp SE ID	(FK) -- The role name for the Shape Elem ID of the "Dimensionality 2 Shape Element" that is used as the "Zone Shape Element Component".

Other Attributes: none

SML:

```
ENTITY Zone-Shape-Element-Component
   KEY
      Zone-Shape-Element "consists of" P
         ROLE Zone-SE-ID FOR Shape-Elem-ID
      Dimensionality-2-Shape-Element "is used as"
         ROLE Comp-SE-ID FOR Shape-Elem-ID
   ENDK
ENDE
```

EXPRESS:

```
ENTITY Zone_Shape_Element_Component;
END_ENTITY;
```

2 NOMINAL SHAPE INFORMATION MODEL

2.1 Purpose

This document presents a conceptual model of information used to represent nominal shape. This includes geometry, solids, and topology. Geometry includes points, curves, and surfaces. Solids is scope down to the two most popular solid representation methods: boundary representation (B-rep) and constructive solid geometry (CSG). Topology is required by B-rep, but is defined independently from B-rep. The intention is that the same topology entities used in B-rep can be used for other purposes as well.

2.2 Method

These IDEF1X models were developed from the IPIM, as neither the Curves & Surfaces Committee nor the Solids Committee did model development in IDEF1X. Care has been taken to maintain conformity between the IPIM and the IDEF1X by using the same names and words as much as possible. There are two major departures from this philosophy, however. The first is that common attributes are not migrated to the leaf entities as in the IPIM. Instead the common attributes appear in the appropriate supertype. The second is that "coordinated lists" are not used here. Instead new entities were created to bundle the coordinated elements together explicitly. For example SEGMENT/GEO-44 bundles the elements from the COMPOSITE_CURVE/GEO-33 attributes "segments" and "senses".

2.3 GEOMETRY

Entity Name: **GEOMETRY**

Entity Number: **GEO-1**

This the supertype of all geometric entities.

Primary Key Attributes

GEOMETRY_ID

Other Attributes

GEOMETRY_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
    ENTITY geometry
    SUPERTYPE OF (point XOR
                  vector XOR
                  axis_placement XOR
                  transformation_matrix XOR
                  curve XOR
                  surface)
  END_ENTITY;
```

Entity Name: **POINT**

Entity Number: **GEO-2**

A point is a location in some coordinate space.

Primary Key Attributes

POINT_ID

Other Attributes

POINT TYPE (discriminator)

Business Rules

EXPRESS Specification

```
  ENTITY point
    SUPERTYPE OF (cartesian_point XOR
                  point_on_curve XOR
                  point_on_surface)
    SUBTYPE OF (geometry);
  END_ENTITY;
```

Entity Name: **VECTOR**

Entity Number: **GEO-3**

Collects the two types of vector: DIRECTION/GEO-14 and VECTOR_WITH_MAGNITUDE/GEO-17.

Primary Key Attributes

VECTOR ID

Other Attributes

VECTOR_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
ENTITY vector
  SUPERTYPE OF (direction XOR
                vector_with_magnitude)
  SUBTYPE OF (geometry);
END_ENTITY;
```

Entity Name: AXIS_PLACEMENT

Entity Number: GEO-4

The local environment for definition of a geometry entity. It locates the entity to be defined and gives its orientation.

Primary Key Attributes

AXIS_PLACEMENT_ID

Other Attributes

AXIS_PLACEMENT_TYPE (discriminator)

CARTESIAN POINT_ID (FK)
The location.

AXIS_DIRECTION_ID (FK)
Direction of local Z axis.

Business Rules

EXPRESS Specification

```
ENTITY axis_placement
  SUPERTYPE OF (axis1_placement XOR
                axis2_placement)
  SUBTYPE OF (geometry);
END_ENTITY;
```

Entity Name: **TRANSFORMATION_MATRIX**

Entity Number: **GEO-5**

A general geometric transformation including translation, rotation, mirroring and scaling.

Primary Key Attributes

TRANSFORMATION_MATRIX_ID

Other Attributes

AXIS1.THREE_SPACE_DIRECTION_ID (FK)
The approximate direction of the required X axis.

AXIS2.THREE_SPACE_DIRECTION_ID (FK)
The approximate direction of the required Y axis.

AXIS3.THREE_SPACE_DIRECTION_ID (FK)
The exact direction of the required Z axis.

CARTESIAN_POINT_ID (FK)
The required translation.

SCALE
Number value of scaling factor.

Business Rules

EXPRESS Specification

```
ENTITY transformation
  SUBTYPE OF (geometry);
  axis1        : OPTIONAL three_space_direction;
  axis2        : OPTIONAL three_space_direction;
  axis3        : OPTIONAL three_space_direction;
  local_origin : OPTIONAL cartesian_point;
  scale        : OPTIONAL REAL;
END_ENTITY;
```

Entity Name: **CURVE**

Entity Number: **GEO-6**

The class of all curves.

Primary Key Attributes

CURVE_ID

Other Attributes

CURVE_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
ENTITY curve
  SUPERTYPE OF (line XOR conic XOR bounded_curve XOR
                curve_on_surface XOR offset_curve)
  SUBTYPE OF (geometry);
END_ENTITY;
```

Entity Name: **SURFACE**

Entity Number: **GEO-7**

The general class of all surfaces.

Primary Key Attributes

SURFACE_ID

Other Attributes

SURFACE_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
ENTITY surface
  SUPERTYPE OF (elementary_surface XOR swept_surface XOR
                bounded_surface XOR offset_surface XOR
                rectangular_composite_surface)
  SUBTYPE OF (geometry);
END_ENTITY;
```

Entity Name: **CARTESIAN_POINT**

Entity Number: **GEO-8**

A point defined in a cartesian coordinate system.

Primary Key Attributes

CARTESIAN_POINT_ID

Other Attributes

CARTESIAN_POINT_TYPE (discriminator)

X_COORDINATE

Y_COORDINATE

Business Rules

EXPRESS Specification

```
ENTITY cartesian_point
  SUPERTYPE OF (cartesian_two_coordinate XOR
                cartesian_three_coordinate)
  SUBTYPE OF (point);
END_ENTITY;
```

Entity Name: **CARTESIAN_TWO_POINT**

Entity Number: **GEO-10**

A point defined in two dimensional Euclidean space.

Primary Key Attributes

CARTESIAN_TWO_POINT_ID

Other Attributes

Business Rules

EXPRESS Specification

```
ENTITY cartesian_two_coordinate
```

```
    SUBTYPE OF (cartesian_point);
    x_coordinate : REAL;
    y_coordinate : REAL;
  END_ENTITY;
```

Entity Name: **CARTESIAN_THREE_POINT**

Entity Number: **GEO-11**

A point defined in three dimensional Euclidean space.

Primary Key Attributes

CARTESIAN_THREE_COORDINATE_ID

Other Attributes

Z_COORDINATE

Business Rules

EXPRESS Specification

```
  ENTITY cartesian_three_coordinate
    SUBTYPE OF (cartesian_point);
    x_coordinate : REAL;
    y_coordinate : REAL;
    z_coordinate : REAL;
  END_ENTITY;
```

Entity Name: **POINT_ON_CURVE**

Entity Number: **GEO-12**

A point located in the parametric space of a curve.

Primary Key Attributes

POINT_ON_CURVE_ID

Other Attributes

CURVE_ID (FK)

POINT_PARAMETER
The parametric value of the point.

Business Rules

EXPRESS Specification

```
    ENTITY point_on_curve_coordinate
      SUBTYPE OF (point);
      basis_curve     : curve;
      point_parameter : REAL;
    END_ENTITY;
```

Entity Name: **POINT_ON_SURFCAE**

Entity Number: **GEO-13**

A point located in the parametric space of a surface.

Primary Key Attributes

POINT_ON_SURFACE_ID

Other Attributes

SURFACE_ID (FK)

POINT PARAMETER_1
The first parameter value of the point location.

POINT_PARAMETER_2
The second parameter value of the point location.

Business Rules

EXPRESS Specification

```
    ENTITY point_on_surface
      SUBTYPE OF (point);
      basis_surface     : surface;
      point_parameter_1 : REAL;
      point_parameter_2 : REAL;
    END_ENTITY;
```

Entity Name: **DIRECTION**

Entity Number: **GEO-14**

A geometric direction.

Primary Key Attributes

DIRECTION ID

Other Attributes

DIRECTION_TYPE (discriminator)

X

The direction ratio with respect to the X axis.

Y

The direction ratio with respect to the Y axis.

Business Rules

EXPRESS Specification

```
ENTITY direction
  SUPERTYPE OF (two_space_direction XOR three_space_direction)
  SUBTYPE OF (vector);
END_ENTITY;
```

Entity Name: TWO_SPACE_DIRECTION

Entity Number: GEO-15

A direction vector in Euclidean two space.

Primary Key Attributes

TWO_SPACE_DIRECTION_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY two_space_direction
  SUBTYPE OF (direction);
  x : REAL;
  y : REAL;
```

```
    END_ENTITY;
```

Entity Name: **THREE_SPACE_DIRECTION**

Entity Number: **GEO-16**

A direction vector in Euclidean three space.

Primary Key Attributes

THREE_SPACE_DIRECTION_ID

Other Attributes

Z
    The direction ratio with respect to the Z axis.

Business Rules

EXPRESS Specification

```
    ENTITY three_space_direction
      SUBTYPE OF (direction);
      x : REAL;
      y : REAL;
      z : REAL;
    END_ENTITY;
```

Entity Name: **VECTOR_WITH_MAGNITUDE**

Entity Number: **GEO-17**

A direction vector and the magnitude of the vector.

Primary Key Attributes

VECTOR_WITH_MAGNITUDE_ID

Other Attributes

DIRECTION ID (FK)
    The orientation.

MAGNITUDE
    Real value which is the magnitude of the vector.

Business Rules

EXPRESS Specification

```
ENTITY vector_with_magnitude
  SUBTYPE OF (vector);
  orientation : direction;
  magnitude   : REAL;
END_ENTITY;
```

Entity Name: AXIS1_PLACEMENT

Entity Number: GEO-18

An axisymmetric local coordinate system.

Primary Key Attributes

AXIS1_PLACEMENT_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY axis1_placement
  SUBTYPE OF (axis_placement);
  location : point;
  axis     : OPTIONAL direction;
END_ENTITY;
```

Entity Name: AXIS2_PLACEMENT

Entity Number: GEO-19

A complete local, cartesian coordinate system.

Primary Key Attributes

AXIS2_PLACEMENT_ID

Other Attributes

REF_DIRECTION_ID (FK)
The approximate direction of the local X axis.

Business Rules

EXPRESS Specification

```
ENTITY axis2_placement
  SUBTYPE OF (axis_placement);
  location      : point;
  axis          : OPTIONAL direction;
  ref_direction : OPTIONAL direction;
END_ENTITY;
```

Entity Name: LINE

Entity Number: GEO-20

An unbounded straight line. The positive direction of the line is in the positive direction of its direction vector.

Primary Key Attributes

LINE_ID

Other Attributes

CARTESIAN_POINT_ID (FK)
Location of the line.

DIRECTION_ID (FK)
The direction of the line.

Business Rules

EXPRESS Specification

```
ENTITY line
  SUBTYPE OF (curve);
  pnt : point;
  dir : direction;
END_ENTITY;
```

Entity Name: CONIC

Entity Number: GEO-21

A conical curve. Namely a circle, ellipse, hyperbola, or parabola.

Primary Key Attributes

CONIC_ID

Other Attributes

CONIC_TYPE (discriminator)

AXIS2_PLACEMENT_ID (FK)
The location and orientation of the conic.

Business Rules

EXPRESS Specification

```
ENTITY conic
  SUPERTYPE OF (circle XOR ellipse XOR hyperbola XOR parabola);
  SUBTYPE OF (curve);
END_ENTITY;
```

Entity Name: BOUNDED_CURVE

Entity Number: GEO-22

A class of curves with finite length. The length may be finite naturally (as a circle) or finite due to trimming.

Primary Key Attributes

BOUNDED CURVE_ID

Other Attributes

BOUNDED_CURVE_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
    ENTITY bounded_curve
      SUPERTYPE OF (line_segment XOR bezier_curve XOR b_spline_curve XOR
                    trimmed_curve XOR composite_curve);
      SUBTYPE OF (curve);
    END_ENTITY;
```

Entity Name: **CURVE_ON_SURFACE**

Entity Number: **GEO-23**

The class of curves whose members are restricted to being contained in a specified surface.

Primary Key Attributes

CURVE_ON_SURFACE_ID

Other Attributes

CURVE_ON_SURFACE_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
    ENTITY curve_on_surface
      SUPERTYPE OF (pcurve XOR surface_curve XOR intersection_curve
                    XOR composite_curve_on_surface);
      SUBTYPE OF (curve);
    END_ENTITY;
```

Entity Name: **OFF_SET**

Entity Number: **GEO-24**

A curve a constant distance from a basis curve.

Primary Key Attributes

OFFSET_CURVE_ID

Other Attributes

CURVE ID (FK)
The curve that is being offset.

DISTANCE
The distance of the offset from the basis curve.

SELF_INTERSECTION
Three value flag to indicate whether curve self intersects:

TRUE
Curve does self intersect.

FALSE
Curve does not self intersect.

UNDEFINED
Whether curve self intersects or not is unknown.

OFFSET_CURVE_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
ENTITY offset_curve
  SUPERTYPE OF (d2_offset_curve XOR d3_offset_curve)
  SUBTYPE OF (curve);
END_ENTITY;
```

Entity Name: **CIRCLE**

Entity Number: **GEO-25**

A complete circle.

Primary Key Attributes

CIRCLE_ID

Other Attributes

RADIUS
Real number value which is the radius of the circle.

Business Rules

EXPRESS Specification

```
ENTITY circle;
  SUBTYPE OF (conic);
  radius   : REAL:
  position : axis2_placement;
END_ENTITY;
```

Entity Name: **ELLIPSE**

Entity Number: **GEO-26**

A complete ellipse.

Primary Key Attributes

ELLIPSE_ID

Other Attributes

SEMI_AXIS_1
    Real number value which is the major radius.

SEMI_AXIS_2
    Real number value which is the minor radius.

Business Rules

EXPRESS Specification

```
ENTITY ellipse;
  SUBTYPE OF (conic);
  semi_axis_1 : REAL;
  semi_axis_2 : REAL;
  position : axis2_placement;
END_ENTITY;
```

Entity Name: **HYPERBOLA**

Entity Number: **GEO-27**

An unbounded hyperbola.

Primary Key Attributes

HYPERBOLA_ID

Other Attributes

SEMI_AXIS
Real number value which is the length of the "major radius" of the hyperbola.

SEMI_IMAG_AXIS
Real number value which is the length of the "minor radius".

Business Rules

EXPRESS Specification

```
ENTITY hyperbola;
  SUBTYPE OF (conic);
  semi_axis      : REAL;
  semi_imag_axis : REAL;
  position       : axis2_placement;
END_ENTITY;
```

Entity Name: **PARABOLA**

Entity Number: **GEO-28**

An unbounded parabola.

Primary Key Attributes

PARABOLA_ID

Other Attributes

FOCAL_DIST
Real number value which is the distance of the focal point from the vertex point.

Business Rules

EXPRESS Specification

```
ENTITY parabola;
  SUBTYPE OF (conic);
```

```
    focal_dist       : REAL;
    position         : axis2_placement;
  END_ENTITY;
```

Entity Name: **LINE_SEGMENT**

Entity Number: **GEO-29**

A straight line segment. This entity is included for efficiency. Alternately a TRIMMED_CURVE/GEO-32 trimming a LINE/GEO-20 could be used.

Primary Key Attributes

LINE_SEGMENT_ID

Other Attributes

FIRST_POINT_ID (FK) The starting location of the line segment.

SECOND_POINT_ID (FK) The ending location of the line segment.

Business Rules

EXPRESS Specification

```
  ENTITY line_segment
    SUBTYPE OF (bounded_curve);
    first_point      : cartesian_point;
    last_point       : cartesian_point;
  END_ENTITY;
```

Entity Name: **BEZIER_CURVE**

Entity Number: **GEO-30**

A Bezier curve. It should be noted that every Bezier curve has an equivalent representation as a B-spline curve, but not every B-spline curve can be represented as a single Bezier curve.

Primary Key Attributes

BEZIER_CURVE_ID

Other Attributes

RATIONAL
Logical value which indicates whether the curve is rational (TRUE) or simple polynomial (FALSE).

UNIFORM
Logical value which indicates whether the knot set is uniform (TRUE) or not uniform (FALSE).

DEGREE
Integer value which is the algebraic degree of the basis functions.

FORM_NUMBER
Symbol used to identify particular type of curve.

SELF_INTERSECTION
Three value flag to indicate whether curve self intersects:

TRUE
Curve does self intersect.

FALSE
Curve does not self intersect.

UNDEFINED
Whether curve self intersects or not is unknown.

Business Rules

EXPRESS Specification

```
ENTITY bezier_curve
  SUBTYPE OF (bounded_curve);
  rational        : LOGICAL;
  degree          : INTEGER;
  control_points  : ARRAY [0:k] OF cartesian_point;
  weights         : OPTIONAL ARRAY {0:k} OF REAL;
  form_number     : OPTIONAL bspline_curve_form;
  self_intersect  : true_false_or_undefined;
END_ENTITY;
```

Entity Name: B_SPLINE_CURVE

Entity Number: GEO-31

A b-spline curve. The b-spline may be either rational or not rational.

Primary Key Attributes

B_SPLINE_CURVE_ID

Other Attributes

RATIONAL
: Logical value which indicates whether the curve is rational (TRUE) or simple polynomial (FALSE).

UNIFORM
: Logical value which indicates whether the knot set is uniform (TRUE) or not uniform (FALSE).

DEGREE
: Integer value which is the algebraic degree of the basis functions.

FORM_NUMBER
: Enumeration selection used to identify the particular type of curve.

SELF INTERSECTION
: Three value flag to indicate whether curve self intersects:

  TRUE
  : Curve does self intersect.

  FALSE
  : Curve does not self intersect.

  UNDEFINED
  : Whether curve self intersects or not is unknown.

Business Rules

EXPRESS Specification

```
ENTITY b_spline_curve
  SUBTYPE OF (bounded_curve);
  rational        : LOGICAL;
  uniform         : LOGICAL;
  degree          : INTEGER;
  control_points  : ARRAY [0:#] OF cartesian_point;
  weights         : OPTIONAL ARRAY {0:#} OF REAL;
  form_number     : OPTIONAL bspline_curve_form;
  self_intersect  : true_false_or_undefined;
END_ENTITY;
```

Entity Name: **TRIMMED_CURVE**

Entity Number: **GEO-32**

A portion of a curve.

Primary Key Attributes

TRIMMED_CURVE_ID

Other Attributes

TRIMMED_CURVE_TYPE (discriminator)

CURVE_ID (FK)
Curve being trimmed.

SENSE
Logical value which indicates whether the curve is being traversed in the direction of increasing parametric value (TRUE) or decreasing parametric value (FALSE).

Business Rules

EXPRESS Specification

```
ENTITY trimmed_curve
  SUBTYPE OF (bounded_curve);
  basis_curve     : curve;
  parameter_1     : OPTIONAL REAL;
  parameter_2     : OPTIONAL REAL;
  point_1         : OPTIONAL cartesian_point;
  point_2         : OPTIONAL cartesian_point;
  sense           : LOGICAL;
END_ENTITY;
```

Entity Name: **COMPOSITE_CURVE**

Entity Number: **GEO-33**

A collection of curves joined end to end.

Primary Key Attributes

COMPOSITE_CURVE_ID

Other Attributes

CLOSED CURVE
Logical value which indicates whether the curve is closed (TRUE) or open (FALSE).

SELF_INTERSECTION
Three value flag to indicate whether curve self intersects:

TRUE
Curve does self intersect.

FALSE
Curve does not self intersect.

UNDEFINED
Whether curve self intersects or not is unknown.

Business Rules

EXPRESS Specification

```
ENTITY composite_curve
  SUBTYPE OF (bounded_curve);
  closed_curve    : LOGICAL;
  segments        : LIST [1:#] OF bounded_curve;
  senses          : ARRAY [1:#] OF LOGICAL:
  transitions     : ARRAY [1:#] OF curve_transition_code;
  param_range     : OPTIONAL ARRAY [1:#] OF REAL;
END_ENTITY;
```

Entity Name: **CONTROL_POINT_BEZIER**

Entity Number: **GEO-34**

A control point a BEZIER_CURVE/GEO-30.

Primary Key Attributes

BEZIER_CURVE_ID (FK)

CONTROL_POINT_BEZIER_ID

Other Attributes

CARTESIAN_POINT_ID (FK)

WEIGHTS
Real number value of weight associated with this control point.

Business Rules

EXPRESS Specification

See attribute "control_points" in EXPRESS for BEZIER_CURVE/GEO-30.

Entity Name: **CONTROL_POINT_ORDER_BEZIER**

Entity Number: **GEO-35**

IDEF1X defaults to unordered sets. This entity makes CONTROL_POINT_BEZIER/GEO-34 an ordered list.

Primary Key Attributes

BEZIER_CURVE_ID (FK)

PREDECESSOR.CONTROL_POINT_BEZIER (FK)

SUCCESSOR.CONTROL_POINT_BEZIER (FK)

Other Attributes

None

Business Rules

EXPRESS Specification

See attribute "control_points" in EXPRESS for BEZIER_CURVE/GEO-30.

Entity Name: **KNOT**

Entity Number: **GEO-36**

A knot for a B_SPLINE_CURVE/GEO-31.

Primary Key Attributes

B_SPLINE_CURVE_ID (FK)

KNOT_ID

Other Attributes

MULTIPLICITY
Integer value of multiplicity of this knot.

KNOT_VALUE
Real number value of this knot which is one of a set of knots used to define the B-spline basis function.

Business Rules

EXPRESS Specification

See attributes "knots" and "knot_multiplicities" in the EXPRESS for B_SPLINE_CURVE/GEO-31.

Entity Name: **CONTROL_POINT**

Entity Number: **GEO-37**

A control point for a B_SPLINE_CURVE/GEO-31.

Primary Key Attributes

B SPLINE_CURVE_ID (FK)

CONTROL_POINT_ID

Other Attributes

CARTESIAN_POINT_ID (FK)

WEIGHTS
Real number value of weight associated with this control point.

Business Rules

EXPRESS Specification

See attributes "control_points" and "weights" in the EXPRESS for B_SPLINE_CURVE/GEO-31.

Entity Name: **CONTROL_POINT_ORDER**

Entity Number: **GEO-38**

IDEF1X defaults to unordered sets. This entity makes CONTROL_POINT/GEO-37 an ordered list.

Primary Key Attributes

B_SPLINE_CURVE_ID (FK)

PREDECESSOR.CONTROL_POINT_ID (FK)

SUCCESSOR.CONTROL_POINT_ID (FK)

Other Attributes

None

Business Rules

EXPRESS Specification

See attributes "control points" and "weights" in the EXPRESS for B_SPLINE CURVE/GEO-31.

Entity Name: **POINT_POINT_TRIMMED_CURVE**

Entity Number: **GEO-39**

A curve trimmed with two cartesian points.

Primary Key Attributes

TRIMMED CURVE_ID (FK)

Other Attributes

POINT_1.CARTESIAN_POINT_ID (FK)

POINT_2.CARTESIAN_POINT_ID (FK)

Business Rules

EXPRESS Specification

See the EXPRESS for TRIMMED_CURVE/GEO-32.

Entity Name: **POINT_PARAM_TRIMMED_CURVE**

Entity Number: **GEO-40**

A curve trimmed with one cartesian point and one parametric point.

Primary Key Attributes

TRIMMED_CURVE_ID (FK)

Other Attributes

CARTESIAN POINT_ID (FK)
First trimming point.

PARAMETER_2
Real number value which is the second trimming point in the parametric space of the basis curve.

Business Rules

EXPRESS Specification

See the EXPRESS for TRIMMED_CURVE/GEO-32.

Entity Name: **PARAM_POINT_TRIMMED_CURVE**

Entity Number: **GEO-41**

A curve trimmed with one cartesian point and one parametric point.

Primary Key Attributes

TRIMMED_CURVE_ID (FK)

Other Attributes

PARAMETER_1
Real number value which is the first trimming point in the parametric space of the basis curve.

CARTESIAN_POINT_ID (FK)
Second trimming point.

Business Rules

EXPRESS Specification

See the EXPRESS for TRIMMED_CURVE/GEO-32.

Entity Name: **PARAM_PARAM_TRIMMED_CURVE**

Entity Number: **GEO-42**

A curve trimmed with two parametric values.

Primary Key Attributes

PARAMETER_1
: Real number value which is the first trimming point in the parametric space of the basis curve.

PARAMETER_2
: Real number value which is the second trimming point in the parametric space of the basis curve.

Other Attributes

None

Business Rules

EXPRESS Specification

See the EXPRESS for TRIMMED_CURVE/GEO-32.

Entity Name: **KNOT_ORDER**

Entity Number: **GEO-43**

IDEF1X defaults to unordered sets. This entity makes KNOT/GEO-36 an ordered list.

Primary Key Attributes

B SPLINE_CURVE_ID (FK)

PREDECESSOR.KNOT_ID (FK)

SUCCESSOR.KNOT_ID (FK)

Other Attributes

None

Business Rules

EXPRESS Specification

See attributes "control_points" and "weights" in the EXPRESS for B_SPLINE_CURVE/GEO-31.

Entity Name: **SEGMENT**

Entity Number: **GEO-44**

A component curve of a COMPOSITE_CURVE/GEO-33.

Primary Key Attributes

COMPOSITE_CURVE_ID (FK)

SEGMENT_ID

Other Attributes

BOUNDED_CURVE_ID (FK)
A component curve.

SENSE
Logical value which indicates whether the sense of component curve agrees or differs from the sense of the composite curve.

Business Rules

EXPRESS Specification

See attribute "segments" in EXPRESS for COMPOSITE_CURVE/GEO-33.

Entity Name: **SEGMENT_ORDER**

Entity Number: **GEO-45**

IDEF1X defaults to unordered sets. This entity makes SEGMENT/GEO-44 an ordered list.

Primary Key Attributes

COMPOSITE_CURVE_ID (FK)

PREDECESSOR.SEGMENT_ID (FK)

SUCCESSOR.SEGMENT_ID (FK)

Other Attributes

TRANSITION
Enumeration selection for form of transition between predecessor and successor.

PARAM RANGE
Real number value which is the composite curve parameter value at this join.

Business Rules

EXPRESS Specification

See attribute "segments"in EXPRESS for COMPOSITE_CURVE/GEO-33.

Entity Name: PCURVE

Entity Number: GEO-46

A curve defined in the parametric space of a surface.

Primary Key Attributes

PCURVE_ID

Other Attributes

SURFACE ID (FK)
The surface on which the curve lies.

CURVE_ID (FK)
A 2D curve.

Business Rules

EXPRESS Specification

```
    ENTITY pcurve
      SUBTYPE OF (curve_on_surface);
      basis_surface : surface;
      basis_curve   : curve;
    END_ENTITY;
```

Entity Name: SURFACE_CURVE

Entity Number: GEO-47

A bounded curve on a surface.

Primary Key Attributes

SURFACE_CURVE_ID

Other Attributes

CURVE ID (FK)
The curve which is the three dimensional image of the surface curve.

SURFACE_ID (FK)
The surface on which the curve lies.

MASTER
Enumeration selection for representation "preferred" by sending system.

Business Rules

EXPRESS Specification

```
ENTITY surface_curve
  SUBTYPE OF (curve_on_surface);
  surface_1  : surface;
  curve_1    : curve;
  pcurve_s1  : OPTIONAL pcurve;
  master     : OPTIONAL enumeration_curve1_pcurve1;
END_ENTITY;
```

Entity Name: SURFACE_CURVE_PCURVE

Entity Number: GEO-48

Captures information that a SURFACE_CURVE/GEO-47 may optionally have an associated PCURVE/GEO-46. An associated PCURVE/GEO-46 is the two dimensional parametric image of the SURFACE_CURVE/GEO-47.

Primary Key Attributes

SURFACE CURVE_ID (FK)

Other Attributes

PCURVE_ID (FK)
The curve which is the two dimensional image of the surface curve.

Business Rules

EXPRESS Specification

See attribute "pcurve_s1" in EXPRESS for SURFACE_CURVE/GEO-47.

Entity Name: INTERSECTION_CURVE

Entity Number: GEO-49

An intersection curve is defined by intersecting two surfaces. The multiple representation permits the receiving system to recompute the intersection curve if it has the capability.

Primary Key Attributes

INTERSECTION_CURVE_ID

Other Attributes

CURVE_ID (FK)

MASTER_REPRESENTATION
Enumeration selection for representation "preferred" by sending system.

SELF_INTERSECTION
Three value flag to indicate whether curve self intersects:

TRUE
Curve does self intersect.

FALSE
Curve does not self intersect.

UNDEFINED
Whether curve self intersects or not is unknown.

Business Rules

EXPRESS Specification

```
ENTITY intersection_curve
  SUBTYPE OF (curve_on_surface);
  pcurve_s1             : OPTIONAL pcurve;
  surface_s1            : OPTIONAL surface;
  pcurve_s2             : OPTIONAL pcurve;
  surface_s2            : OPTIONAL surface;
  basis_curve           : curve;
  master_representation : OPTIONAL intersection_enumeration;
  self_intersection     : true_false_or_undefined;
END_ENTITY;
```

Entity Name: **COMPOSITE_CURVE_ON_SURFACE**

Entity Number: **GEO-50**

An assembly of curves on a surface.

Primary Key Attributes

COMPOSITE_CURVE_ON_SURFACE_ID

Other Attributes

SURFACE_ID (FK)

CLOSED_CURVE
Logical value which indicates whether the curve is closed (TRUE) or open (FALSE).

SELF_INTERSECTION
Three value flag to indicate whether curve self intersects:

TRUE
Curve does self intersect.

FALSE
Curve does not self intersect.

UNDEFINED
Whether curve self intersects or not is unknown.

Business Rules

EXPRESS Specification

```
ENTITY composite_curve_on_surface
  SUBTYPE OF (curve_on_surface);
  basis_surface  : surface;
  closed_curve   : LOGICAL;
  segments       : LIST [1:#] OF curve_on_surface;
  senses         : ARRAY [1:#] OF LOGICAL;
  transitions    : ARRAY [1:#] OF curve_transition_code;
END_ENTITY;
```

Entity Name: **PCURVE_PCURVE_INTERSECTION**

Entity Number: **GEO-51**

One of three definition choices of the INTERSECTION_CURVE/GEO-49. In this choice the intersection curve is defined with two PCURVE/GEO-46.

Primary Key Attributes

INTERSECTION_CURVE_ID (FK)

Other Attributes

PCURVE_S1.PCURVE_ID (FK)
The intersection curve of the two surfaces defined in the parametric space of the first surface.

PCURVE_S2.PCURVE_ID (FK)
The intersection curve of the two surfaces defined in the parametric space of the second surface.

Business Rules

EXPRESS Specification

See EXPRESS for INTERSECTION_CURVE/GEO-49. This IDEF1X entity represents one valid set of options.

Entity Name: **PCURVE_SURFACE_INTERSECTION**

Entity Number: **GEO-52**

One of three definition choices of the INTERSECTION_CURVE/GEO-49. In this choice the intersection curve is defined with one PCURVE/GEO-46 and one SURFACE/GEO-7.

Primary Key Attributes

INTERSECTION_CURVE_ID (FK)

Other Attributes

PCURVE_ID (FK)
The intersection curve of the two surfaces defined in the parametric space of the first surface.

SURFACE_ID (FK)
The second surface of the intersection.

Business Rules

EXPRESS Specification

See EXPRESS for INTERSECTION_CURVE/GEO-49. This IDEF1X entity represents one valid set of options

Entity Name: SURFACE_SURFACE_INTERSECTION

Entity Number: GEO-53

One of three definition choices of the INTERSECTION_CURVE/GEO-49. In this choice the intersection curve is defined with two SURFACE/GEO-7.

Primary Key Attributes

INTERSECTION_CURVE_ID (FK)

Other Attributes

SURFACE S1.SURFACE ID (FK)
The first surface of the intersection.

SURFACE_S2.SURFACE ID (FK)
The second surface of the intersection.

Business Rules

EXPRESS Specification

See EXPRESS for INTERSECTION_CURVE/GEO-49. This IDEF1X entity represents one valid set of options.

Entity Name: ON_SURFACE_SEGMENT

Entity Number: GEO-54

The use of a CURVE_ON_SURFACE/GEO-23 as a component curve of a COMPOSITE_CURVE_ON_SURFACE/GEO-50.

Primary Key Attributes

COMPOSITE_CURVE_ON_SURFACE_ID (FK)

ON SURFACE_SEGMENT_ID

Other Attributes

CURVE_ON_SURFACE_ID (FK)
A component curve.

SENSE
Logical value which indicates whether the sense of this component curve agrees (TRUE) with the composite curve or not (FALSE).

Business Rules

EXPRESS Specification

See attribute "segments" in EXPRESS for COMPOSITE_CURVE_ON_SURFACE/GEO-50.

Entity Name: **ON_SURFACE_SEGMENT_ORDER**

Entity Number: **GEO-55**

IDEF1X defaults to unordered sets. This entity makes ON_SURFACE_SEGMENT/GEO-54 an ordered list.

Primary Key Attributes

COMPOSITE_CURVE_ON_SURFACE_ID (FK)

PREDECESSOR.ON_SURFACE_SEGMENT_ID (FK)

SUCCESSOR.ON_SURFACE_SEGMENT_ID (FK)

Other Attributes

TRANSITION
Enumeration selection for the transition code between predecessor curve and successor curve. This applies to the 3-D representations of curves, not to pcurves.

Business Rules

EXPRESS Specification

See attribute "segments" in EXPRESS for COMPOSITE_CURVE_ON_SURFACE/GEO-50.

Entity Name: **TWO_D_OFFSET_CURVE**

Entity Number: **GEO-56**

This defines a simple plane-offset curve by offsetting by DISTANCE along the normal to BASIS_CURVE in the plane of BASIS_CURVE.

Primary Key Attributes

2D_OFFSET_CURVE_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY d2_offset_curve
  SUBTYPE OF (offset_curve);
  basis_curve    : curve;
  distance       : REAL;
  self_intersect : true_false_or_undefined;
END_ENTITY;
```

Entity Name: **THREE_D_OFFSET_CURVE**

Entity Number: **GEO-57**

A curve generated as an offset from another curve in three space.

Primary Key Attributes

3D_OFFSET_CURVE_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY d3_offset_curve
  SUBTYPE OF (offset_curve);
  basis_curve    : curve;
  distance       : REAL;
  self_intersect : true_false_or_undefined;
  ref_direction  : direction;
END_ENTITY;
```

Entity Name: **ELEMENTARY_SURFACE**

Entity Number: **GEO-58**

The class of elementary surfaces. Namely plane, cylinder, cone, sphere and torus.

Primary Key Attributes

ELEMENTAL_SURFACE_ID

Other Attributes

ELEMENTAL_SURFACE_TYPE (discriminator)

AXIS2_PLACEMENT_ID (FK)
Location and orientation of the surface.

Business Rules

EXPRESS Specification

```
ENTITY elementary_surface
  SUPERTYPE OF (plane XOR
                cylindrical_surface XOR
                conical_surface XOR
                spherical_surface XOR
                toroidal_surface)
  SUBTYPE OF (surface);
END_ENTITY;
```

Entity Name: BEZIER_SURFACE

Entity Number: GEO-59

A Bezier surface.

Primary Key Attributes

BEZIER_SURFACE_ID

Other Attributes

U_RATIONAL
Logical value which indicates whether the surface is rational (TRUE) or simple polynomial (FALSE) in first (u) parametric direction.

V_RATIONAL
Logical value which indicates whether the surface is rational (TRUE) or simple polynomial (FALSE) in second (v) parametric direction.

U_UNIFORM
: Logical value which indicates whether the knot set is uniform (TRUE) or not uniform (FALSE) in "u".

V_UNIFORM
: Logical value which indicates whether the knot set is uniform (TRUE) or not uniform (FALSE) in "v".

U_DEGREE
: Integer value which is the algebraic degree of the basis functions in "u".

V_DEGREE
: Integer value which is the algebraic degree of the basis functions in "v".

FORM_NUMBER
: Enumeration selection used to identify the particular type of surface.

Business Rules

EXPRESS Specification

```
ENTITY bezier_surface
  SUBTYPE OF (bounded_surface);
  u_rational     : LOGICAL;
  v_rational     : LOGICAL;
  u_uniform      : LOGICAL;
  v_uniform      : LOGICAL;
  u_degree       : INTEGER;
  v_degree       : INTEGER;
  u_upper        : INTEGER;
  v_upper        : INTEGER;
  control_points : ARRAY [0:u_upper] OF
                   ARRAY [0:v_upper] OF cartesian_point;
  weights        : OPTIONAL ARRAY [0:u_upper] OF
                            ARRAY [0:v_upper] OF REAL;
  form_number    : OPTIONAL bspline_surface_form;
END_ENTITY;
```

Entity Name: B_SPLINE_SURFACE

Entity Number: GEO-60

A b-spline surface.

Primary Key Attributes

B_SPLINE_SURFACE_ID

Other Attributes

U_RATIONAL
: Logical value which indicates whether the surface is rational (TRUE) or simple polynomial (FALSE) in first (u) parametric direction.

V_RATIONAL
: Logical value which indicates whether the surface is rational (TRUE) or simple polynomial (FALSE) in second (v) parametric direction.

U_UNIFORM
: Logical value which indicates whether the knot set is uniform (TRUE) or not uniform (FALSE) in "u".

V_UNIFORM
: Logical value which indicates whether the knot set is uniform (TRUE) or not uniform (FALSE) in "v".

U_DEGREE
: Integer value which is the algebraic degree of the basis functions in "u".

V_DEGREE
: Integer value which is the algebraic degree of the basis functions in "v".

FORM NUMBER
: Enumeration selection used to identify the particular type of surface.

Business Rules

EXPRESS Specification

```
ENTITY b_spline_surface
  SUBTYPE OF (bounded_surface);
  u_rational        : LOGICAL;
  v_rational        : LOGICAL;
  u_uniform         : LOGICAL;
  v_uniform         : LOGICAL;
  u_degree          : INTEGER;
  v_degree          : INTEGER;
  u_upper           : INTEGER;
  v_upper           : INTEGER;
  control_points    : ARRAY [0:u_upper] OF
```

```
                          ARRAY [0:v_upper] OF cartesian_point;
    u_multiplicities : ARRAY [1:knot_u] OF INTEGER:
    u_knots          : ARRAY [1:knot_u] OF REAL:
    v_multiplicities : ARRAY [1:knot_v] OF INTEGER:
    v_knots          : ARRAY [1:knot_v] OF REAL:
    weights          : OPTIONAL ARRAY [0:u_upper] OF
                                ARRAY [0:v_upper] OF REAL;
    form_number      : OPTIONAL bspline_surface_form;
  DERIVE
    knot_u : INTEGER := u_degree + u_upper + 2;
    knot_v : INTEGER := v_degree + v_upper + 2;
  END_ENTITY;
```

Entity Name: **SWEPT_SURFACE**

Entity Number: **GEO-61**

A surface that is constructed by sweeping a curve by another curve.

Primary Key Attributes

SWEPT_SURFACE_ID

Other Attributes

CURVE_ID (FK)

DIRECTION_ID (FK)

SWEPT_SURFACE_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
  ENTITY swept_surface
    SUPERTYPE OF (surface_of_revolution XOR
                  surface_of_linear_extrusion)
    SUBTYPE OF (surface);
  END_ENTITY;
```

Entity Name: **RECTANGULAR_TRIMMED_SURFACE**

Entity Number: **GEO-62**

A simple bounded surface in which the boundaries are constant parametric lines.

Primary Key Attributes

RECTANGULAR_TRIMMED_SURFACE_ID

Other Attributes

SURFACE_ID (FK)
: Surface to be trimmed.

UMIN
: Real number value of first "u" parametric value.

UMAX
: Real number value of second "u" parametric value.

VMIN
: Real number value of first "v" parametric value.

VMAX
: Real number value of second "v" parametric value.

Business Rules

EXPRESS Specification

```
ENTITY rectangular_trimmed_surface
  SUBTYPE OF (bounded_surface);
  basis_surface : EXTERNAL surface;
  umin          : REAL;
  vmin          : REAL;
  umax          : REAL;
  vmax          : REAL;
END_ENTITY;
```

Entity Name: BOUNDED_SURFACE

Entity Number: GEO-63

A class of surfaces with finite area. The area may be finite naturally (as a sphere) or finite due to trimming.

Primary Key Attributes

BOUNDED_SURFACE_ID

Other Attributes

BOUND_SURFACE_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
    ENTITY bounded_surface
      SUPERTYPE OF (b_spline_surface XOR
                    bezier_surface XOR
                    rectangular_trimmed_surface XOR
                    curve_bounded_surface)
      SUBTYPE OF (surface);
    END_ENTITY;
```

Entity Name: **OFFSET_SURFACE**

Entity Number: **GEO-64**

This is a procedural definition of a simple offset surface at a normal distance from the originating surface.

Primary Key Attributes

OFFSET_SURFACE_ID

Other Attributes

SURFACE_ID (FK)
The surface that is to be offset.

DISTANCE
Real value which is offset distance.

SELF_INTERSECTION
Three value flag to indicate whether curve self intersects:

TRUE
Curve does self intersect.

FALSE
Curve does not self intersect.

UNDEFINED
Whether curve self intersects or not is unknown.

Business Rules

EXPRESS Specification

```
ENTITY offset_surface
  SUBTYPE OF (surface);
  basis_surface  : surface;
  distance       : REAL;
  self_intersect : true_false_or_undefined;
END_ENTITY;
```

Entity Name: **RECTANGULAR_COMPOSITE_SURFACE**

Entity Number: **GEO-65**

This is a composite surface having a simple rectangular topology of patches. Each patch (component surface) must be a bound and topologically rectangular and therefore be either a RECTANGULAR_COMPOSITE_SURFACE_PATCH/GEO-79 and/or B_SPLINE_SURFACE/GEO-60.

Each patch is , if necessary, reparameterized from 0 to 1 and the resulting composite surface has a simple cumulative parameterization.

It is required that there is at least positional continuity between adjacent surfaces.

Primary Key Attributes

RECTANGULAR_COMPOSITE_SURFACE_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY rectangular_composite_surface
  SUBTYPE OF (surface);
  n_u      : INTEGER;
  n_v      : INTEGER;
  surfaces : ARRAY [1:n_u] OF
             ARRAY [1:n_v] OF surface;
  u_senses : ARRAY [1:n_u] OF
             ARRAY [1:n_v] OF LOGICAL;
  v_senses : ARRAY [1:n_u] OF
```

```
                ARRAY [1:n_v] OF LOGICAL;
    END_ENTITY;
```

Entity Name: **PLANE**

Entity Number: **GEO-66**

A unbounded planar surface.

Primary Key Attributes

PLANE_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
    ENTITY plane
      SUBTYPE OF (elementary_surface);
      position : axis2_placement;
    END_ENTITY;
```

Entity Name: **CYLINDRICAL_SURFACE**

Entity Number: **GEO-67**

An unbounded cylindrical surface.

Primary Key Attributes

CYLINDRICAL_SURFACE_ID

Other Attributes

RADIUS
    Real value which is the radius of the cylinder.

Business Rules

EXPRESS Specification

```
ENTITY cylindrical_surface
  SUBTYPE OF (elementary_surface);
  radius   : REAL;
  position : axis2_placement;
END_ENTITY;
```

Entity Name: CONICAL_SURFACE

Entity Number: GEO-68

An unbounded surface of a cone.

Primary Key Attributes

CONICAL_SURFACE_ID

Other Attributes

SEMI_ANGLE
: Real value which is the cone semi-angle in degrees.

RADIUS
: Real value which is the radius of the circular curve of intersection between the cone and a plane perpendicular to the axis of the cone passing through the location point.

Business Rules

EXPRESS Specification

```
ENTITY conical_surface
  SUBTYPE OF (elementary_surface);
  semi_angle : REAL;
  radius     : REAL;
  position   : axis2_placement;
END_ENTITY;
```

Entity Name: SPHERICAL_SURFACE

Entity Number: GEO-69

A complete spherical surface.

Primary Key Attributes

SPHERICAL_SURFACE_ID

Other Attributes

RADIUS

Business Rules

EXPRESS Specification

```
ENTITY spherical_surface
  SUBTYPE OF (elementary_surface);
  radius   : REAL;
  position : axis2_placement;
END_ENTITY;
```

Entity Name: TOROIDAL_SURFACE

Entity Number: GEO-70

The complete surface of a torus.

Primary Key Attributes

TOROIDAL_SURFACE_ID

Other Attributes

MAJOR_RADIUS
 Real value which is the major radius of the torus.

MINOR_RADIUS
 Real value which is the minor radius of the torus.

Business Rules

EXPRESS Specification

```
ENTITY toroidal_surface
  SUBTYPE OF (elementary_surface);
  major_radius : REAL;
  minor_radius : REAL;
```

```
    position      : axis2_placement;
  END_ENTITY;
```

Entity Name: **SURFACE_OF_LINEAR_EXTRUSION**

Entity Number: **GEO-71**

A simple swept surface or a generalized cylinder obtained by sweeping a curve in a given direction.

Primary Key Attributes

SURFACE_OF_LINEAR_EXTRUSION_ID

Other Attributes

DIRECTION_ID (FK)
The direction of extrusion.

CURVE_ID (FK)
The curve to be swept.

Business Rules

EXPRESS Specification

```
  ENTITY surface_of_linear_extrusion
    SUBTYPE OF (swept_surface);
    axis            : direction;
    extruded_curve  : curve;
  END_ENTITY;
```

Entity Name: **SURFACE_OF_REVOLUTION**

Entity Number: **GEO-72**

A surface obtained by rotating a curve a complete revolution about an axis.

Primary Key Attributes

SURFACE_OF_REVOLUTION_ID

Other Attributes

CARTESIAN_POINT_ID (FK)
: A point on the axis of revolution.

DIRECTION_ID (FK)
: The direction of the axis of revolution.

CURVE_ID (FK)
: The curve that is revolved about the axis.

Business Rules

EXPRESS Specification

```
ENTITY surface_of_revolution
  SUBTYPE OF (swept_surface);
  axis_point      : point;
  axis            : direction;
  revolved_curve  : curve;
END_ENTITY;
```

Entity Name: B_SPLINE_SURFACE_KNOT

Entity Number: GEO-73

A knot of a B-spline surface.

Primary Key Attributes

B_SPLINE_SURFACE_ID (FK)

B_SPLINE_SURFACE_KNOT_ID

Other Attributes

U_OR_V
: Enumeration selection which indicates whether this is for the first (u) parametric or second (v).

MULTIPLICITY
: Integer value of multiplicity of this knot.

KNOT_VALUE
: Real number value of this knot which is one of a set of knots used to define the B-spline basis function.

Business Rules

EXPRESS Specification

In the EXPRESS for B_SPLINE_SURFACE/GEO-60 see the following attributes:

- u_multiplicities
- u_knots
- v_multiplicities
- v_knots

Entity Name: **BS_SURFACE_KNOT_ORDER**

Entity Number: **GEO-74**

IDEF1X defaults to unordered sets. This entity makes BS_SURFACE_KNOT/GEO-73 a matrix.

Primary Key Attributes

B_SPLINE_SURFACE_KNOT_ID

PREDECESSOR.B_SPLINE_SURFACE_KNOT_ID (FK)

SUCCESSOR.B_SPLINE_SURFACE_KNOT_ID (FK)

Other Attributes

None

Business Rules

EXPRESS Specification

In the EXPRESS for B_SPLINE_SURFACE/GEO-60 see the following attributes:

- u_multiplicities
- u knots
- v_multiplicities
- v_knots

Entity Name: **BEZIER_SURFACE_CONTROL_POINT**

Entity Number: **GEO-77**

A control point for a BEZIER_SURFACE/GEO-59.

Primary Key Attributes

BEZIER_SURFACE_ID (FK)

BEZIER_SURFACE_CONTROL_POINT_ID

Other Attributes

CARTESIAN_POINT (FK)

WEIGHT
Real number value of weight associated with this control point.

Business Rules

EXPRESS Specification

In the EXPRESS for BEZIER_SURFACE/GEO-59 see attribute control_points.

Entity Name: BZ_SURFACE_CONTROL_POINT_ORDER

Entity Number: GEO-78

IDEF1X defaults to unordered sets. This entity makes BEZIER_SURFACE_CONTROL_POINT/GEO-77 a matrix.

Primary Key Attributes

BEZIER SURFACE_ID (FK)

PREDECESSOR.BEZIER_SURFACE_CONTROL_POINT_ID (FK)

SUCCESSOR.BEZIER_SURFACE_CONTROL_POINT_ID (FK)

U_OR_V
Enumeration selection of the parametric direction of the predecessor-successor relationship.

Other Attributes

None

Business Rules

EXPRESS Specification

In the EXPRESS for BEZIER_SURFACE/GEO-59 see attribute control_points.

Entity Name: **RECTANGULAR_COMPOSITE_SURFACE_PATCH**

Entity Number: **GEO-79**

The use of a RECTANGULAR_TRIMMED_SURFACE/GEO-62 by a RECTANGULAR_COMPOSITE_SURFACE/GEO-65.

Primary Key Attributes

RECTANGULAR_COMPOSITE_SURFACE_ID (FK)

RECTANGULAR_TRIMMED_SURFACE_ID (FK)

Other Attributes

U_SENSE
Logical value which indicates whether the sense of "u" parameterization in composite agrees with (TRUE) the original surface.

V SENSE Logical value which indicates whether the sense of "v" Logical value which indicates whether the sense of "v" parameterization in composite agrees with (TRUE) the original surface.

Business Rules

EXPRESS Specification

In the EXPRESS for RECTANGULAR_COMPOSITE_SURFACE/GEO-65, see the following attributes:

- surfaces
- u_senses
- v_senses

Entity Name: **RC_SURFACE_PATCH_ORDER**

Entity Number: **GEO-80**

IDEF1X defaults to unordered sets. This entity makes RECTANGULAR_COMPOSITE_SURFACE_PATCH/GEO-79 a matrix.

Primary Key Attributes

RECTANGULAR_COMPOSITE_SURFACE_ID (FK)

PREDECESSOR.RECTANGULAR_TRIMMED_SURFACE_ID (FK)

SUCCESSOR.RECTANGULAR_TRIMMED_SURFACE_ID (FK)

U_OR_V
Enumeration selection which indicates whether the predecessor-successor relation is in the "u" (U) or "v" (V) direction.

Other Attributes

None

Business Rules

EXPRESS Specification

In the EXPRESS for RECTANGULAR_COMPOSITE_SURFACE/GEO-65, see the following attributes:

- surfaces
- u_senses
- v_senses

Entity Name: BOUNDED_SURFACE_BOUNDARY

Entity Number: GEO-81

The use of a COMPOSITE_CURVE_ON_SURFACE/GEO-50 as part or all of the boundary of a CURVE_BOUNDED_SURFACE/GEO-110.

Primary Key Attributes

CURVE_BOUNDED_SURFACE_ID (FK)

COMPOSITE_CURVE_ON_SURFACE_ID (FK)

Other Attributes

None

Business Rules

EXPRESS Specification

In EXPRESS for CURVE_BOUNDED_SURFACE/GEO-110, see attribute "boundaries".

Entity Name: **CURVE_BOUNDED_SURFACE**

Entity Number: **GEO-110**

A surface trimmed with COMPOSITE CURVE ON_SURFACE/GEO-50 entities. If the outer boundary is omitted, the natural boundaries of the trimmed surface are assumed.

Primary Key Attributes

CURVE_BOUNDED_SURFACE_ID

Other Attributes

SURFACE_ID (FK)
The surface to be bound.

OUTER_PRESENT
Logical value to indicate whether the outer boundary is explicitly present (TRUE) or is defaulted to the natural boundary (FALSE).

Business Rules

EXPRESS Specification

```
ENTITY curve_bounded_surface
  SUBTYPE OF (bounded_surface);
  basis_surface : surface;
  boundaries    : SET [1:#] OF composite_curve_on_surface;
  outer_present : LOGICAL;
END_ENTITY;
```

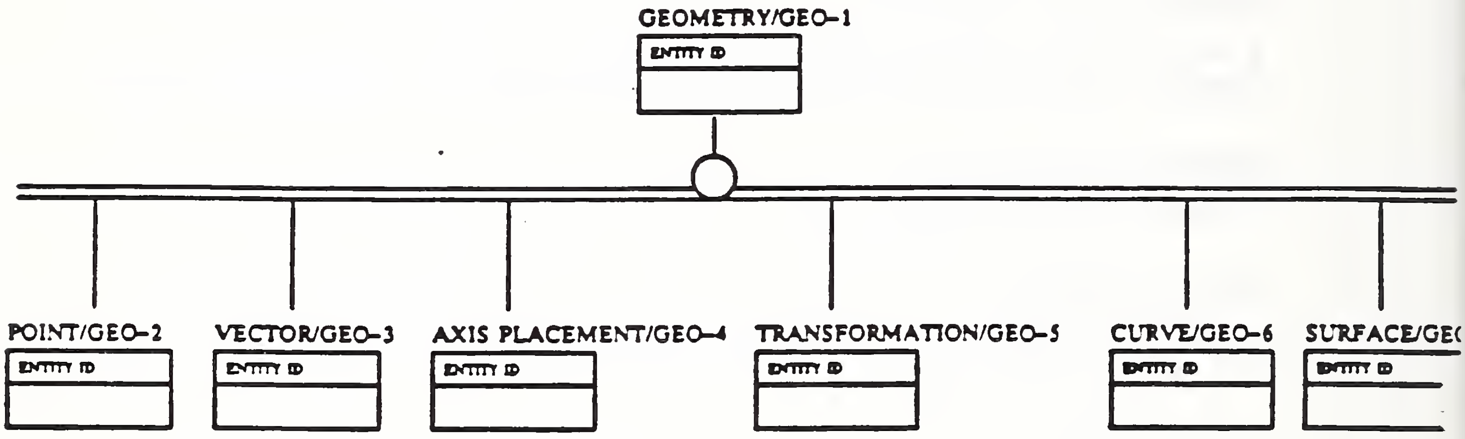


Figure D-1: SHAPE Entity/Relationship Diagram

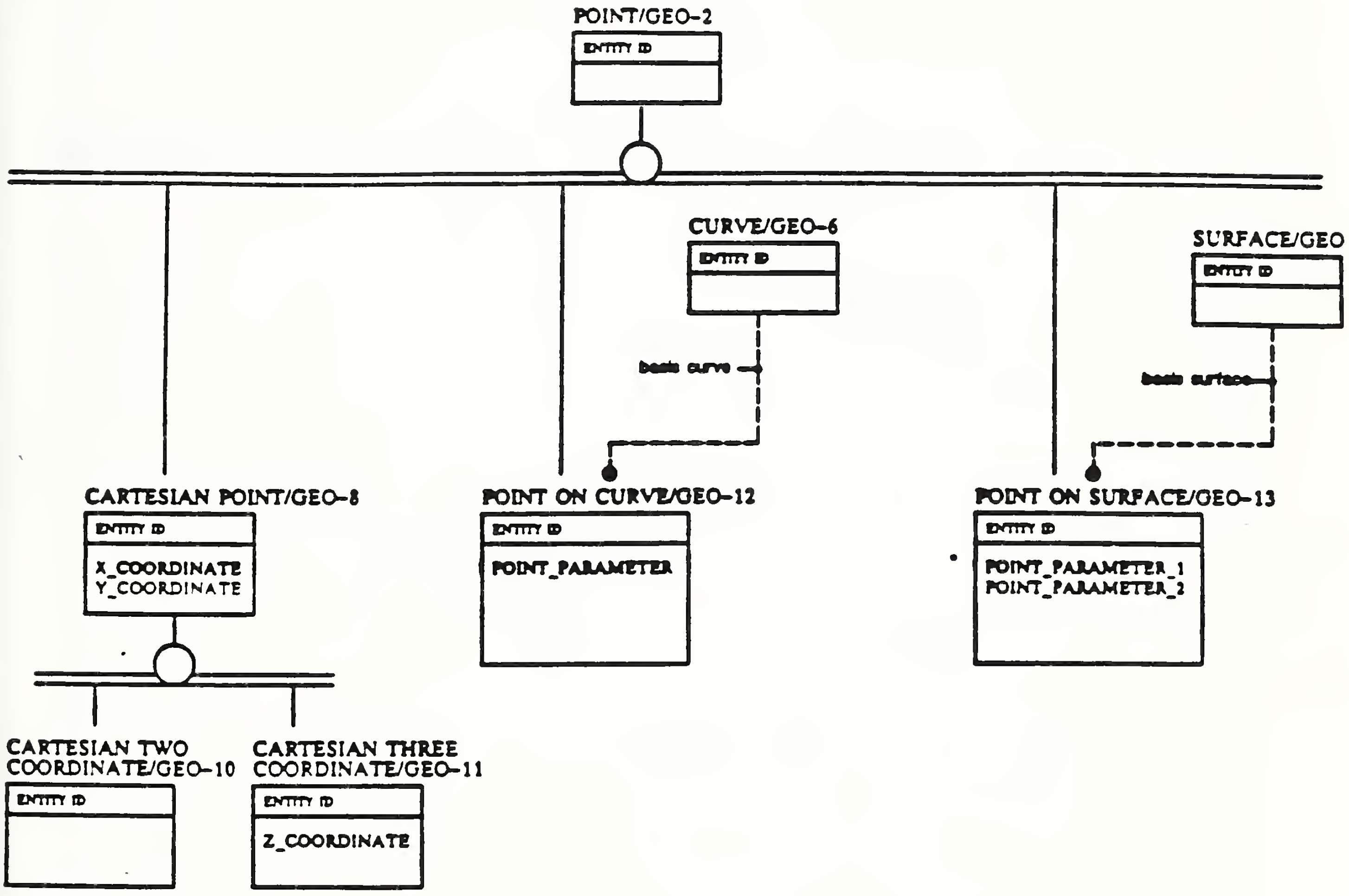


Figure D-2: SHAPE Entity/Relationship Diagram

]

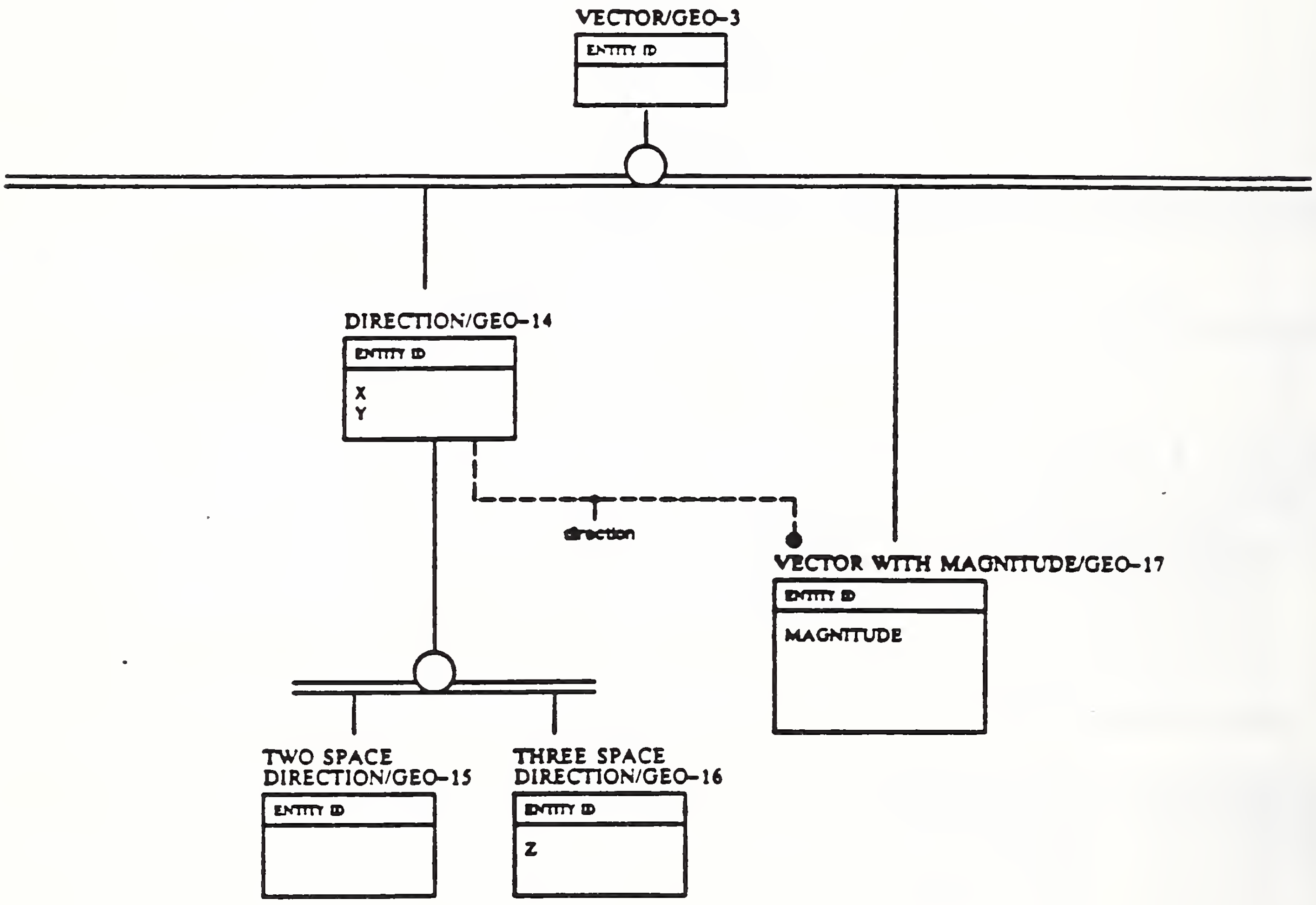


Figure D-3: SHAPE Entity/Relationship Diagram

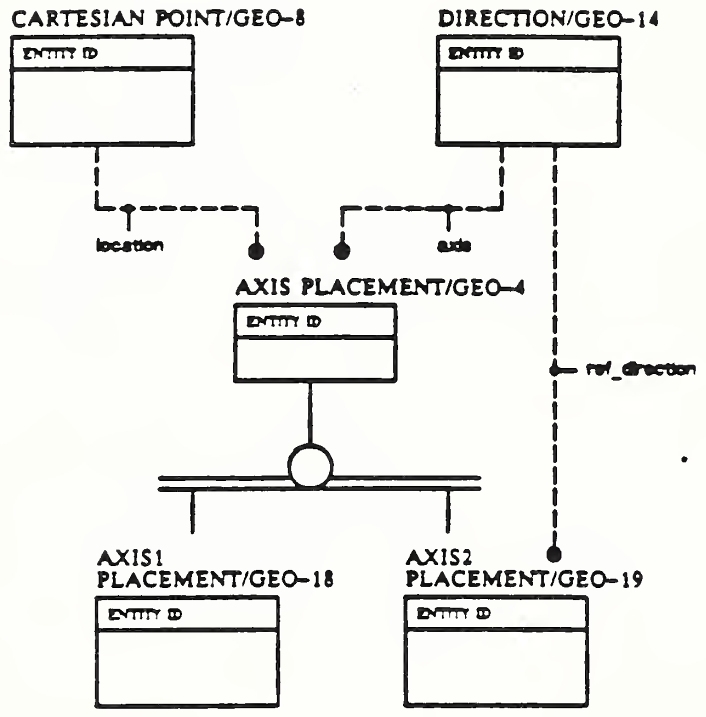


Figure D-4: SHAPE Entity/Relationship Diagram

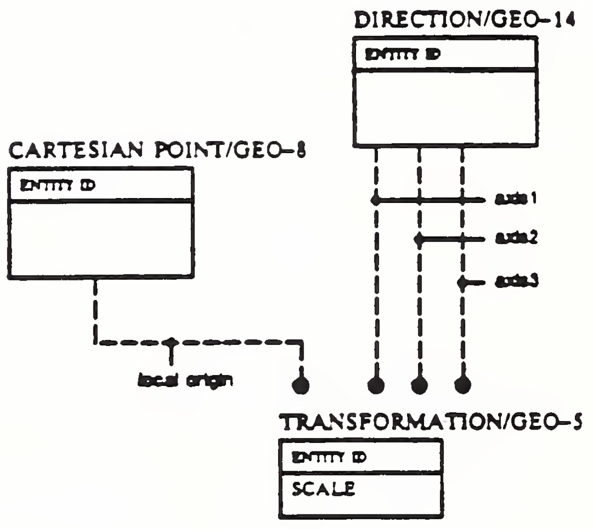


Figure D-5: SHAPE Entity/Relationship Diagram

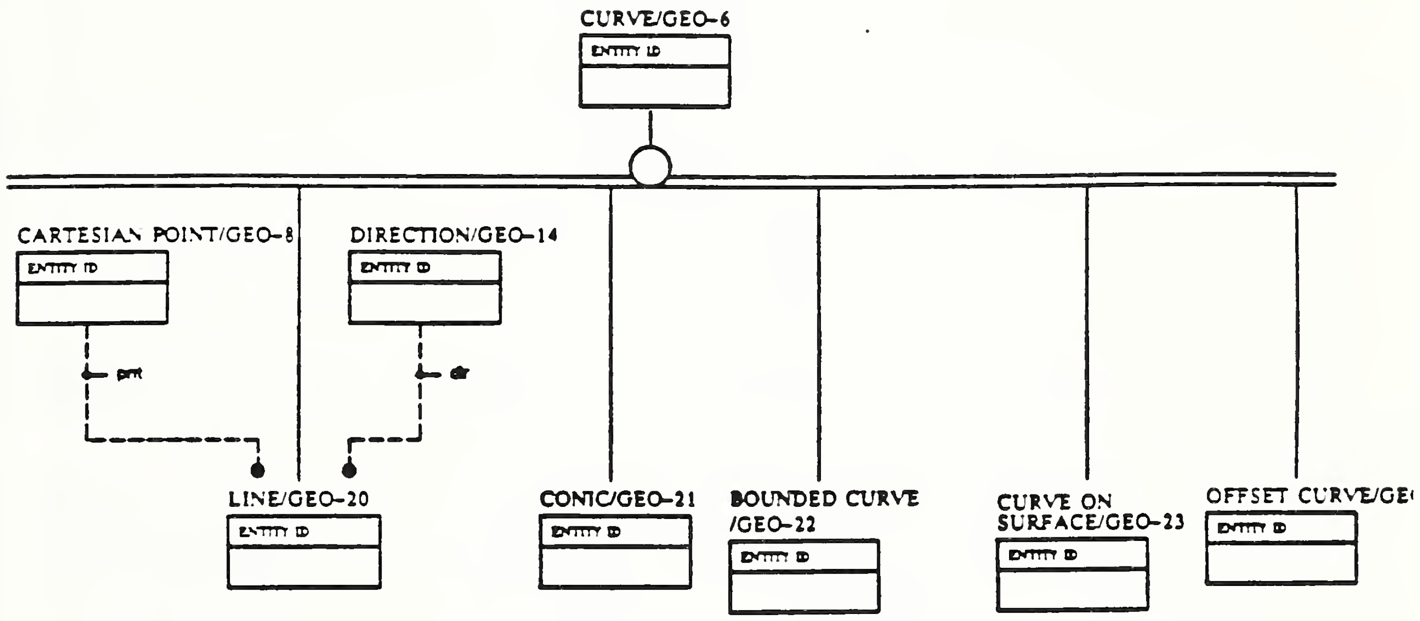


Figure D-6: SHAPE Entity/Relationship Diagram

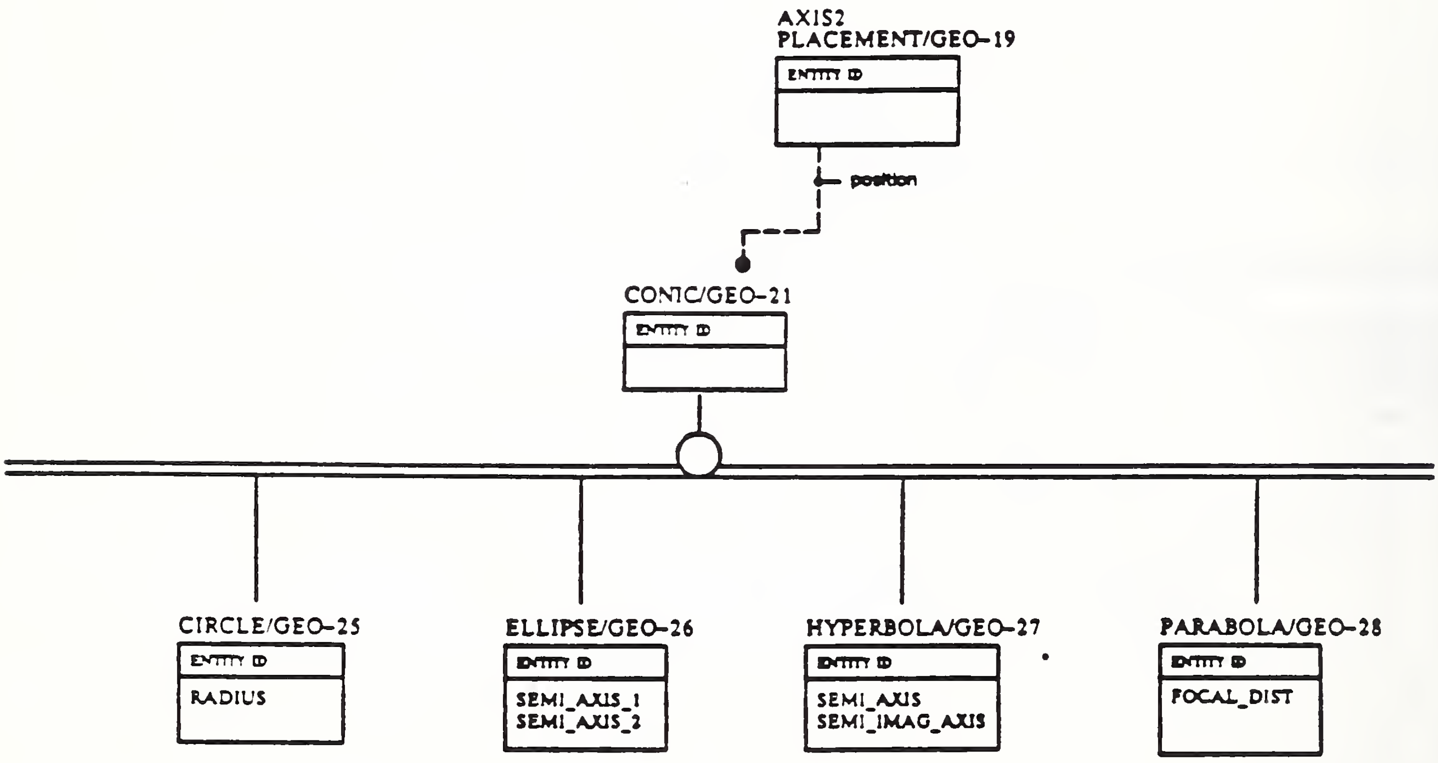


Figure D-7: SHAPE Entity/Relationship Diagram

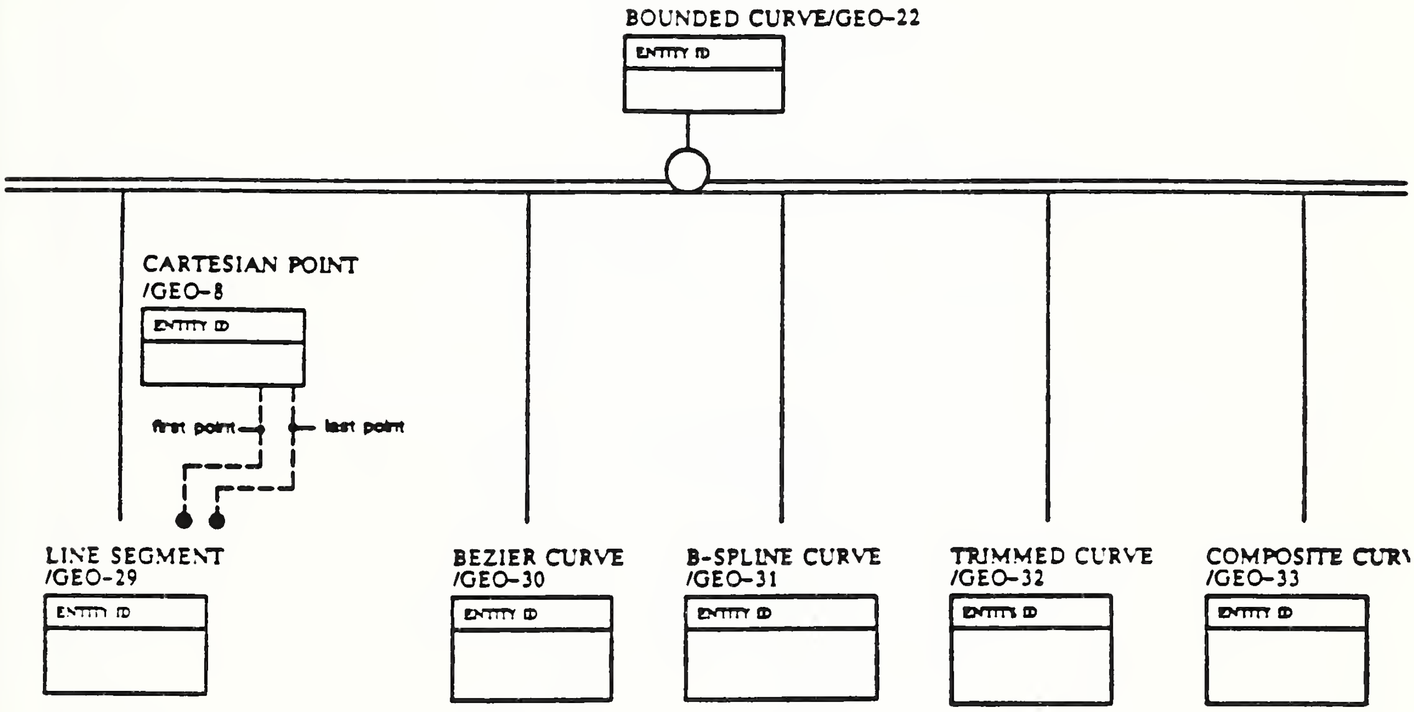


Figure D-8: SHAPE Entity/Relationship Diagram

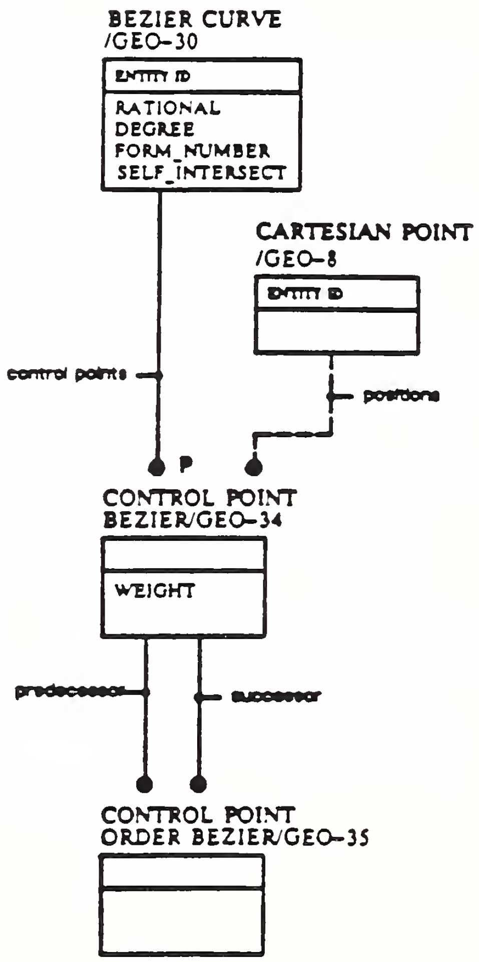


Figure D-9: SHAPE Entity/Relationship Diagram

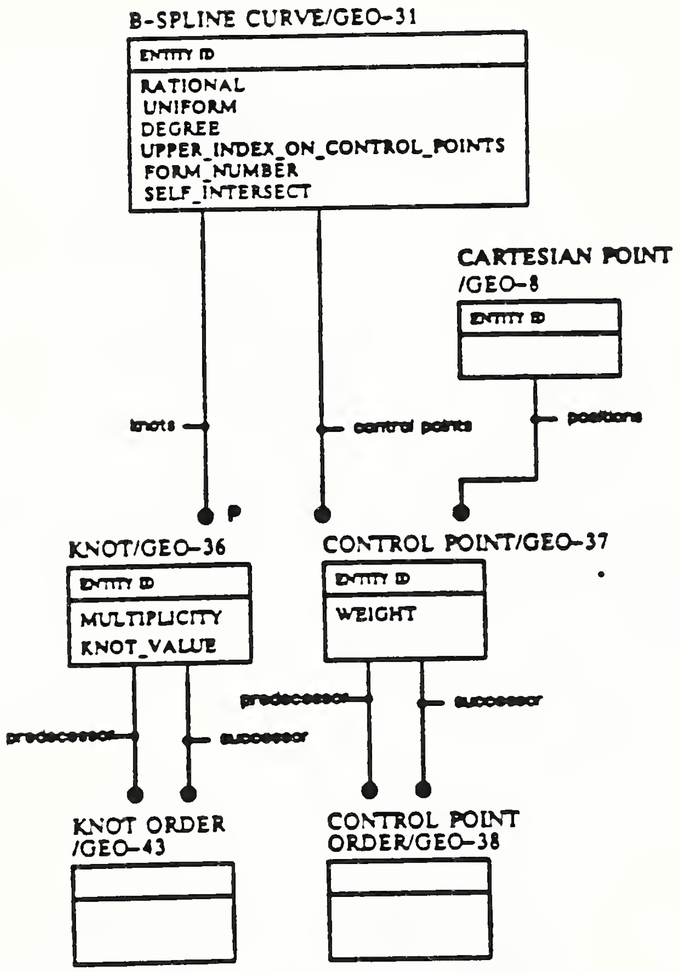


Figure D-10: SHAPE Entity/Relationship Diagram

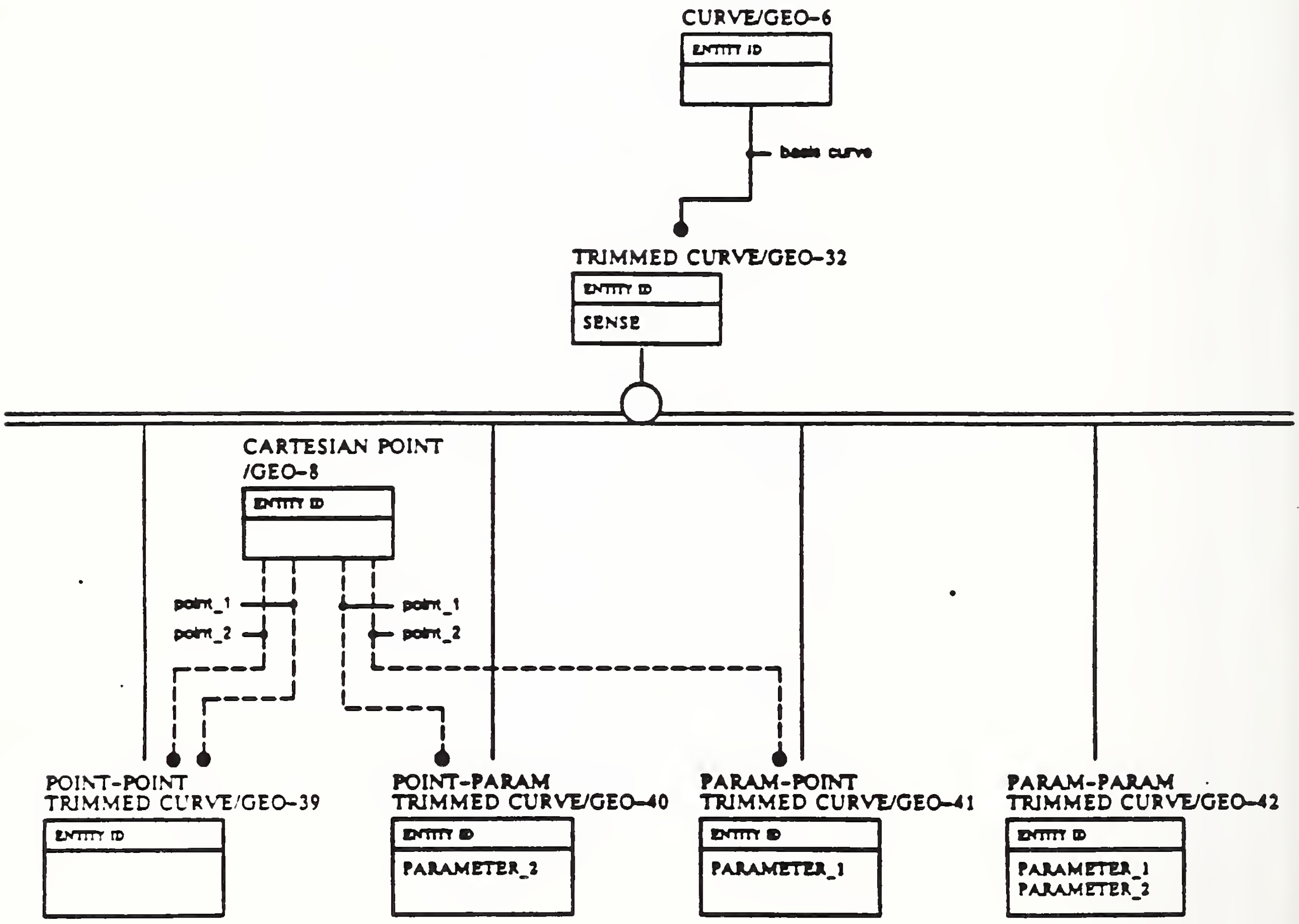


Figure D-11: SHAPE Entity/Relationship Diagram

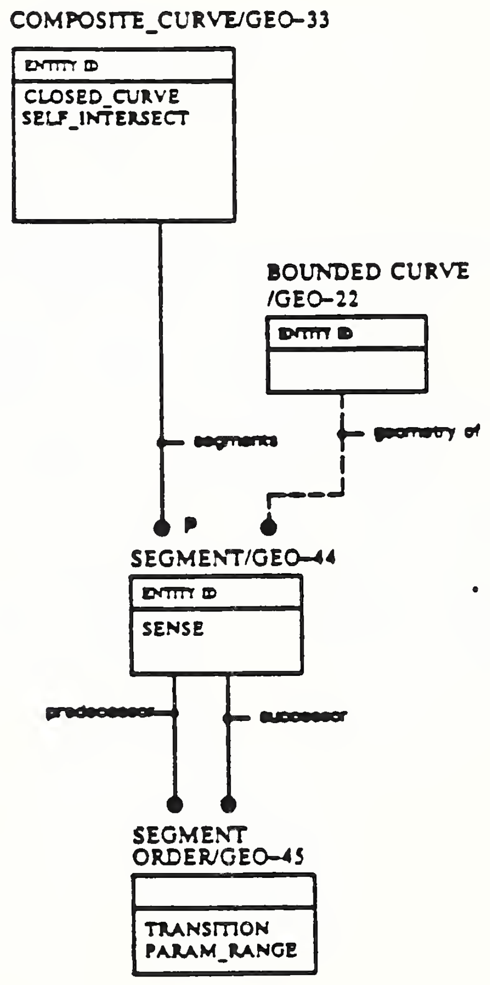


Figure D-12: SHAPE Entity/Relationship Diagram

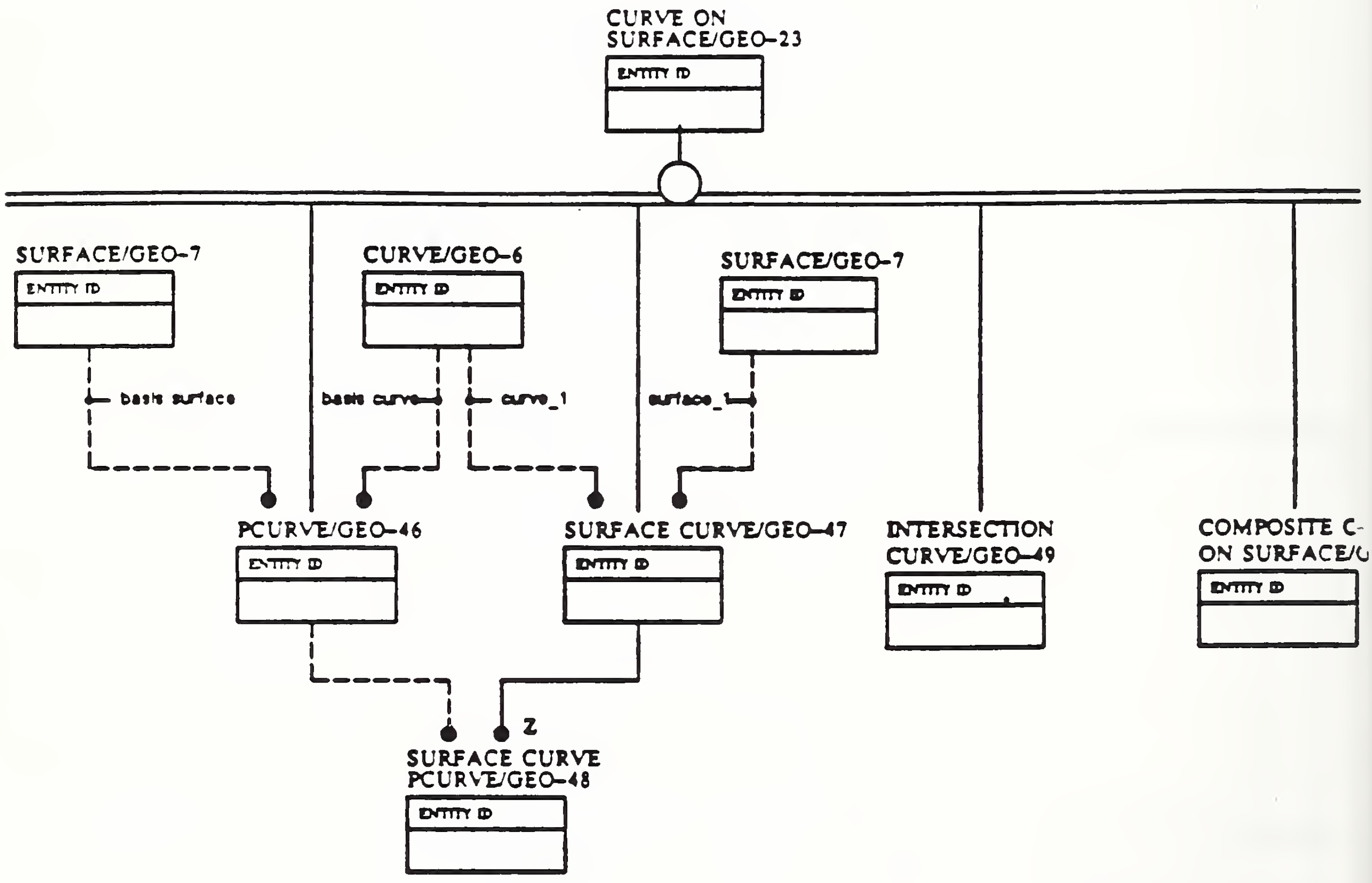


Figure D-13: SHAPE Entity/Relationship Diagram

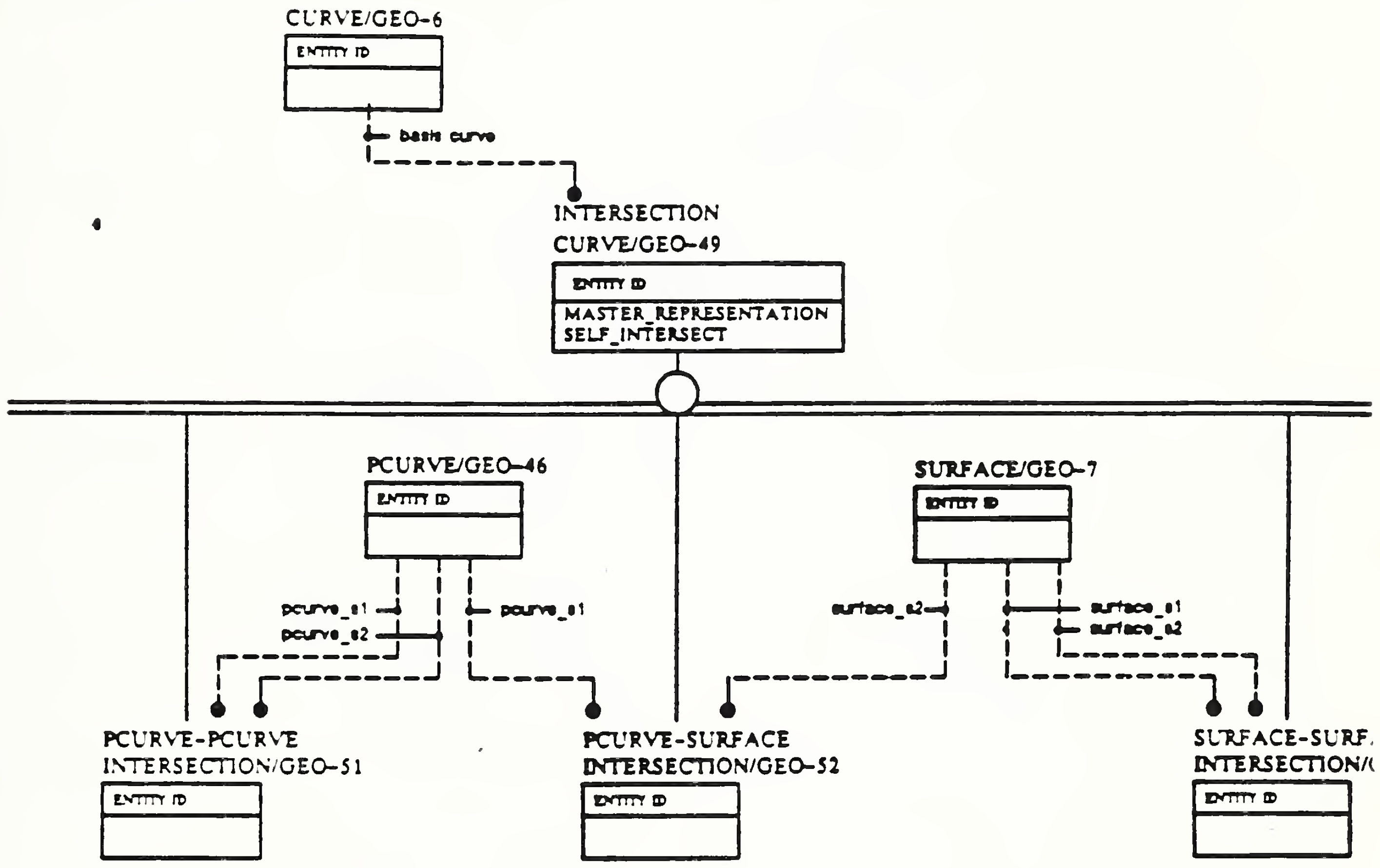


Figure D-14: SHAPE Entity/Relationship Diagram

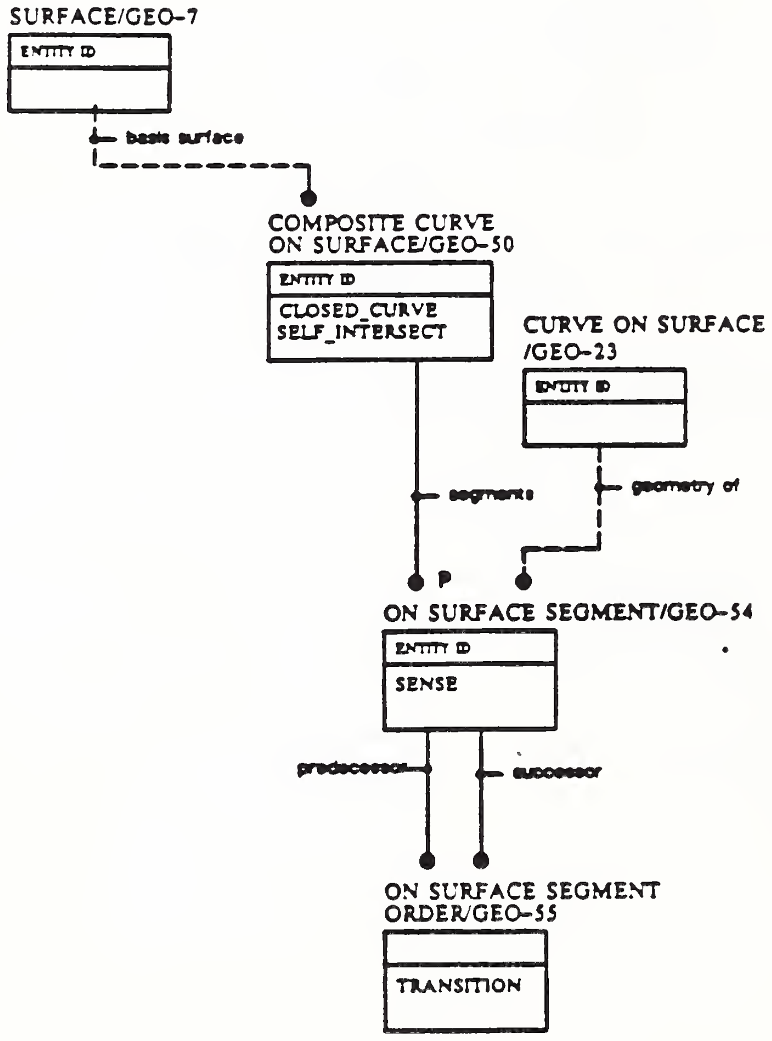


Figure D-15: SHAPE Entity/Relationship Diagram

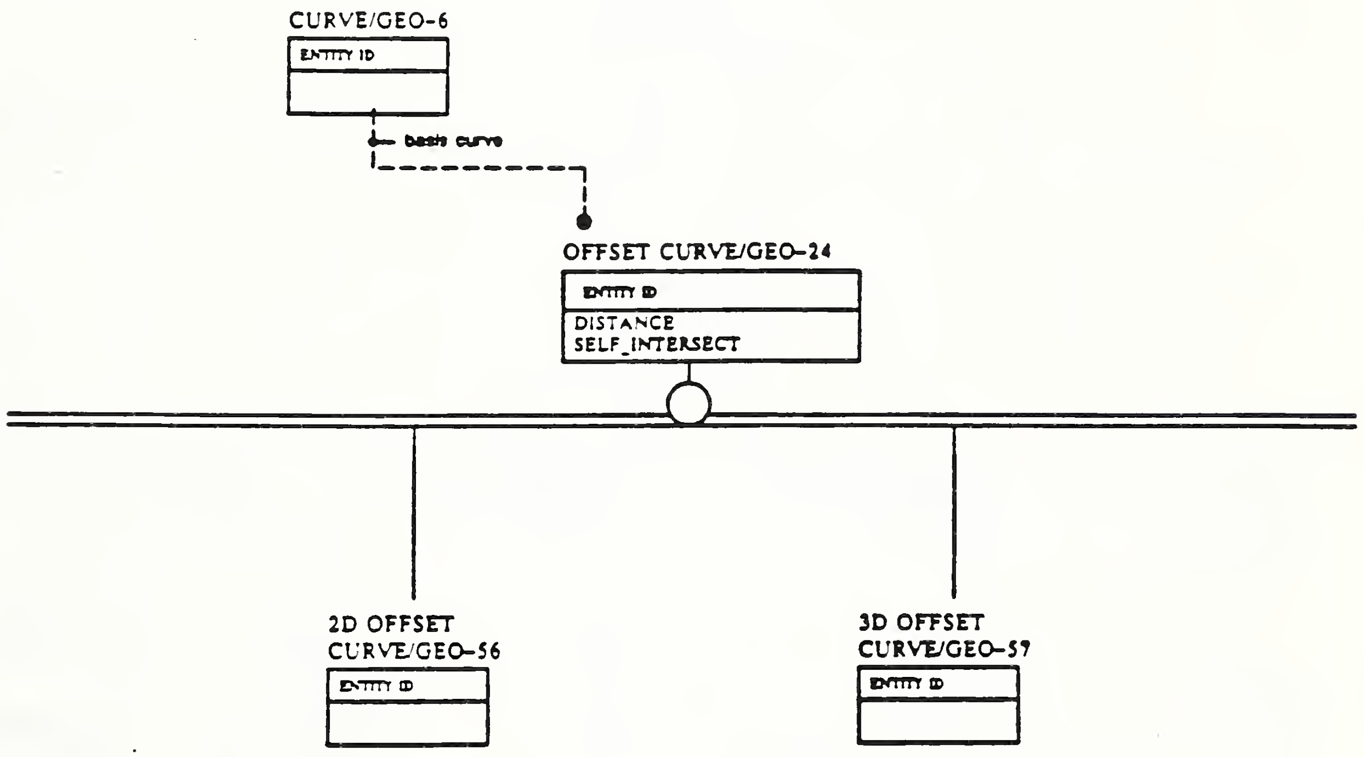


Figure D-16: SHAPE Entity/Relationship Diagram

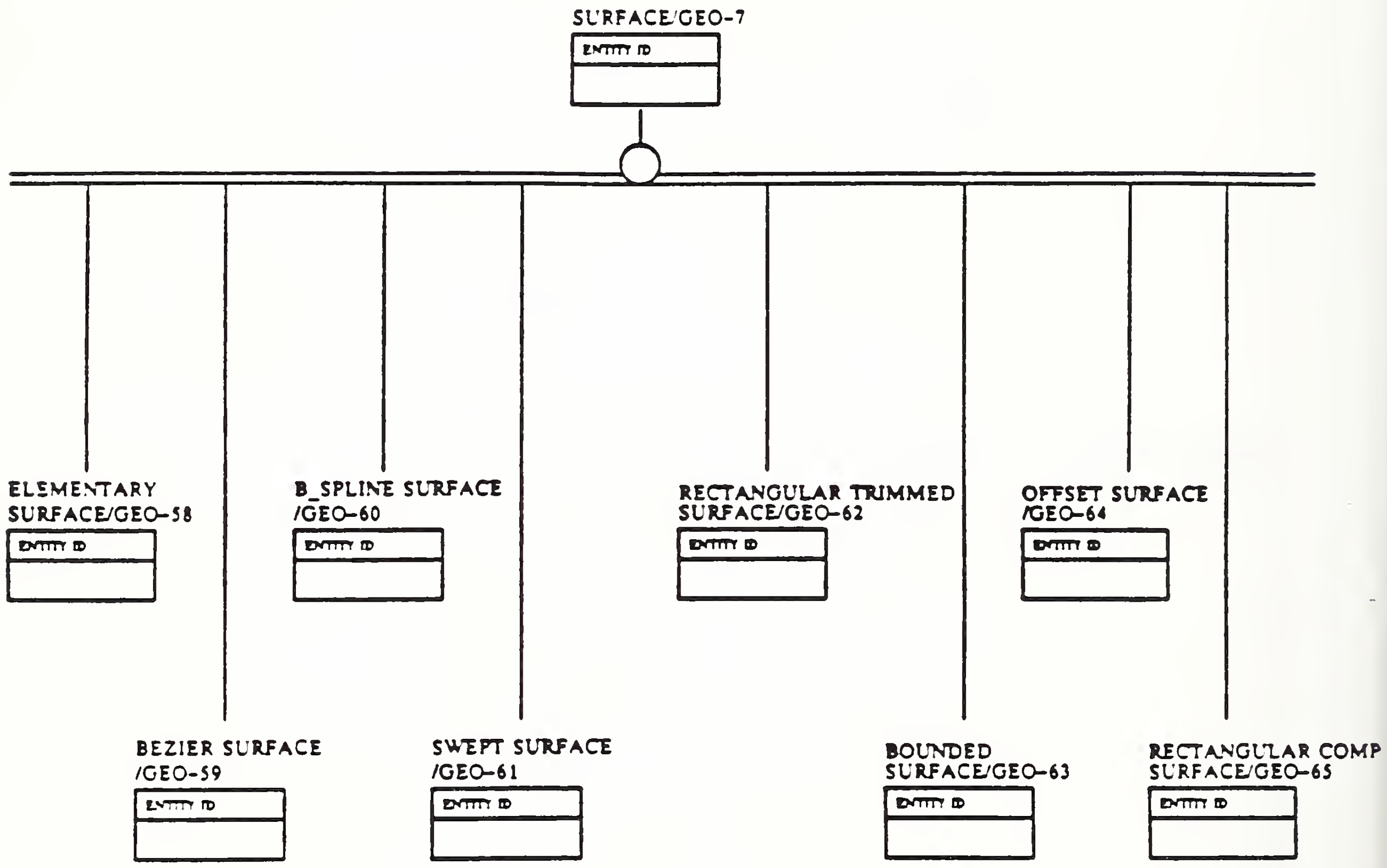


Figure D-17: SHAPE Entity/Relationship Diagram

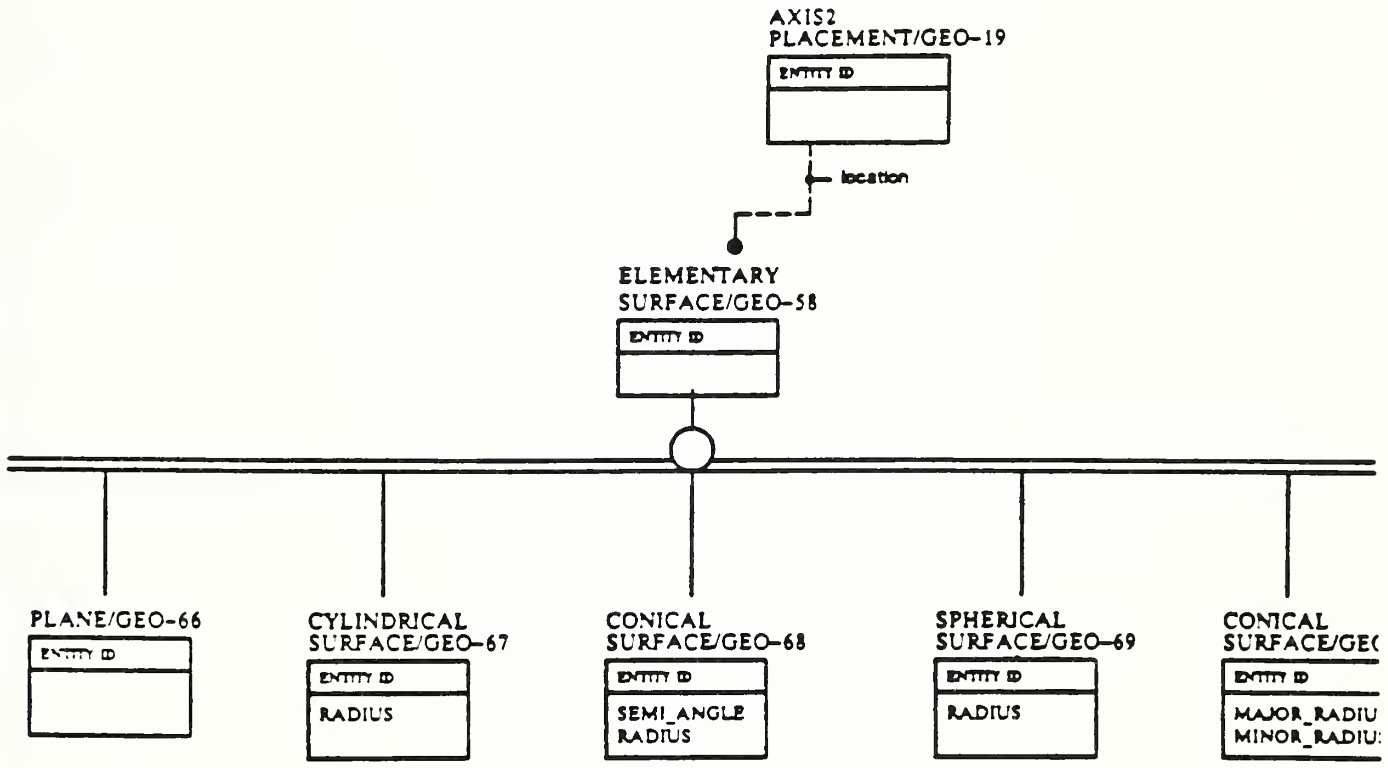


Figure D-18: SHAPE Entity/Relationship Diagram

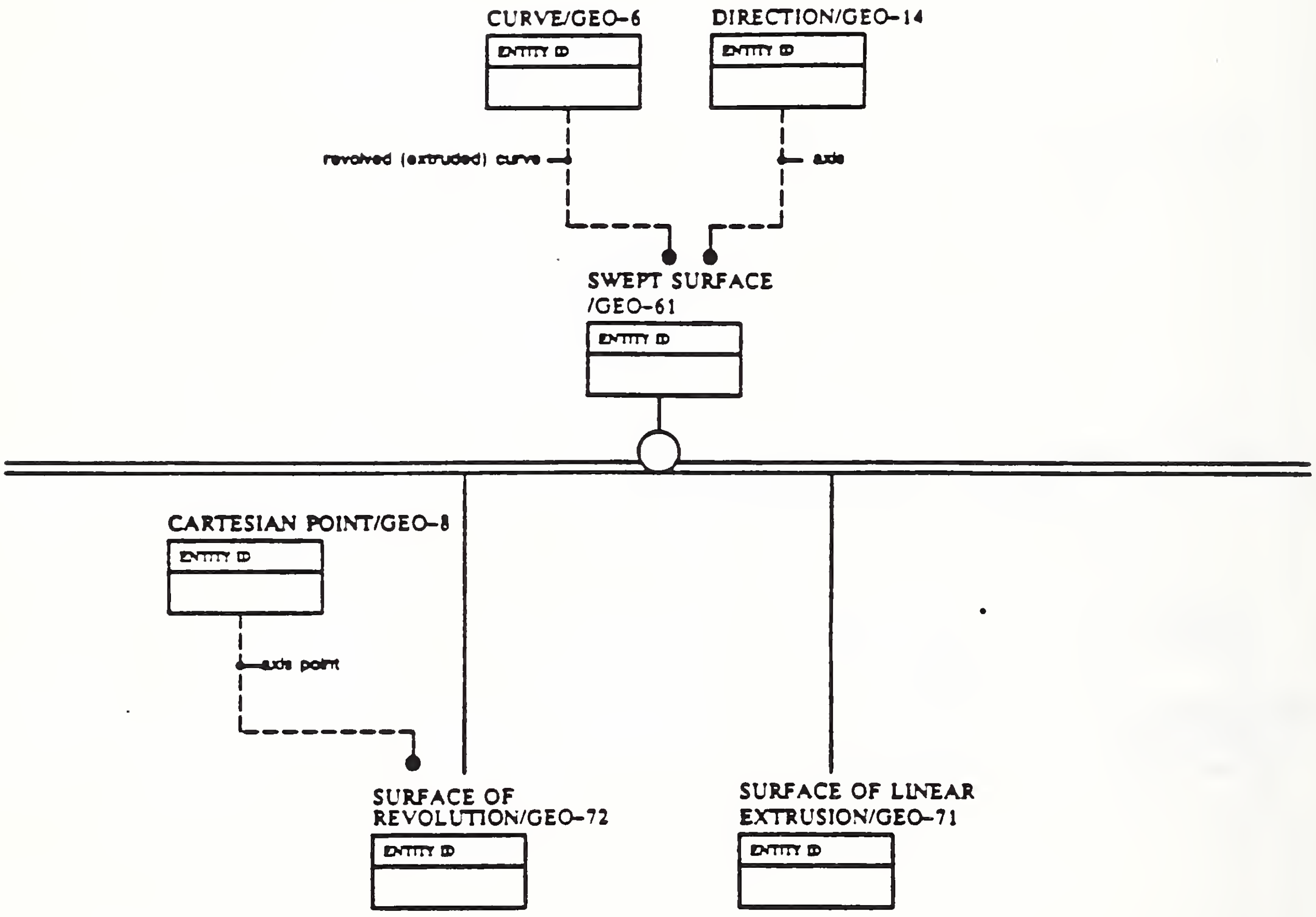


Figure D-19: SHAPE Entity/Relationship Diagram

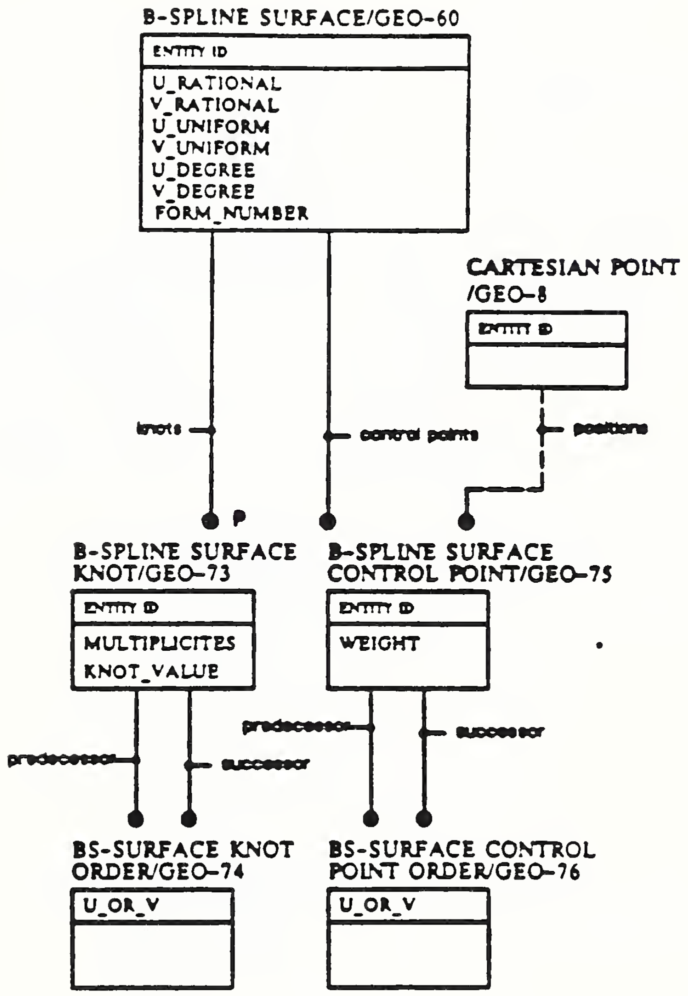


Figure D-20: SHAPE Entity/Relationship Diagram

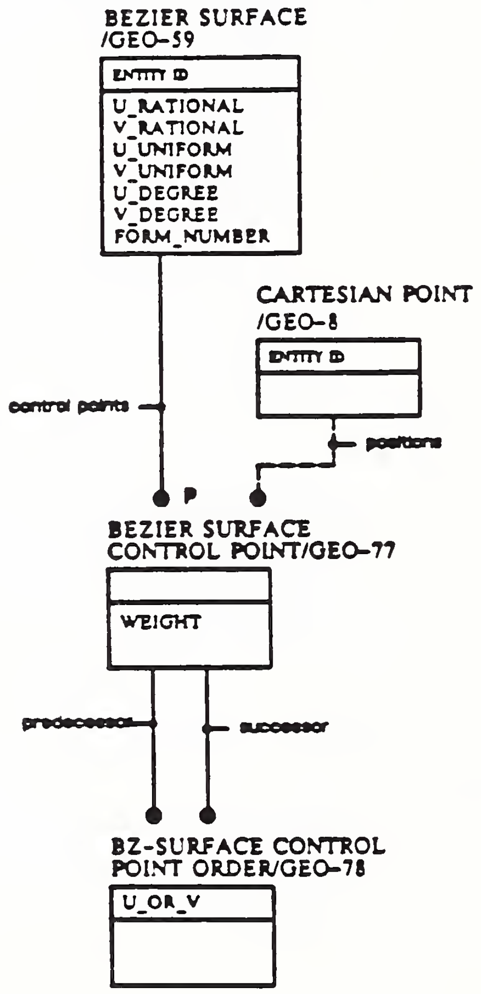


Figure D-21: SHAPE Entity/Relationship Diagram

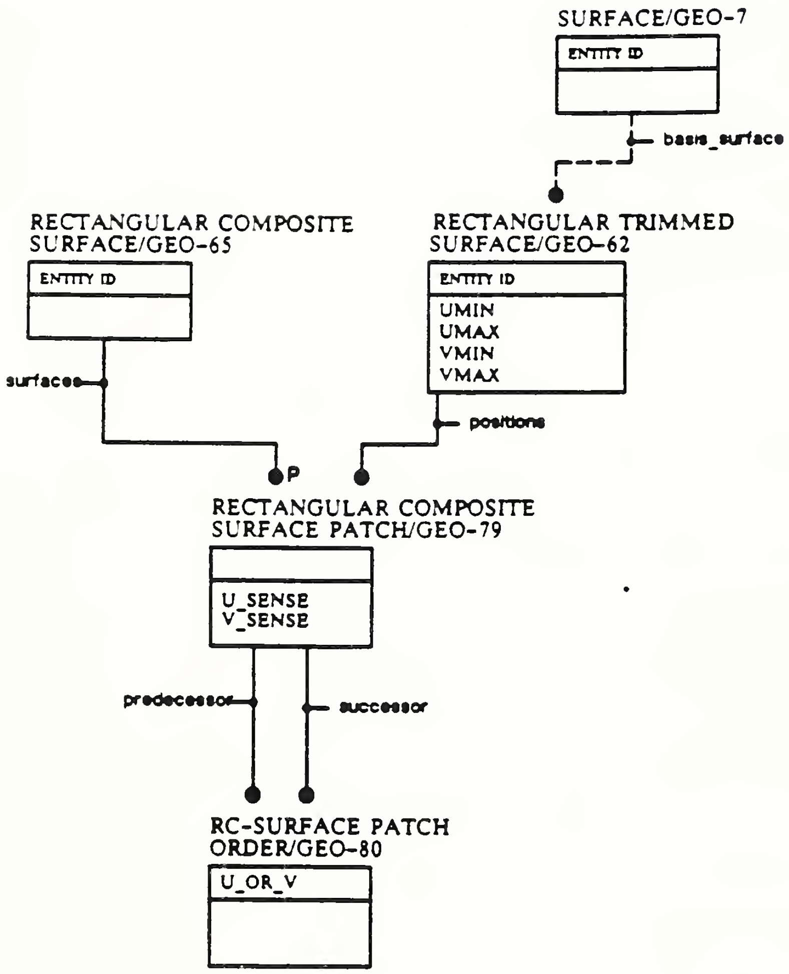

SURFACE/GEO-7
ENTITY ID
basis_surface
RECTANGULAR COMPOSITE SURFACE/GEO-65
ENTITY ID
RECTANGULAR TRIMMED SURFACE/GEO-62
ENTITY ID
UMIN
UMAX
VMIN
VMAX
surfaces
positions
P
RECTANGULAR COMPOSITE SURFACE PATCH/GEO-79
U_SENSE
V_SENSE
predecessor
successor
RC-SURFACE PATCH ORDER/GEO-80
U_OR_V

Figure D-22: SHAPE Entity/Relationship Diagram

2.4 SOLIDS

Entity Name: **SOLID_MODEL**

Entity Number: **GEO-82**

A complete representation of product nominal shape; any point can be classified as being inside, outside or on the boundary of a solid.

Primary Key Attributes

SOLID_MODEL_ID

Other Attributes

SOLID_MODEL_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
ENTITY solid_model
  SUPERTYPE OF (boolean_operation XOR
                csg_primitive XOR
                csg_solid XOR
                facetted_brep XOR
                half_space XOR
                manifold_solid_brep XOR
                solid_instance XOR
                swept_area_solid)
  SUBTYPE OF (shape_model);
END_ENTITY;
```

Entity Name: **CSG_PRIMITIVE**

Entity Number: **GEO-84**

A collector for all CSG primitives. A primitive is a simple solid used in the construction of more complex solids using regularized operations.

Primary Key Attributes

CSG_PRIMITIVE_ID

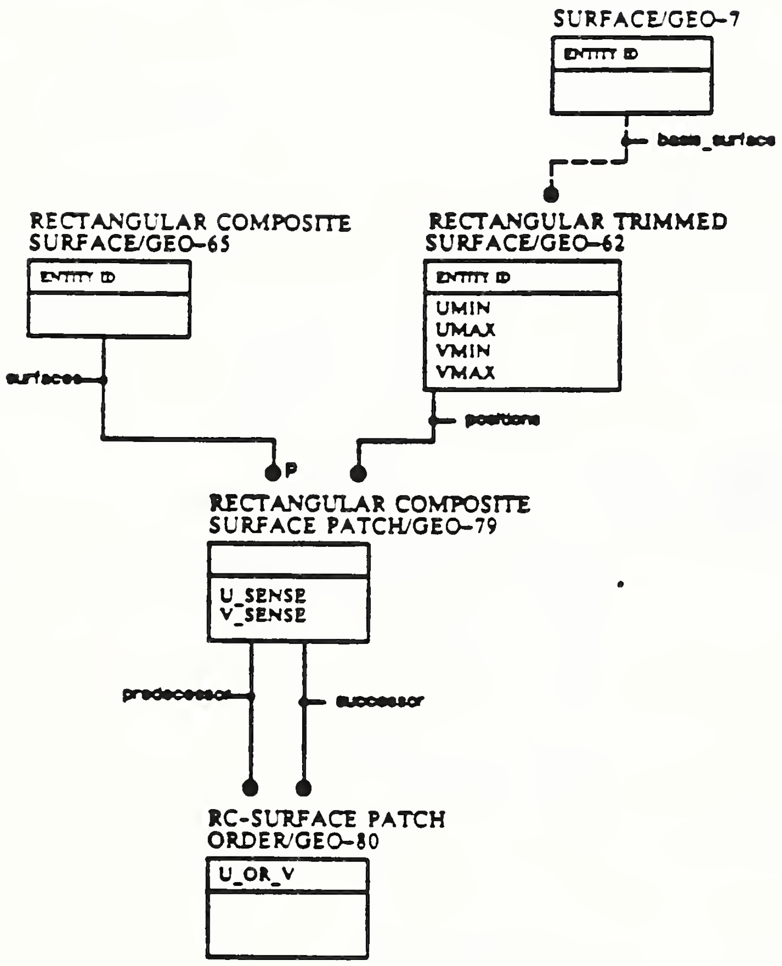

SURFACE/GEO-7
ENTITY ID
base_surface
RECTANGULAR COMPOSITE SURFACE/GEO-65
ENTITY ID
RECTANGULAR TRIMMED SURFACE/GEO-62
ENTITY ID
UMIN
UMAX
VMIN
VMAX
surfaces
positions
P
RECTANGULAR COMPOSITE SURFACE PATCH/GEO-79
U_SENSE
V_SENSE
predecessor
successor
RC-SURFACE PATCH ORDER/GEO-80
U_OR_V

Figure D-22: SHAPE Entity/Relationship Diagram

3.4 SOLIDS

Entity Name: **SOLID_MODEL**

Entity Number: **GEO-82**

A complete representation of product nominal shape; any point can be classified as being inside, outside or on the boundary of a solid.

Primary Key Attributes

SOLID_MODEL_ID

Other Attributes

SOLID_MODEL_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
ENTITY solid_model
  SUPERTYPE OF (boolean_operation XOR
                csg_primitive XOR
                csg_solid XOR
                facetted_brep XOR
                half_space XOR
                manifold_solid_brep XOR
                solid_instance XOR
                swept_area_solid)
  SUBTYPE OF (shape_model);
END_ENTITY;
```

Entity Name: **CSG_PRIMITIVE**

Entity Number: **GEO-84**

A collector for all CSG primitives. A primitive is a simple solid used in the construction of more complex solids using regularized operations.

Primary Key Attributes

CSG_PRIMITIVE_ID

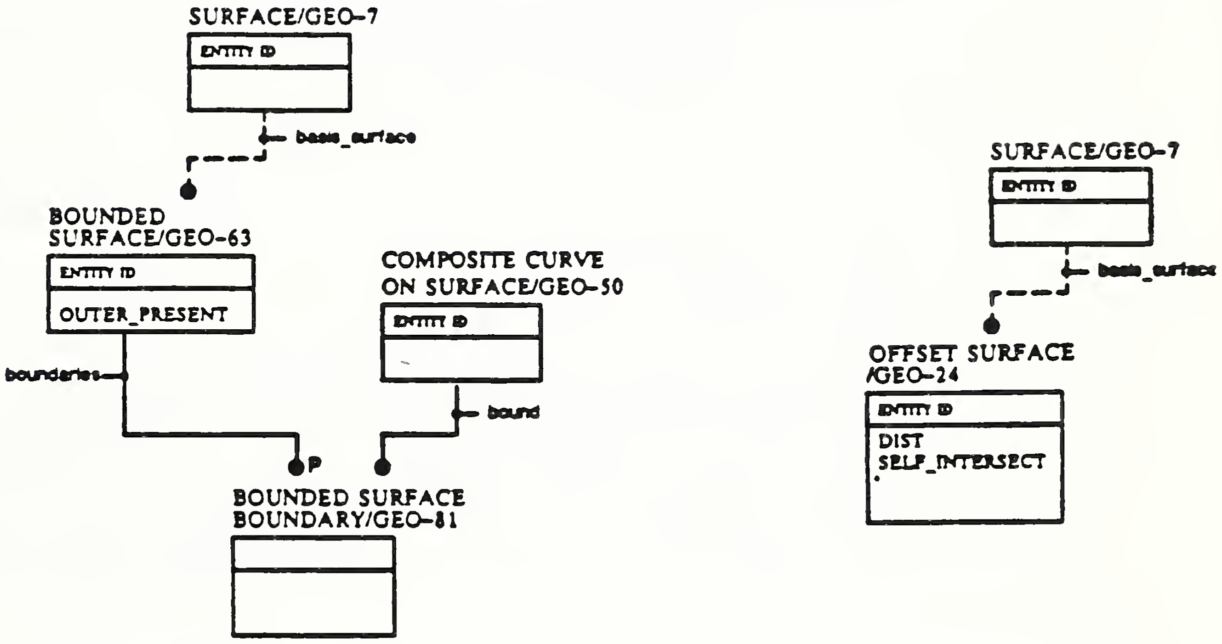


Figure D-23: SHAPE Entity/Relationship Diagram

Other Attributes

CSG_PRIMITIVE_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
    ENTITY csg_primitive
      SUPERTYPE OF (sphere XOR
                    primitive_with_one_axis XOR
                    primitive_with_axes)
      SUBTYPE OF (solid_model);
    END_ENTITY;
```

Entity Name: CSG_SOLID

Entity Number: GEO-85

A solid made by combining simpler solids using regularized Boolean operations. The allowed operations are intersection, union, and difference. A regularized operation is defined as the closure of the interior of the result of the Boolean operation.

The CSG_SOLID entity serves two functions. First it identifies the root Boolean operation. Second it is a means to differentiate intermediate results and significant results. The result of the Boolean operation pointed to by a CSG_SOLID is significant and should be kept, otherwise, the result is only an intermediate result.

Primary Key Attributes

CSG_SOLID_ID

Other Attributes

BOOLEAN_OPERATION_ID (FK)
Boolean expression of primitives and regularized operators describing the solid.

Business Rules

EXPRESS Specification

```
    ENTITY csg_solid
      SUBTYPE OF (solid_model);
      tree_expression : boolean_operation;
    END_ENTITY;
```

Entity Name: **FACETTED_B_REP**

Entity Number: **GEO-86**

The FACETTED BREP has been introduced in order to support the large number of systems that allow boundary type solid representations with planar surfaces only. Facetted models may be represented by MANIFOLD_SOLID_B_REP/GEO-88 but their representation as a FACETTED_BREP/GEO-86 will be more compact.

Primary Key Attributes

FACETTED_BREP_ID

Other Attributes

SHELL_LOGICAL_STRUCTURE_ID (FK)
A closed shell defining the exterior boundary of the solid.

Business Rules

EXPRESS Specification

```
ENTITY facetted_brep
  SUBTYPE OF (solid_model);
  outer : shell_logical_structure;
  voids : SET [0:#] OF shell_logical_structure;
END_ENTITY;
```

Entity Name: **HALF_SPACE**

Entity Number: **GEO-87**

The half space which is the regular subset of the domain which lies on one side of an unbounded surface. The domain is an orthogonal box or all space (all space is the default). See BOX_DOMAIN/GEO-109 for domain definition. Which side of the surface is determined by the surface normals and the complement flag. If the complement flag is FALSE, then the subset is the one the normals point away from. If the complement flag is TRUE, then the subset is the one the normals point into.

For a valid HALF SPACE/GEO-87, the surface must divide the domain into exactly two subsets. Also, within the domain the surface must be manifold and all the surface normals must point into the same subset.

Primary Key Attributes

HALF_SPACE_SOLID_ID

Other Attributes

SURFACE_ID (FK)
: Surface defining side of half space.

COMPLEMENT_FLAG
: Logical value which is the complement flag defined above.

Business Rules

EXPRESS Specification

```
ENTITY half_space
  SUBTYPE OF (solid_model);
  base_surface    : surface;
  enclosure       : OPTIONAL box_domain;
  complement_flag : LOGICAL;
END_ENTITY;
```

Entity Name: MANIFOLD_SOLID_B_REP

Entity Number: GEO-88

A manifold solid is an arcwise connected closed finite volume and the surface(s) of the solid is arcwise connected orientable compact two-manifold. There is no restriction on the genus of the volume, nor on the number of voids within the volume.

Primary Key Attributes

MANIFOLD_SOLID_B_REP_ID

Other Attributes

CLOSED_SHELL_LOGICAL_STRUCTURE_ID (FK)
: A closed shell defining the exterior boundary of the solid.

Business Rules

EXPRESS Specification

```
ENTITY manifold_solid_brep
```

```
    SUBTYPE OF (solid_model);
    outer : shell_logical_structure;
    voids : SET OF [0:#] OF shell_logical_structure;
  END_ENTITY;
```

Entity Name: **SOLID_INSTANCE**

Entity Number: **GEO-89**

A copy of another solid at a new location.

Primary Key Attributes

SOLID_INSTANCE_ID

Other Attributes

AXIS2_PLACEMENT_ID (FK)
  Location and orientation at which the solid instance takes place.

SOLID MODEL ID (FK)
  Solid Model which is the object of the solid instance.

Business Rules

EXPRESS Specification

```
  ENTITY solid_instance
    SUBTYPE OF (solid_model);
    solid_to_be_copied : solid_model;
    location           : axis2_placement;
  END_ENTITY;
```

Entity Name: **SWEPT_AREA_SOLID**

Entity Number: **GEO-90**

A collector for solids defined by a sweeping action on planar faces.

Primary Key Attributes

SWEPT_AREA_SOLID_ID

Other Attributes

SWEPT_AREA_SOLID_TYPE (discriminator)

FACE_ID (FK)
Face to be swept.

Business Rules

EXPRESS Specification

```
ENTITY swept_area_solid
  SUPERTYPE OF (solid_of_revolution XOR
                solid_of_linear_extrusion)
  SUBTYPE OF (solid_model);
END_ENTITY;
```

Entity Name: **BOOLEAN_OPERATION**

Entity Number: **GEO-91**

A regularized operation on two solids to create a new solid. Valid operations are regularized union, regularized intersection, regularized complement, and regularized difference. For purposes of Boolean operations, a solid is a regularized set of points.

Primary Key Attributes

BOOLEAN_OPERATION_ID

Other Attributes

BOOLEAN_OPERATION_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
ENTITY boolean_operation
  SUPERTYPE OF (union XOR
                intersection XOR
                difference)
END_ENTITY;
```

Entity Name: **UNION**

Entity Number: **GEO-92**

UNION on two solids is the regularization of the set of all points that are in the FIRST_OPERAND or the SECOND_OPERAND or both.

Primary Key Attributes

UNION_ID

Other Attributes

FIRST_OPERAND.SOLID_MODEL_ID (FK)

SECOND_OPERAND.SOLID_MODEL_ID (FK)

Business Rules

EXPRESS Specification

```
ENTITY union
  SUBTYPE OF (boolean_operation);
  first_operand  : solid_model;
  second_operand : solid_model;
END_ENTITY;
```

Entity Name: **INTERSECTION**

Entity Number: **GEO-93**

INTERSECTION on two solids is the regularization of the set of all points that are in both the FIRST_OPERAND and the SECOND_OPERAND.

Primary Key Attributes

INTERSECTION_ID

Other Attributes

FIRST_OPERAND.SOLID_MODEL_ID (FK)

SECOND_OPERAND.SOLID_MODEL_ID (FK)

Business Rules

EXPRESS Specification

```
ENTITY intersection
  SUBTYPE OF (boolean_operation);
  first_operand  : solid_model;
  second_operand : solid_model;
END_ENTITY;
```

Entity Name: **DIFFERENCE**

Entity Number: **GEO-94**

DIFFERENCE on two solids is the regularization of the set of all points that are in the WORK_PIECE, but not in the TO_BE_REMOVED.

Primary Key Attributes

DIFFERENCE_ID

Other Attributes

WORK_PIECE.SOLID_MOLDEL_ID (FK)

TO_BE_REMOVED.SOLID_MODEL_ID (FK)

Business Rules

EXPRESS Specification

```
ENTITY difference
  SUBTYPE OF (boolean_operation);
  work_piece    : solid_model;
  to_be_removed : solid_model;
END_ENTITY;
```

Entity Name: **BREP_SHELL_LOGICAL_STRUCTURE**

Entity Number: **GEO-96**

The use of a CLOSED_SHELL/TOP-18 by a MANIFOLD_SOLID_B_REP/GEO-88 as a interior void.

Primary Key Attributes

MANIFOLD_SOLID_B_REP_ID (FK)

CLOSED_SHELL_ID (FK)

Other Attributes

FLAG
Logical value which indicates whether the shell normal agrees with (TRUE) or is in the opposite direction (FALSE) to the manifold solid normal.

Business Rules

EXPRESS Specification

```
ENTITY closed_shell_logical_structure;
  closed_shell_element : closed_shell;
  flag                 : LOGICAL;
END_ENTITY;
```

Entity Name: PRIMITIVE_WITH_ONE_AXIS

Entity Number: GEO-97

A collector for axis symmetrical CSG primitives.

Primary Key Attributes

PRIMITIVE_WITH_ONE_AXIS_ID

Other Attributes

PRIMITIVE_WITH_ONE_AXIS_TYPE (discriminator)

AXIS1_PLACEMENT (FK)
The location of a point on the axis and the direction of the axis.

Business Rules

EXPRESS Specification

```
ENTITY primitive_with_one_axis
  SUPERTYPE OF (right_circular_cone XOR
                right_circular_cylinder XOR
```

```
                  torus)
      SUBTYPE OF (csg_primitive);
    END_ENTITY;
```

Entity Name: **RIGHT_CIRCULAR_CYLINDER**

Entity Number: **GEO-98**

A right circular cylinder CSG primitive.

Primary Key Attributes

RIGHT_CIRCULAR_CYLINDER_ID

Other Attributes

RADIUS
  Real number value which is the radius of the cylinder.

HEIGHT
  Real number value which is the height of the cylinder.

Business Rules

EXPRESS Specification

```
    ENTITY right_circular_cylinder
      SUBTYPE OF (primitive_with_one_axis);
      radius      : REAL;
      position    : axis1_placement;
      height      : REAL;
    END_ENTITY;
```

Entity Name: **RIGHT_CIRCULAR_CONE**

Entity Number: **GEO-99**

A right circular cone CSG primitive.

Primary Key Attributes

RIGHT_CIRCULAR_CONE_ID

Other Attributes

SEMI-ANGLE
Real number value which is one half the angle of the cone in degrees.

RADIUS
Real number value which is the radius of the cone at the axis point. That is a non-zero radius means the cone is truncated.

HEIGHT
Real number value which is the distance the base of the cone and the point at which the radius is measured.

Business Rules

EXPRESS Specification

```
ENTITY right_circular_cone
  SUBTYPE OF (primitive_with_one_axis);
  semi_angle : REAL;
  radius     : REAL;
  position   : axis1_placement;
  height     : REAL;
END_ENTITY;
```

Entity Name: TORUS

Entity Number: GEO-100

A torus CSG primitive.

Primary Key Attributes

TORUS_ID

Other Attributes

MAJOR_RADIUS
Real number which is the radius of the directrix.

MINOR_RADIUS
Real number which is the radius of the generatrix.

Business Rules

EXPRESS Specification

```
ENTITY torus
  SUBTYPE OF (primitive_with_one_axis);
  major_radius : REAL;
  minor_radius : REAL;
  position     : axis1_placement;
END_ENTITY;
```

Entity Name: SPHERE

Entity Number: GEO-101

A sphere CSG primitive.

Primary Key Attributes

SPHERE_ID

Other Attributes

RADIUS
Real value which is the radius of the sphere.

Business Rules

EXPRESS Specification

```
ENTITY sphere
  SUBTYPE OF (csg_primitive);
  radius : REAL;
  center : point;
END_ENTITY;
```

Entity Name: PRIMITIVE_WITH_AXES

Entity Number: GEO-102

A collector for non-Axisymmetric CSG primitives.

Primary Key Attributes

PRIMITIVE_WITH_AXES_ID

Other Attributes

PRIMITIVE_WITH_AXES_TYPE (discriminator)

AXIS2_PLACEMENT_ID

Business Rules

EXPRESS Specification

```
    ENTITY primitive_with_axes
      SUPERTYPE OF (right_angular_wedge XOR
                    block)
      SUBTYPE OF (csg_primitive);
    END_ENTITY;
```

Entity Name: RIGHT_ANGULAR_WEDGE

Entity Number: GEO-104

A right angular wedge CSG primitive. The wedge may be truncated or come to an apex.

Primary Key Attributes

RIGHT_ANGULAR_WEDGE_ID

Other Attributes

X

Real number value which is the size of the wedge along the X axis.

Y

Real number value which is the size of the wedge along the Y axis.

Z

Real number value which is the size of the wedge along the Z axis.

LTX

Real number value which is the distance in the positive X direction of the smaller surface of the wedge.

Business Rules

EXPRESS Specification

```
ENTITY right_angular_wedge
  SUBTYPE OF (primitive_with_axes);
  x        : REAL;
  y        : REAL;
  z        : REAL;
  ltx      : REAL;
  position : axis2_Placement;
END_ENTITY;
```

Entity Name: BLOCK

Entity Number: GEO-105

A rectangular block CSG primitive.

Primary Key Attributes

BLOCK_ID

Other Attributes

X

Real number value which is the size of the block along the X axis.

Y

Real number value which is the size of the block along the Y axis.

Z

Real number value which is the size of the block along the Z axis.

Business Rules

EXPRESS Specification

```
ENTITY block
  SUBTYPE OF (primitive_with_axes);
  x        : REAL;
  y        : REAL;
  z        : REAL;
  position : axis2_Placement;
```

```
END_ENTITY;
```

Entity Name: **SOLID_OF_LINEAR_EXTRUSION**

Entity Number: **GEO-106**

A SOLID_OF_LINEAR_EXTRUSION is a solid defined by sweeping a planar face. The direction translation is defined by a direction vector. The planar face may have holes which will sweep into holes in the solid.

Primary Key Attributes

SOLID OF_LINEAR_EXTRUSION_ID

Other Attributes

DIRECTION ID (FK)
The direction in which the face is to be swept.

DEPTH
Real number which is the distance the face is to be swept.

Business Rules

EXPRESS Specification

```
ENTITY solid_of_linear_extrusion
  SUBTYPE OF (swept_area_solid);
  extruded_face       : face;
  extruded_direction  : direction;
  depth               : REAL;
END_ENTITY;
```

Entity Name: **SOLID_OF_REVOLUTION**

Entity Number: **GEO-107**

A SOLID OF REVOLUTION is a solid formed by revolving a planar face about an axis. The axis must be in the plane of the face and the axis must not intersect the interior of the face. The planar face may have holes which will sweep into holes in the solid.

Primary Key Attributes

SOLID_OF_REVOLUTION_ID

Other Attributes

AXIS1_PLACEMENT_ID (FK)
Axis about which swept will be made.

ANGLE
Real number which is angle through which the sweep will be made. The angle is in degrees.

Business Rules

EXPRESS Specification

```
ENTITY solid_of_revolution
  SUBTYPE OF (swept_area_solid);
  axis            : axis1_placement;
  extruded_face   : face;
  angle           : REAL;
END_ENTITY;
```

Entity Name: **BOX_DOMAIN**

Entity Number: **GEO-109**

A BOX DOMAIN is an orthogonal box which may be used to limit the domain of a HALF_SPACE/GEO-87.

Primary Key Attributes

HALF_SPACE_SOLID_ID (FK)

Other Attributes

X_MIN
Real value which is X coordinate of most negative corner of box.

Y_MIN
Real value which is Y coordinate of most negative corner of box.

Z_MIN
Real value which is Z coordinate of most negative corner of box.

X_MAX
Real value which is X coordinate of most positive corner of box.

Y_MAX
Real value which is X coordinate of most positive corner of box.

Z_MAX

Real value which is X coordinate of most positive corner of box.

Business_Rules

EXPRESS Specification

```
ENTITY box_domain
  x_min : REAL:
  y_min : REAL:
  z_min : REAL:
  x_max : REAL:
  y_max : REAL:
  z_max : REAL:
END_ENTITY;
```

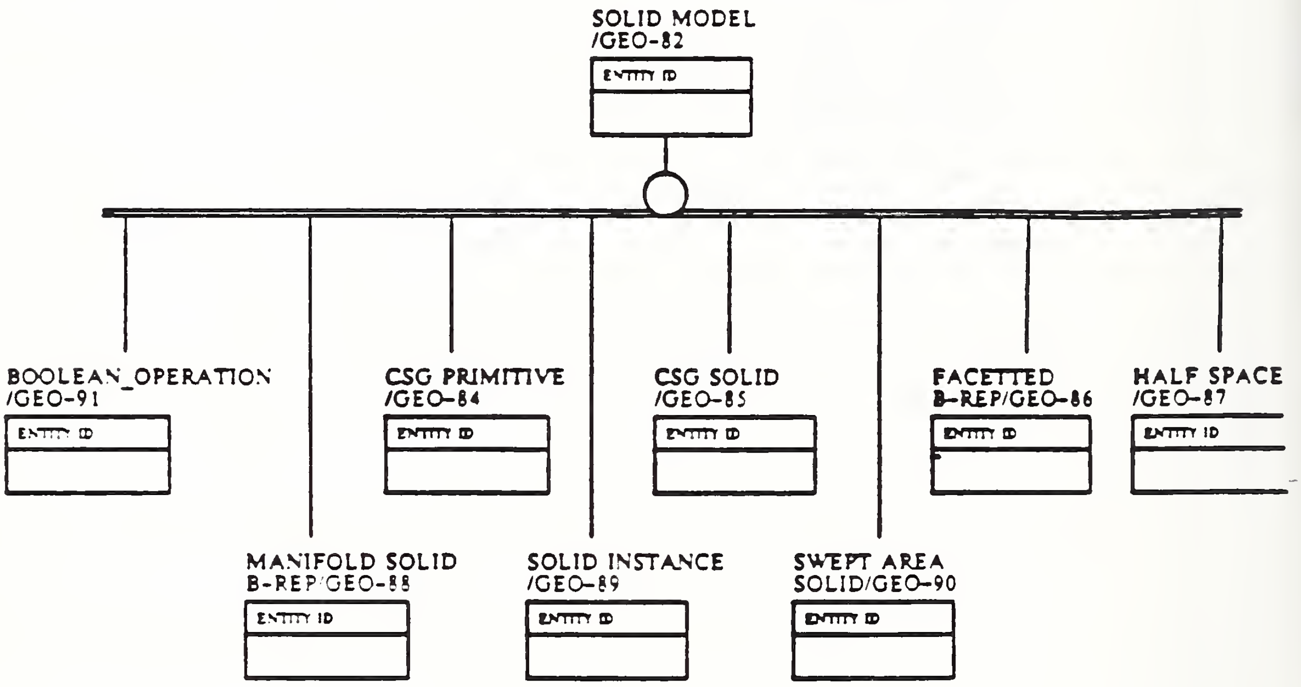


Figure D-24: SHAPE Entity/Relationship Diagram

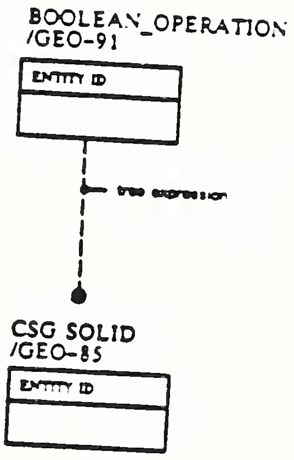


Figure D-25: SHAPE Entity/Relationship Diagram

SECTION 3: NOMINAL SHAPE INFORMATION MODEL

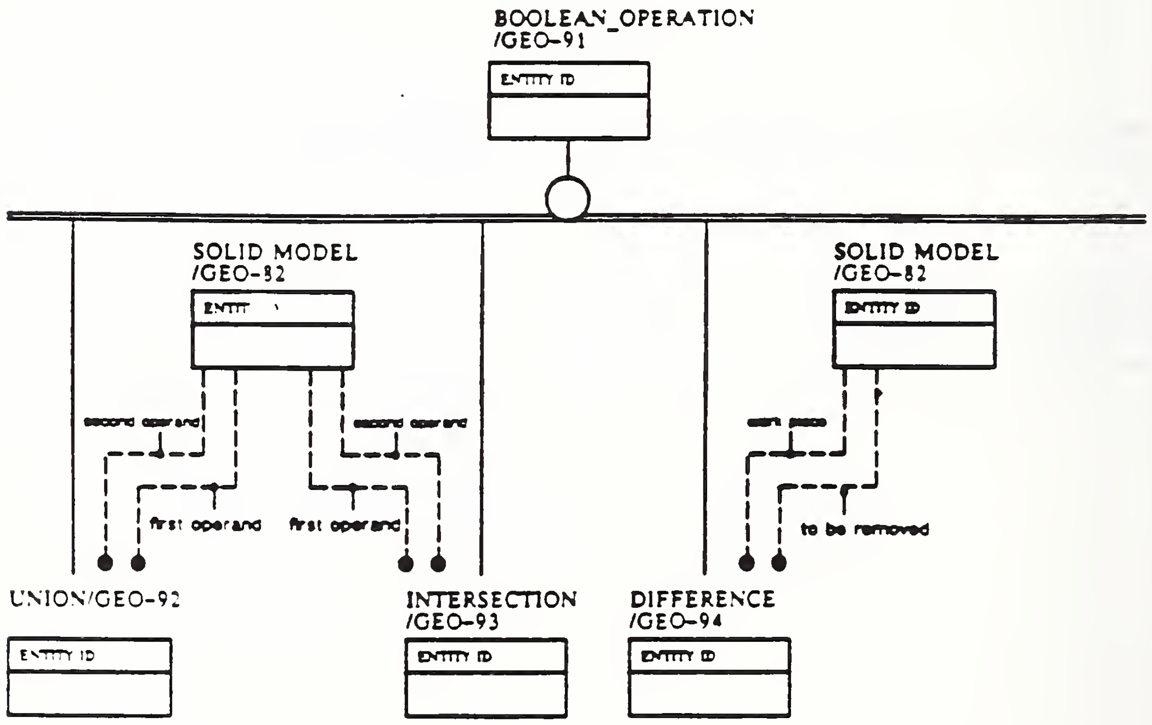


Figure D-26: SHAPE Entity/Relationship Diagram

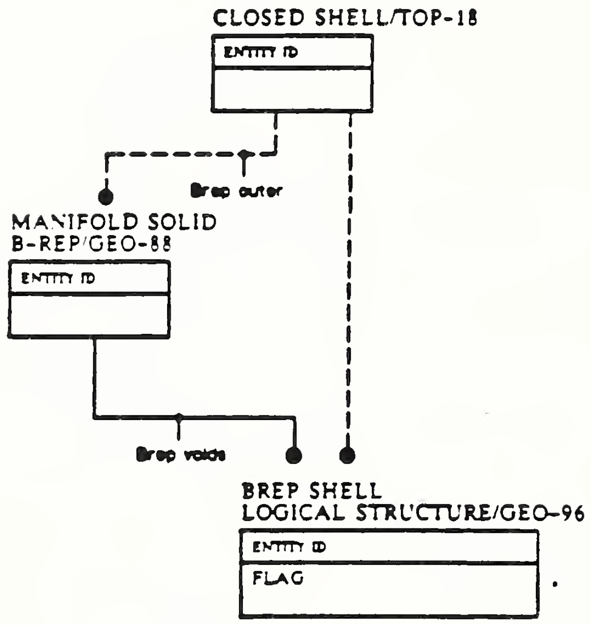


Figure D-27: SHAPE Entity/Relationship Diagram

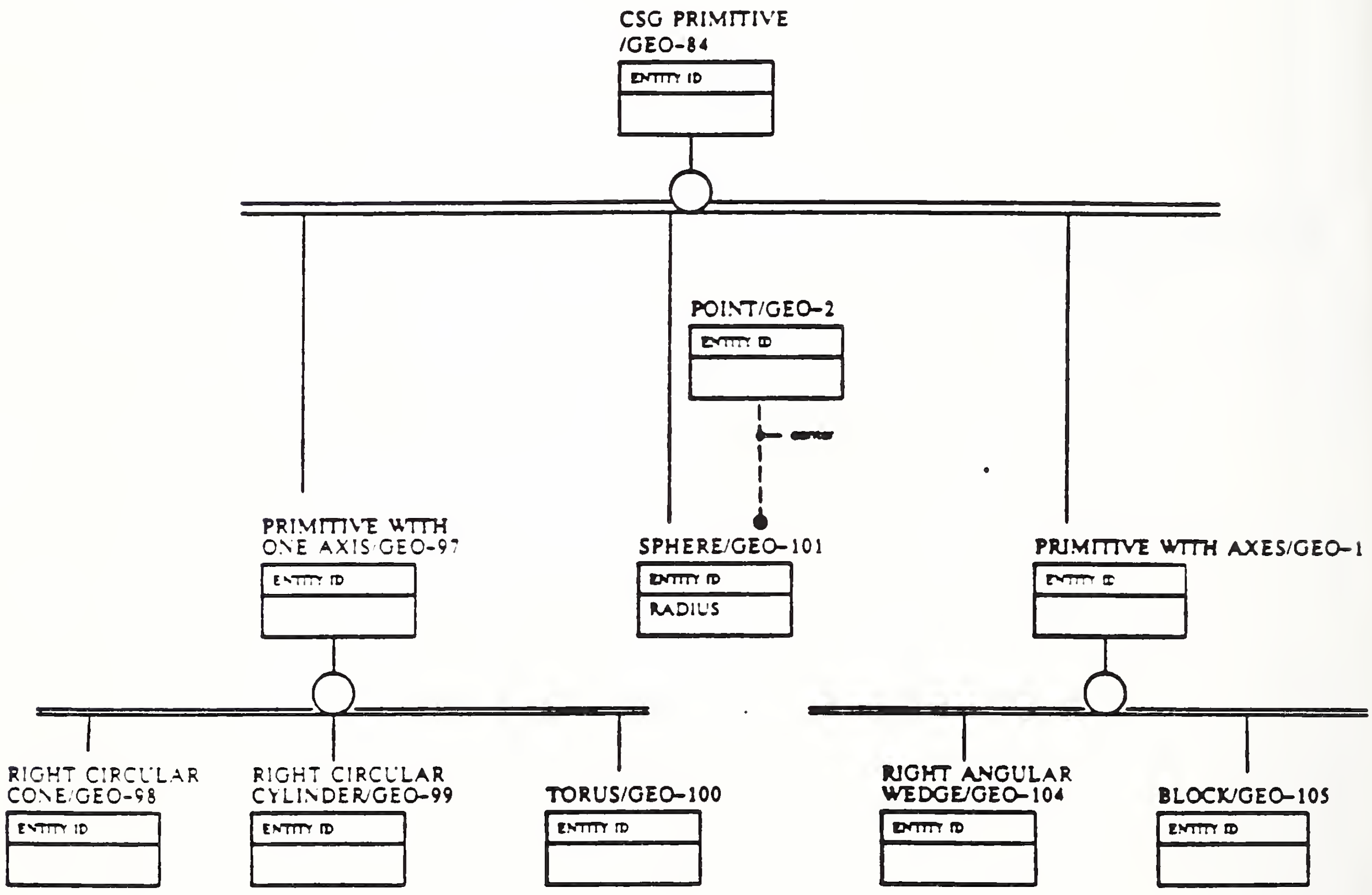


Figure D-28: SHAPE Entity/Relationship Diagram

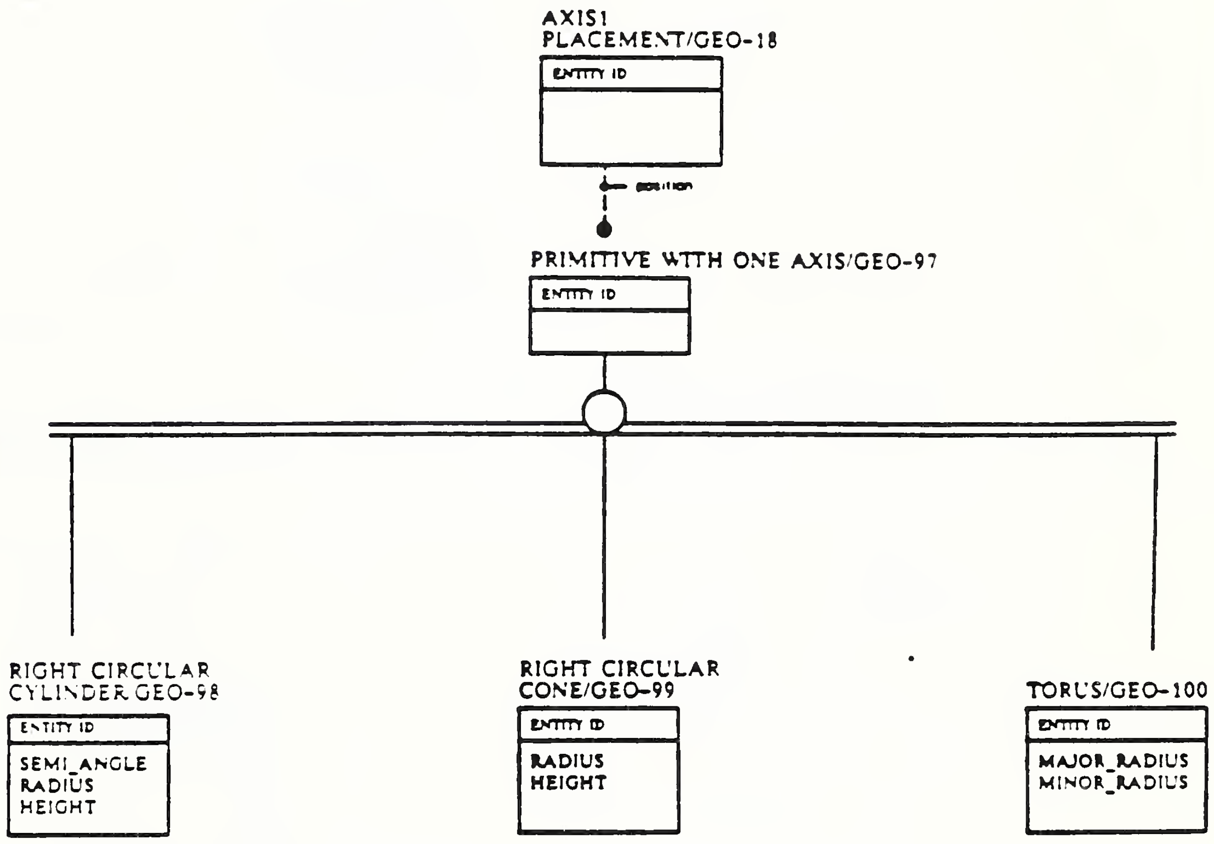


Figure D-29: SHAPE Entity/Relationship Diagram

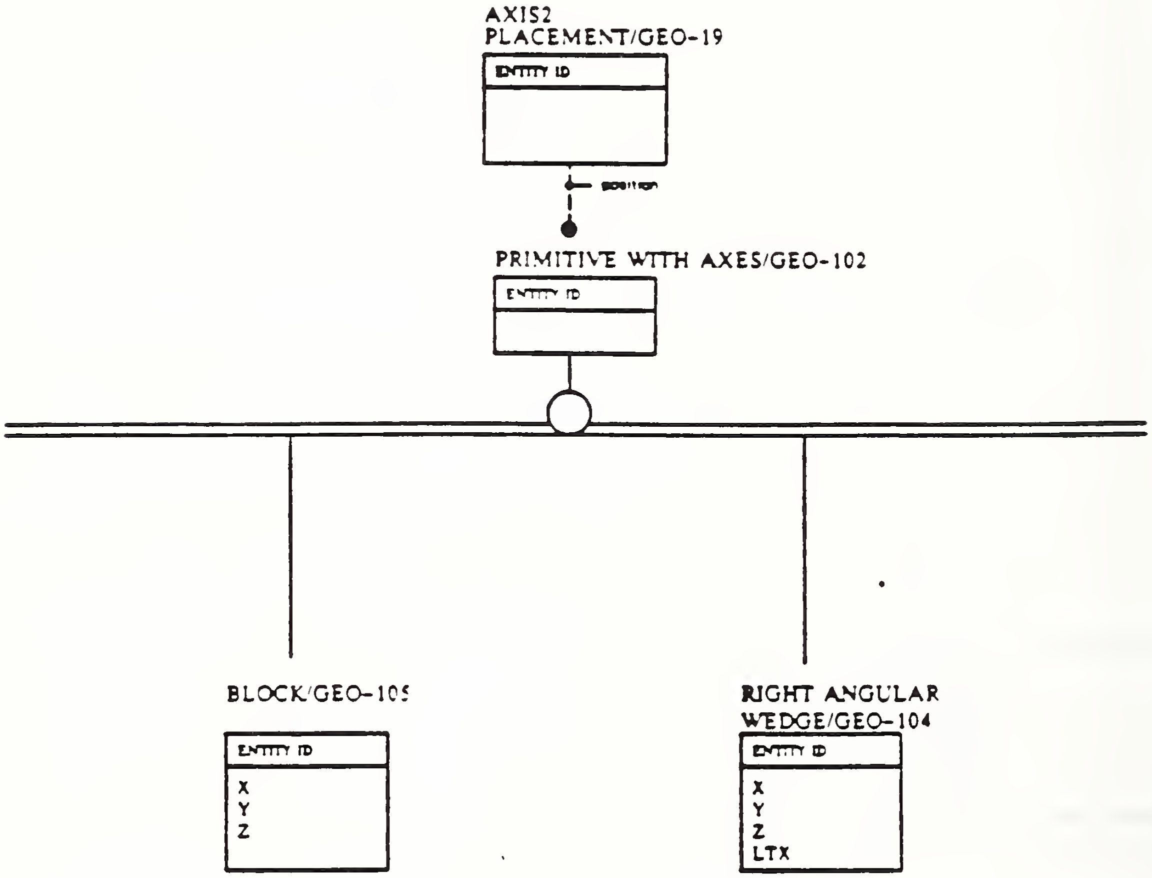


Figure D-30: SHAPE Entity/Relationship Diagram

N 288

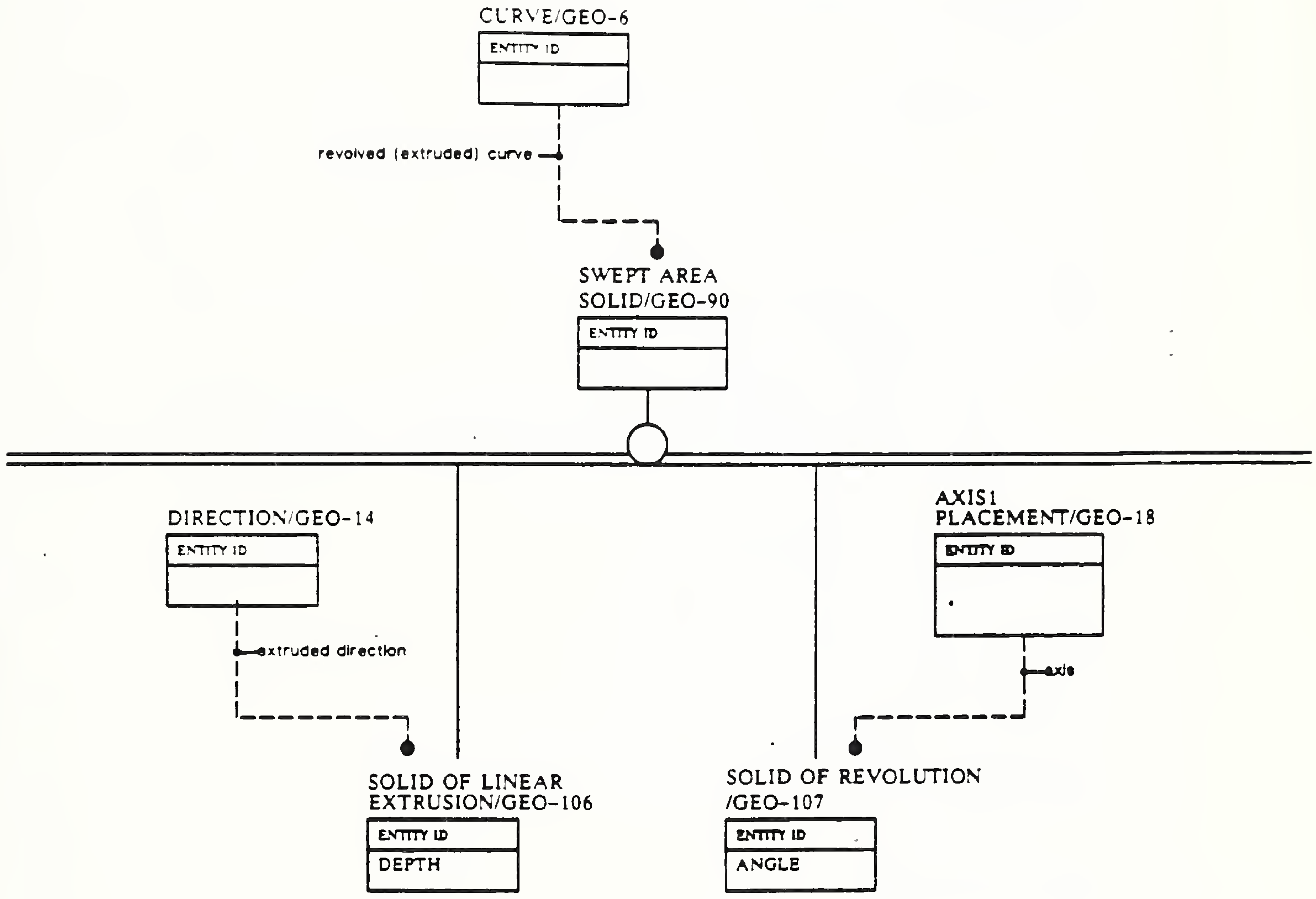


Figure D-31: SHAPE Entity/Relationship Diagram

2.5 TOPOLOGY

Entity Name: TOPOLOGY

Entity Number: TOP-1

A collector for all topological entities.

Primary Key Attributes

TOPOLOGY_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY topology
  SUPERTYPE OF (vertex XOR edge XOR path XOR loop XOR face XOR
                subface XOR shell XOR region);
END_ENTITY;
```

Entity Name: VERTEX

Entity Number: TOP-2

A topological vertex.

Primary Key Attributes

VERTEX_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY vertex
  SUBTYPE OF (topology);
```

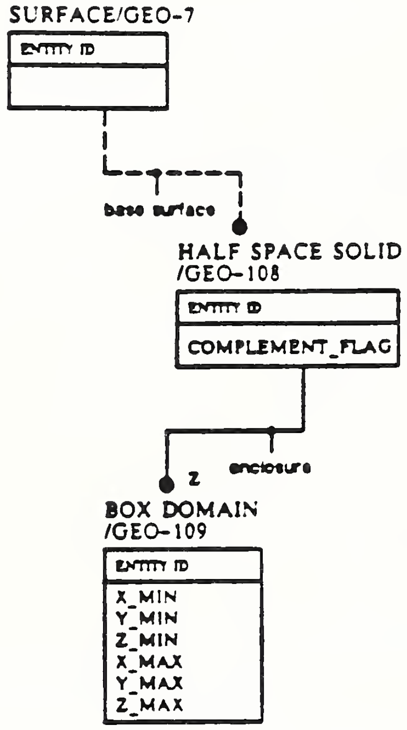


Figure D-32: SHAPE Entity/Relationship Diagram

```
    vertex_point : OPTIONAL point;
  END_ENTITY;
```

Entity Name: **EDGE**

Entity Number: **TOP-3**

A topological edge.

Primary Key Attributes

EDGE_ID

Other Attributes

EDGE_START_VERTEX_ID (FK)
 Start point (vertex) of the edge.

EDGE_END (FK)
 End point (vertex) of the edge.

Business Rules

EXPRESS Specification

```
  ENTITY edge
    SUBTYPE OF (topology);
    edge_start : vertex;
    edge_end   : vertex;
    edge_curve : OPTIONAL curve_logical_structure;
  END_ENTITY;
```

Entity Name: **LOOP**

Entity Number: **TOP-4**

A collector for all types of topological loops.

Primary Key Attributes

LOOP_ID

Other Attributes

LOOP_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
    ENTITY loop
      SUPERTYPE OF (vertex_loop XOR edge_loop XOR poly_loop)
      SUBTYPE OF (topology);
    END_ENTITY;
```

Entity Name: FACE

Entity Number: TOP-5

A topological face.

Primary Key Attributes

FACE_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
    ENTITY face
      SUBTYPE OF (topology);
      outer_bound    : OPTIONAL loop_logical_structure;
      bounds         : set [1 : #] OF loop_logical_structure;
      face_surface   : OPTIONAL surface_logical_structure;
    END_ENTITY;
```

Entity Name: SHELL

Entity Number: TOP-6

A collector for all types of topological shells.

Primary Key Attributes

SHELL_ID

Other Attributes

SHELL_TYPE (discriminator)

Business Rules

EXPRESS Specification

```
ENTITY shell
  SUPERTYPE OF (vertex_shell XOR wire_shell XOR open_shell XOR
                closed_shell)
  SUBTYPE OF (topology);
END_ENTITY;
```

Entity Name: **PATH**

Entity Number: **TOP-7**

A collection of edges joined end to end.

Primary Key Attributes

PATH_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY path
  SUBTYPE OF (topology);
  open_edge_list : LIST [1 : #] OF UNIQUE edge_logical_structure;
END_ENTITY;
```

Entity Name: **SUBFACE**

Entity Number: **TOP-8**

A SUBFACE is a portion of the domain of a FACE/TOP-5 or another SUBFACE/TOP-8.

Primary Key Attributes

SUBFACE_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY subface
  SUBTYPE OF (topology);
  outer_bound : loop_logical_structure;
  bounds      : SET [1 : #] OF loop_logical_structure;
  trimming    : select_face_or_subface;
END_ENTITY;
```

Entity Name: REGION

Entity Number: TOP-9

A collection of SHELL/TOP-6.

Primary Key Attributes

REGION_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY region
  SUBTYPE OF (topology);
  outer_region_boundary : OPTIONAL shell_logical_structure;
  region_boundaries     : SET [1 : #] OF shell_logical_structure;
END_ENTITY;
```

Entity Name: **VERTEX_LOOP**

Entity Number: **TOP-10**

A loop composed of a single vertex.

Primary Key Attributes

VERTEX_LOOP_ID

Other Attributes

VERTEX_ID (FK)
The unique vertex which composes the entire loop.

Business Rules

EXPRESS Specification

```
ENTITY vertex_loop
  SUBTYPE OF (loop);
  loop_vertex : UNIQUE vertex;
END_ENTITY;
```

Entity Name: **POLY_LOOP**

Entity Number: **TOP-11**

A ordered co-planar collection of points forming the vertices of a loop. The loop is composed of straight line segments joining point in the collection to the succeeding point in the collection. The closing segment is from the last to the first point in the collection. The direction of the loop is the direction of the line segments.

Primary Key Attributes

POLY LOOP_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY poly_loop
  SUBTYPE OF (loop);
  polygon : LIST [3 : #] OF UNIQUE point;
END_ENTITY;
```

Entity Name: EDGE_LOOP

Entity Number: TOP-12

A topological loop represented by an ordered collection of (edge + logical) pairs such that adjacent edges in the loop are adjacent in the collection. The vertices of the loop may be determined by examining the edge data. The logical indicator is used to identify whether the positive edge direction agrees with (TRUE) or is opposed to (FALSE) the positive direction of the loop.

Primary Key Attributes

EDGE_LOOP_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY edge_loop
  SUBTYPE OF (loop);
  loop_edges : LIST [1 : #] OF UNIQUE edge_logical_structure;
END_ENTITY;
```

Entity Name: LOCATED_VERTEX

Entity Number: TOP-13

The use of a POINT/GEO-2 to locate a VERTEX/TOP-2 in a coordinate space.

Primary Key Attributes

VERTEX_ID (FK)

Other Attributes

POINT_ID (FK)
Location of the vertex.

Business Rules

EXPRESS Specification

See located_vertex attribute of EXPRESS for VERTEX/TOP-2.

Entity Name: **POLY_POINT**

Entity Number: **TOP-14**

The use of a POINT/GEO-2 in a POLY-LOOP/TOP-11.

Primary Key Attributes

POLY_LOOP_ID (FK)

POINT_ID (FK)

Other Attributes

None

Business Rules

EXPRESS Specification

See polygon attribute of EXPRESS for POLY_LOOP/TOP-11.

Entity Name: **CURVE_LOGICAL_STRUCTURE**

Entity Number: **TOP-15**

The use of a CURVE/GEO-6 as the underlying geometry of a EDGE/TOP-3.

Primary Key Attributes

EDGE_ID (FK)

Other Attributes

CURVE_ID (FK)
The underlying geometry of the edge.

FLAG
Logical value which indicates whether the curve direction agrees with (TRUE) or is in the opposite direction (FALSE) to the edge direction.

Business Rules

EXPRESS Specification

```
ENTITY curve_logical_structure;
  curve_element : curve;
  flag          : LOGICAL;
END_ENTITY;
```

Entity Name: **LOOP_EDGE_LOGICAL_STRUCTURE**

Entity Number: **TOP-16**

The use of an EDGE/TOP-3 in a EDGE_LOOP/TOP-12.

Primary Key Attributes

EDGE_LOOP_ID (FK)

EDGE_ID (FK)

FLAG
Logical value which indicates whether the edge direction agrees with (TRUE) or is in the opposite direction (FALSE) to the loop direction.

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY loop_edge_logical_structure;
  edge_element : edge;
  flag         : LOGICAL;
```

```
END_ENTITY;
```

Entity Name: **PATH_EDGE_LOGICAL_STRUCTURE**

Entity Number: **TOP-17**

The use of an EDGE/TOP-3 in a PATH/TOP-7.

Primary Key Attributes

PATH_ID (FK)

EDGE_ID (FK)

Other Attributes

FLAG
Logical value which indicates whether the edge direction agrees with (TRUE) or is in the opposite direction (FALSE) to the path direction.

Business Rules

EXPRESS Specification

Use edge_logical_structure defined in EXPRESS for LOOP_EDGE_LOGICAL_STRUCTURE/TOP-16.

Entity Name: **CLOSED_SHELL**

Entity Number: **TOP-18**

A collection of faces joined side to side to create a boundary which divides space into two regions, one finite and the other infinite. The topological normal of the shell is directed from the finite to the infinite region.

Primary Key Attributes

CLOSED_SHELL_ID (FK)

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY closed_shell
  SUBTYPE OF (shell);
  cshell_boundary : SET [1 : # ] OF face_logical_structure;
END_ENTITY;
```

Entity Name: **OPEN_SHELL**

Entity Number: **TOP-19**

A collection of faces joined side to side to create an arcwise connected manifold oriented finite topological surfaces that is mappable to a plane.

Primary Key Attributes

OPEN_SHELL_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
ENTITY open_shell
  SUBTYPE OF (shell);
  shell_boundary : SET [1 : # ] OF face_logical_structure;
END_ENTITY;
```

Entity Name: **VERTEX_SHELL**

Entity Number: **TOP-20**

A shell consisting of a single VERTEX_LOOP/TOP-10.

Primary Key Attributes

VERTEX_SHELL_ID

Other Attributes

VERTEX_LOOP_ID (FK)

Business Rules

EXPRESS Specification

```
    ENTITY vertex_shell
      SUBTYPE OF (shell);
      vertex_shell_boundary : UNIQUE vertex_loop;
    END_ENTITY;
```

Entity Name: **WIRE_SHELL**

Entity Number: **TOP-21**

A shell of dimensionality 1. It is represented by a connect graph, specifically by the set of loops forming the graph.

Primary Key Attributes

WIRE_SHELL_ID

Other Attributes

None

Business Rules

EXPRESS Specification

```
    ENTITY wire_shell
      SUBTYPE OF (shell);
      wire_shell_boundary : SET [1 : #] OF edge_loop;
    END_ENTITY;
```

Entity Name: **CLOSED_SHELL_FACE_LOGICAL_STRUCTURE**

Entity Number: **TOP-22**

The use of a FACE/TOP-5 as a component of a CLOSED_SHELL/TOP-18.

<u>Primary Key Attributes</u>

CLOSED_SHELL_ID (FK)

FACE_ID (FK)

<u>Other Attributes</u>

FLAG
Logical value which indicates whether the face direction agrees with (TRUE) or is in the opposite direction (FALSE) to the shell direction.

<u>Business Rules</u>

<u>EXPRESS Specification</u>

```
ENTITY face_logical_structure;
  face_element : face;
  flag         : LOGICAL;
END_ENTITY;
```

<u>Entity Name:</u> **OPEN_SHELL_FACE_LOGICAL_STRUCTURE**

<u>Entity Number:</u> **TOP-23**

The use of a FACE/TOP-5 as a component of an OPEN_SHELL/TOP-19.

<u>Primary Key Attributes</u>

OPEN_SHELL_ID (FK)

FACE_ID (FK)

<u>Other Attributes</u>

FLAG
Logical value which indicates whether the face direction agrees with (TRUE) or is in the opposite direction (FALSE) to the shell direction.

<u>Business Rules</u>

<u>EXPRESS Specification</u>

See entity face_logical_structure in EXPRESS for CLOSED_SHELL_FACE_LOGICAL_STRUCTURE/TOP-22.

Entity Name: SURFACE_LOGICAL_STRUCTURE

Entity Number: TOP-24

The use of a SURFACE/GEO-7 as the geometry of a FACE/TOP-5.

Primary Key Attributes

FACE_ID (FK)

Other Attributes

SURFACE_ID (FK) Geometric surface underlying face.

FLAG
Logical value which indicates whether the surface normal agrees with (TRUE) or is in the opposite direction (FALSE) to the face normal.

Business Rules

EXPRESS Specification

```
ENTITY surface_logical_structure;
  surface_element : surface;
  flag            : LOGICAL;
END_ENTITY;
```

Entity Name: LOOP_LOGICAL_STRUCTURE

Entity Number: TOP-25

The use of a LOOP/TOP-4 as a portion of or all of the boundary of a FACE/TOP-5.

Primary Key Attributes

FACE_ID (FK)

LOOP_ID (FK)

Other Attributes

FLAG
Logical value which indicates whether the loop direction agrees with (TRUE) or is in the opposite direction (FALSE) to the face direction.

OUTER_BOUND
Three value flag to indicate whether this loop is an outer bound.

TRUE
Loop is outer bound.

FALSE
Loop is not outer bound.

UNDEFINED
Whether loop is outer bound or not is unknown.

Business Rules

EXPRESS Specification

```
ENTITY loop_logical_structure;
  loop_element : loop;
  flag         : LOGICAL;
END_ENTITY;
```

For EXPRESS of OUTER_BOUND attribute see "outer.bound" attribute in EXPRESS for FACE/TOP-5.

Entity Name: **WIRE_SHELL_LOOP_LOGICAL_STRUCTURE**

Entity Number: **TOP-26**

The use of a LOOP/TOP-4 a a component in a WIRE_SHELL/TOP-21.

Primary Key Attributes

WIRE_SHELL_ID (FK)

EDGE LOOP_ID (FK)

Other Attributes

FLAG
Logical value which indicates whether the loop direction agrees with (TRUE) or is in the opposite direction (FALSE) to the used direction.

Business Rules

EXPRESS Specification

See ENTITY loop_logical_structure in EXPRESS for LOOP_LOGICAL_STRUCTURE/TOP-25.

Entity Name: **SUBFACE_ON_FACE**

Entity Number: **TOP-27**

A SUBFACE/TOP-8 trimming a FACE/TOP-5.

Primary Key Attributes

SUBFACE_ID (FK)

Other Attributes

FACE_ID (FK)

Business Rules

EXPRESS Specification

See EXPRESS entity subface in EXPRESS for SUBFACE/TOP-8.

Entity Name: **RECURSIVE_SUBFACE**

Entity Number: **TOP-28**

A SUBFACE/TOP-8 trimming another SUBFACE/TOP-8.

Primary Key Attributes

SUBFACE_ID (FK)

Other Attributes

TRIMMIMG_SUBFACE_ID (FK)

Business Rules

EXPRESS Specification

See EXPRESS entity subface in EXPRESS for SUBFACE/TOP-8.

Entity Name: **SUBFACE_LOOP_LOGICAL_STRUCTURE**

Entity Number: **TOP-29**

The use of a LOOP/TOP-4 as a portion of or all of the boundary of a SUBFACE/TOP-8.

Primary Key Attributes

SUBFACE_ID (FK)

LOOP_ID (FK)

Other Attributes

FLAG Logical value which indicates whether the loop direction agrees with (TRUE) or is in the opposite direction (FALSE) to the subface direction.

OUTER_BOUND Three value flag to indicate whether this loop is an outer bound. TRUE -loop is outer bound. FALSE -loop is not outer bound. UNDEFINED -Whether loop is outer bound or not is unknown.

Business Rules

EXPRESS Specification

See ENTITY loop_logical_structure in EXPRESS for LOOP_LOGICAL_STRUCTURE/TOP-25.

Entity Name: **REGION_SHELL_LOGICAL_STRUCTURE**

Entity Number: **TOP-30**

The use of a SHELL/TOP-6 as a component of a REGION/TOP-9.

Primary Key Attributes

REGION_ID (FK)

SHELL_ID (FK)

FLAG
Logical value which indicates whether the shell direction agrees with (TRUE) or is in the opposite direction (FALSE) to the region's use of the shell.

Other Attributes

OUTER_REGION_BOUNDARY
Three value flag to indicate whether this shellis an outer bound.

TRUE
Shell is outer bound.

FALSE
Shell is not outer bound.

UNDEFINED
Whether shell is outer bound or not is unknown.

Business Rules

EXPRESS Specification

```
ENTITY shell_logical_structure;
  shell_element : shell;
  flag          : LOGICAL;
END_ENTITY;
```

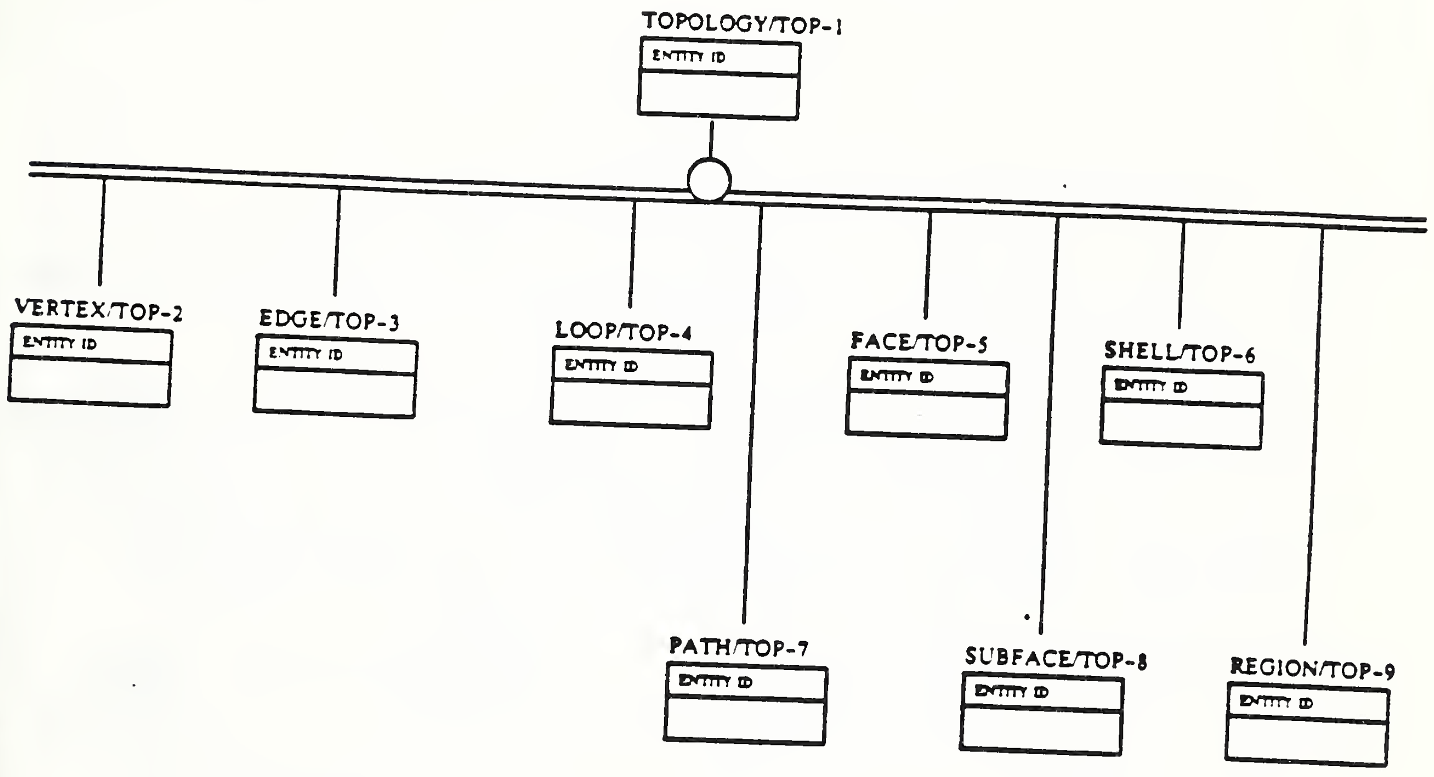


Figure D-33: SHAPE Entity/Relationship Diagram

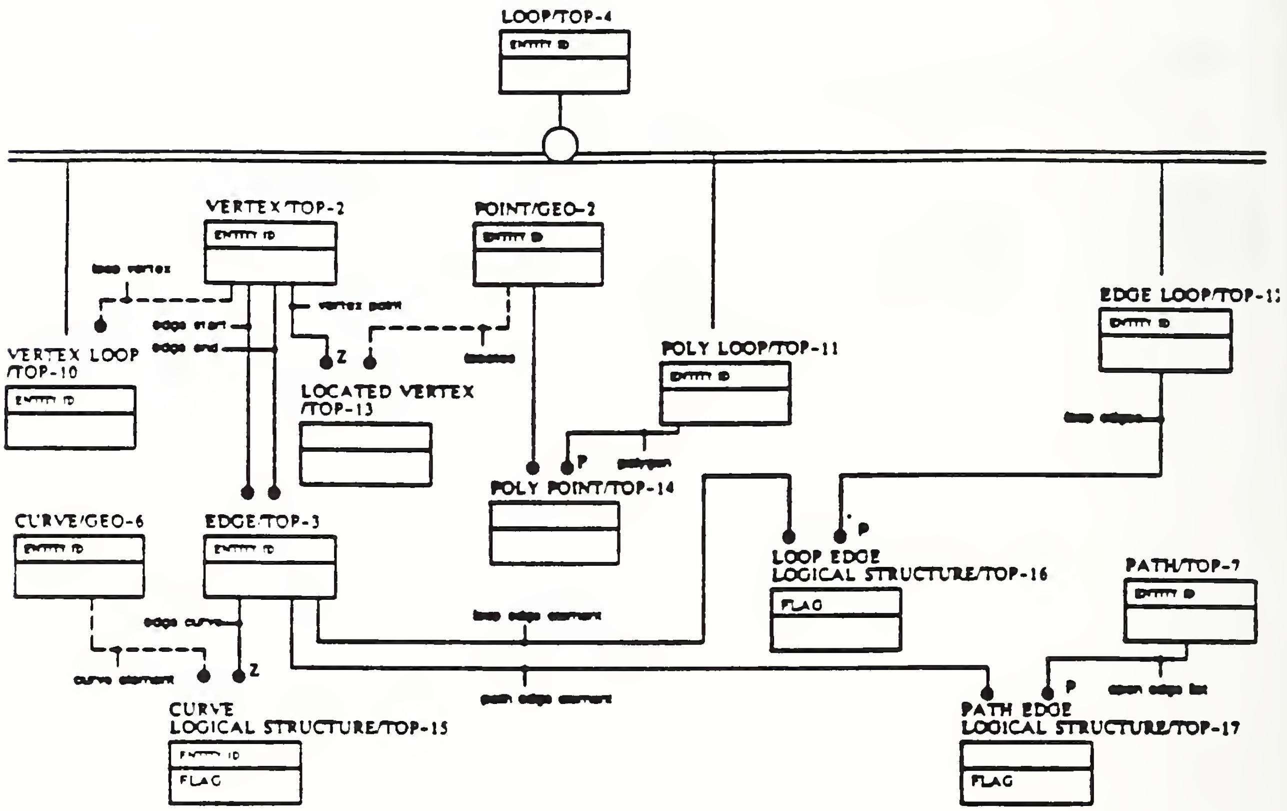


Figure D-34: SHAPE Entity/Relationship Diagram

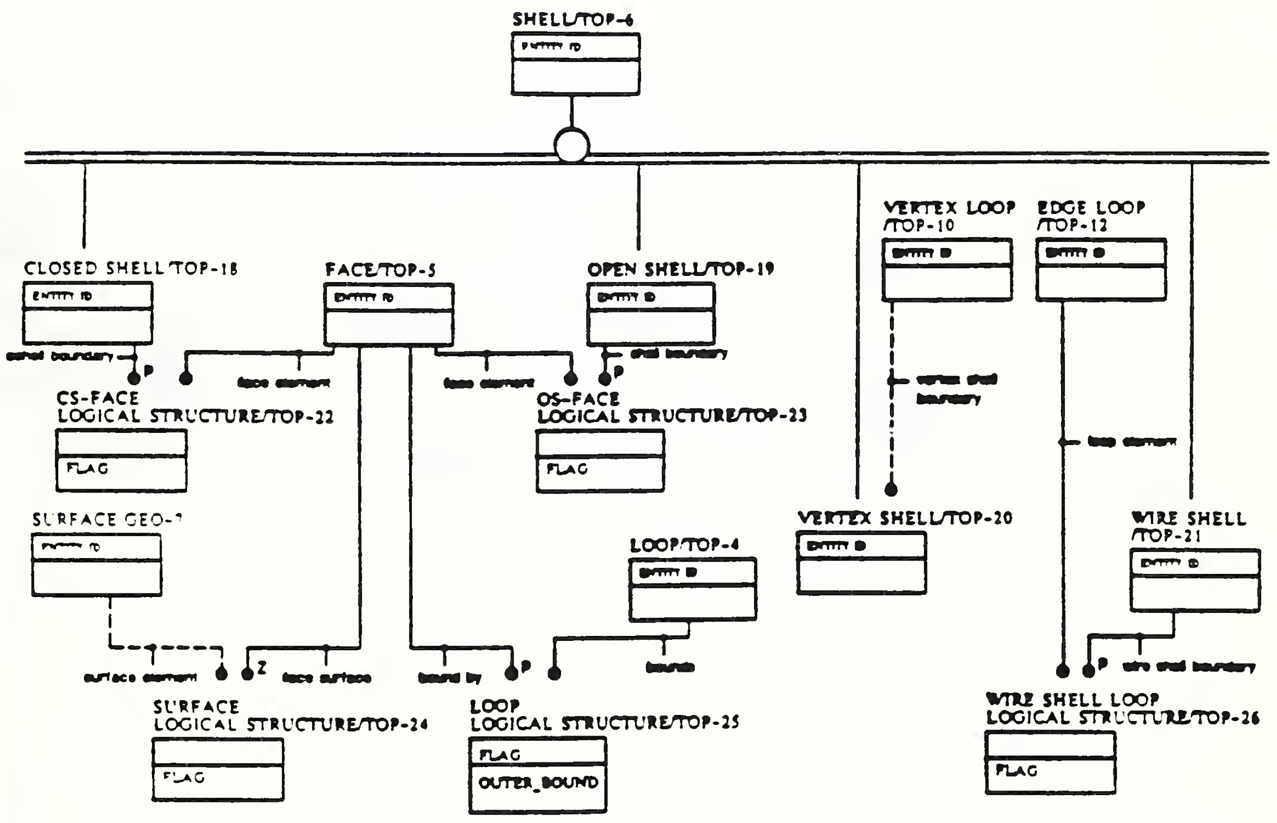


Figure D-35: SHAPE Entity/Relationship Diagram

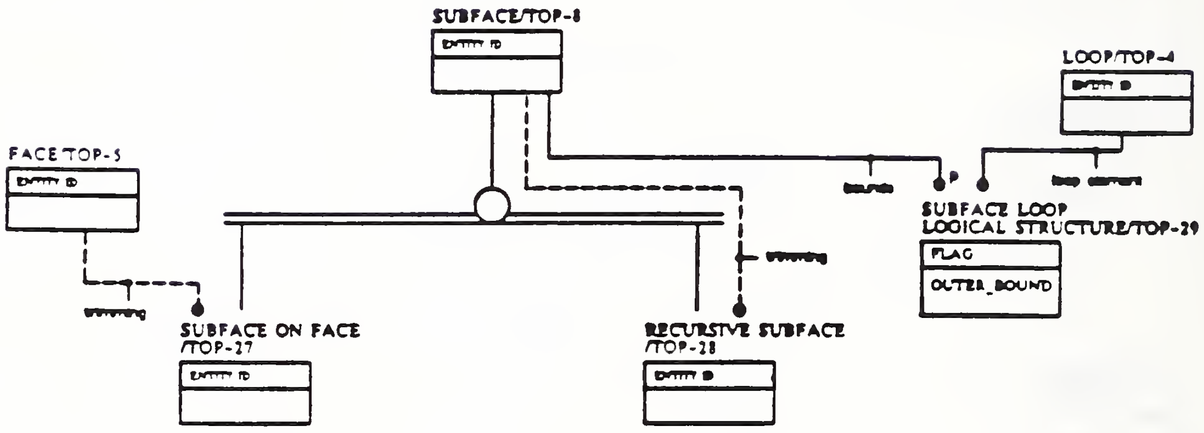


Figure D-36: SHAPE Entity/Relationship Diagram

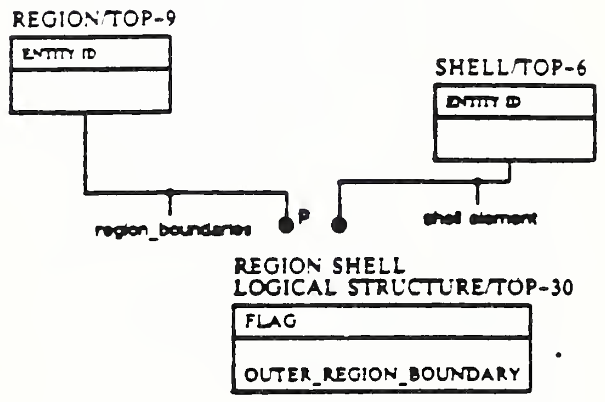


Figure D-37: SHAPE Entity/Relationship Diagram

Number	NAME
GEO-1	GEOMETRY
GEO-2	POINT
GEO-3	VECTOR
GEO-4	AXIS_PLACEMENT
GEO-5	TRANSFORMATION_MATRIX
GEO-6	CURVE
GEO-7	SURFACE
GEO-8	CARTESIAN_POINT
GEO-10	CARTESIAN_TWO_POINT
GEO-11	CARTESIAN_THREE_POINT
GEO-12	POINT_ON_CURVE
GEO-13	POINT_ON_SURFACE
GEO-14	DIRECTION
GEO-15	TWO_SPACE_DIRECTION
GEO-16	THREE_SPACE_DIRECTION
GEO-17	VECTOR_WITH_MAGNITUDE
GEO-18	AXIS1_PLACEMENT
GEO-19	AXIS2_PLACEMENT
GEO-20	LINE
GEO-21	CONIC
GEO-22	BOUNDED CURVE
GEO-23	CURVE_ON_SURFACE
GEO-24	OFF_SET
GEO-25	CIRCLE
GEO-26	ELLIPSE
GEO-27	HYPERBOLA
GEO-28	PARABOLA
GEO-29	LINE_SEGMENT
GEO-30	BEZIER_CURVE
GEO-31	B_SPLINE_CURVE
GEO-32	TRIMMED_CURVE
GEO-33	COMPOSITE_CURVE
GEO-34	CONTROL_POINT_BEZIER
GEO-35	CONTROL_POINT_ORDER_BEZIER
GEO-36	KNOT
GEO-37	CONTROL POINT
GEO-38	CONTROL_POINT_ORDER
GEO-39	POINT_POINT_TRIMMED_CURVE
GEO-40	POINT_PARAM_TRIMMED_CURVE
GEO-41	PARAM_POINT_TRIMMED_CURVE

Table 1: Entity Pool - Numeric Order

Number	NAME
GEO-42	PARAM PARAM_TRIMMED CURVE
GEO-43	KNOT_ORDER
GEO-44	SEGMENT
GEO-45	SEGMENT_ORDER
GEO-46	PCURVE
GEO-47	SURFACE_CURVE
GEO-48	SURFACE_CURVE_PCURVE
GEO-49	INTERSECTION CURVE
GEO-50	COMPOSITE_CURVE_ON_SURFACE
GEO-51	PCURVE_PCURVE INTERSECTION
GEO-52	PCURVE_SURFACE_INTERSECTION
GEO-53	SURFACE_SURFACE_INTERSECTION
GEO-54	ON_SURFACE_SEGMENT
GEO-55	ON_SURFACE_SEGMENT_ORDER
GEO-56	TWO_D_OFFSET_CURVE
GEO-57	THREE_D_OFFSET_CURVE
GEO-58	ELEMENTARY_SURFACE
GEO-59	BEZIER_SURFACE
GEO-60	B_SPLINE_SURFACE
GEO-61	SWEPT_SURFACE
GEO-62	RECTANGULAR_TRIMMED_SURFACE
GEO-63	BOUNDED_SURFACE
GEO-64	OFFSET_SURFACE
GEO-65	RECTANGULAR_COMPOSITE_SURFACE
GEO-66	PLANE
GEO-67	CYLINDRICAL_SURFACE
GEO-68	CONICAL_SURFACE
GEO-69	SPHERICAL_SURFACE
GEO-70	TOROIDAL_SURFACE
GEO-71	SURFACE_OF_LINEAR_EXTRUSION
GEO-72	SURFACE_OF_REVOLUTION
GEO-73	B_SPLINE_SURFACE_KNOT
GEO-74	BS_SURFACE_KNOT_ORDER
GEO-77	BEZIER_SURFACE_CONTROL_POINT
GEO-78	BZ_SURFACE_CONTROL_POINT_ORDER
GEO-79	RECTANGULAR_COMPOSITE_SURFACE_PATCH
GEO-80	RC_SURFACE_PATCH_ORDER
GEO-81	BOUNDED_SURFACE_BOUNDARY
GEO-82	SOLID_MODEL
GEO-84	CSG_PRIMITIVE

Table 1: Entity Pool – Numeric Order

Number	NAME
GEO-85	CSG_SOLID
GEO-86	FACETTED_B_REP
GEO-87	HALF_SPACE
GEO-88	MANIFOLD_SOLID_B_REP
GEO-89	SOLID_INSTANCE
GEO-90	SWEPT_AREA_SOLID
GEO-91	BOOLEAN_OPERATION
GEO-92	UNION
GEO-93	INTERSECTION
GEO-94	DIFFERENCE
GEO-96	BREP_SHELL_LOGICAL_STRUCTURE
GEO-97	PRIMITIVE_WITH_ONE_AXIS
GEO-98	RIGHT_CIRCULAR_CYLINDER
GEO-99	RIGHT_CIRCULAR_CONE
GEO-100	TORUS
GEO-101	SPHERE
GEO-102	PRIMITIVE_WITH_AXES
GEO-104	RIGHT_ANGULAR_WEDGE
GEO-105	BLOCK
GEO-106	SOLID_OF_LINEAR_EXTRUSION
GEO-107	SOLID_OF_REVOLUTION
GEO-108	BOX_DOMAIN
TOP-1	TOPOLOGY
TOP-2	VERTEX
TOP-3	EDGE
TOP-4	LOOP
TOP-5	FACE
TOP-6	SHELL
TOP-7	PATH
TOP-8	SUBFACE
TOP-9	REGION
TOP-10	VERTEX_LOOP
TOP-11	POLY_LOOP
TOP-12	EDGE_LOOP
TOP-13	LOCATED_VERTEX
TOP-14	POLY_POINT
TOP-15	CURVE_LOGICAL_STRUCTURE
TOP-16	LOOP_EDGE_LOGICAL_STRUCTURE
TOP-17	PATH_EDGE_LOGICAL_STRUCTURE
TOP-18	CLOSED_SHELL

Table 1: Entity Pool – Numeric Order

Number	NAME
TOP-19	OPEN_SHELL
TOP-20	VERTEX_SHELL
TOP-21	WIRE_SHELL
TOP-22	CLOSED_SHELL_FACE_LOGICAL_STRUCTURE
TOP-23	OPEN_SHELL_FACE_LOGICAL_STRUCTURE
TOP-24	SURFACE_LOGICAL_STRUCTURE
TOP-25	LOOP.LOGICAL.STRUCTURE
TOP-26	WIRE_SHELL_LOOP_LOGICAL_STRUCTURE
TOP-27	SUBFACE ON_FACE
TOP-28	RECURSIVE_SUBFACE
TOP-29	SUBFACE_LOOP_LOGICAL.STRUCTURE
TOP-30	REGION_SHELL_LOGICAL_STRUCTURE

3 SHAPE VARIATION TOLERANCES

3.1 Abstract

Dimensions on an engineering drawing define the theoretically exact shape of a three-dimensional object. Tolerances on those dimensions define the allowable deviation of the dimension from the nominal value as measured on the manufactured object. ANSI Y14.5M 1982 and ISO 1660,1101 specify the standard representation for dimensions and tolerances on engineering drawings. The reference model captures the semantic content of the dimensions and tolerances as specified in those standards.

3.2 Purpose & Scope

3.2.1 Purpose

The most important task in a manufacturing enterprise is providing sufficient information to production to allow for planning, manufacturing, and inspection of a product. This information is referred to as product definition data. Part of the product definition data is the representation of the desired shape of the product. Another, as equally important, part of this data is information concerning how accurately the manufactured object must correlate to the shape defined within the product definition. These limits on acceptable deviation are referred to as tolerances. To the design engineer, tolerances provide a tool for controlling critical aspects of the products shape. The process planner must make manufacturing decisions based on tolerances because of the varying precision of machine tools. Most importantly, tolerances give Quality Assurance criteria with which to accept or reject a product.

Product definition data is currently conveyed on engineering drawings. The product's shape is represented pictorially with graphics and annotated dimensions which define the theoretically exact shape of the product. Specific tolerances are annotated to the dimensions and defaults are placed elsewhere on the drawing, typically in the title block. As advanced manufacturing systems make more use of digital product models, the shape and the tolerances must be represented completely and unambiguously (this is not to imply that engineering drawings are unambiguous, however.) As the communication of the product definition data migrates from engineering drawings to digital product models, it is important that the meaning of the dimensions and tolerances as found on engineering drawings be preserved.

The reference model contained in this document attempts to identify, define and record that meaning. It is assumed that the readers of this document have not only a working knowledge of the IDEF1X and Express modelling languages, but also a very thorough knowledge of dimensioning and tolerancing practices as described in the ANSI and ISO standards. This document is not a lesson in dimensioning and tolerancing, but captures the information content of the standard practices and concepts.

3.2.2 Scope and Viewpoint

This document provides the definition of the functional content for dimensioning and tolerancing practices as specified by ANSI Y14.5M-1986 and ISO 1101 and 1660. These specifications are considered to be functionally identical for the purposes of this effort.

This information model is intended to completely define all tolerance information specified by ANSI Y14.5M-1982 and the corresponding ISO specifications. Any deficiencies should be commented on in writing.

The primary viewpoint of the reference model will be on the application of the tolerances specified in the above standards to three dimensional, mechanical parts.

The information model contains the functional tolerancing data set as it pertains to a single finished part model. Reference to tolerances as they affect various stages of production or preliminary forms of the part (such as casted design) are not accomodated in this model except by reference to a separate Product Model.

The tolerances described in the model reference Product Model Features as described by the Mechanical Products, Form Features and Solids Committee. These include reference to both explicit and implicit form features, topologies and geometries.

Excluded from the scope are:

- Computing tolerances
- Process tolerances
- Pictorial representations of tolerances
- Dimensioning practices (i.e. what constitutes good dimensioning practice)
- Non-mechanical part tolerances (e.g. electrical component values)
- Surface finish/surface roughness specifications
- Efficiencies regarding computer memory requirements or processing methodologies

3.3 Fundamental Concepts and Assumptions

Product models are assumed to be complete, unambiguous, three-dimensional definitions of the shape of the desired object, typically represented by a Boundary Representation (BREP) Solids model or an equivalent bounded, surfaced, Wireframe Model. The general requirement is the capability to reference shape defining elements of the surface of modelled product. The terms Area, Seam and Corner, as defined in the PDES Integration Model, are used within this model to refer to the appropriate shape element (and correspond roughly to the BREP notions of Face, Edge and Vertex.)

Geometric elements always underlie the Topologic elements Face, Edge and Vertex. (This assumption is probably moot in light of the work of the Integration Committee.)

Product Models contain exact definitions of nominal product geometry, i.e. the model is considered BASIC.

The value of the dimension is implicit in model geometry or is an explicit parameter of an implicit feature. Each Tolerance specified within a model implies an underlying dimension.

Graphical display of tolerance information will conform to ANSI Y14.5M 1982, specifically the Feature Control Frame.

The tolerances described in this information model include both Coordinate Tolerances and Geometric Tolerances. Both type of tolerances are described as they pertain to common tolerancing practices which are used to define the form, fit and function of the modelled product.

Independent or dependent geometric constructs may be needed in addition to shape defining elements to specify certain types of tolerances. Examples of these are hole centerlines, off-part datums or other derived geometries. Therefore, it is assumed that these constructs are present/available as part of the product definition model for reference in tolerances.

All tolerances dimensions are derived from shape/size elements or explicitly stated as part of implicit features.

Note on Model Content

This version of the Tolerance Model expands on two concepts which are only cursorily addressed in earlier versions: dimensions and geometric derivations. Coordinate Tolerances, as defined in previous versions of the model, contained "extra" data that was intended to facilitate the determination of the value of the intended dimension. This version of the model flips the emphasis from the tolerance to the dimension: coordinate dimensions are defined and the tolerance values are the "extra" data.

Geometric derivations are defined to accommodated typical dimension practices which reference geometry that is not part of the shape definition of the object but is derivable from shape elements. The most common examples are centerlines of holes and the spatial intersection of two part surfaces.

Entity numbers used are local only to this model and are included for bookkeeping/review purposes.

This model constitutes an integration of version 2.1 of the model and the results of the interim meeting 15th – 18th February 1988 as reported in the technical report dated 25th March 1988. Because of the new work, some entities from version 2.1 have been deleted or replaced. Replacement entities have been assigned the same entity number as the entity they replaced. New entities have been assigned new number. In particular, the dimension entities have been assigned numbers in the 600's.

This model also constitutes an integration with other mature topical models. The work of the Integration Committee is reflected in this work.

Note on Modelling Conventions

The reference model presented in this package does not strictly conform to IDEF1X modelling techniques. While the model may be read as an IDEF1X model from a structural point of view, the following conventions have been adopted:

1. Key attributes have not been defined. The Keys in the model are strictly identificational (i.e. contain no meaning) and are included to illustrate how an entity "points to" a related entity.

2. The distinction between Identifying and Non-identifying relationships has not uniformly been made. All relationships in this model may be considered non-identifying. This does not mean, however, that the existence of an entity will not depend on the existence of some other entity; this condition still may exist. Unless an attribute has been defined as "Optional",

the attributes of an entity must have a value when the entity is instanced. A fallout of this convention is that Dependent and Independent entities have not been identified.

3. To simplify the maintenance of the model, some liberties have been taken with the entity numbering scheme. Where entities have been included in the model for illustrative purposes only and the definition or existence of the entity is not important to the tolerance model, then entity is given an asterisk(*) rather than a number. When an entity had to be categorized due to IDEF1X syntax constraints (e.g. TOL-ENT = AREA-TOL-ENT + SEAM-TOL-ENT + FOS-TOL-ENT) the categorizations are given the same entity number as the generic parent.

3.4 Glossary

The Definitions provided here are for general terms which are not defined with the context of the model (such as entity and attribute definitions). It should be noted that some of the definitions imply scoping statements or assumptions made about the model.

Product An item(s) which is(are) manufactured, or used in the manufacturing of another item.

Product Model A digital definition/representation of a product.

Drawing A pictorial (image-based, human interpretable) definition/ representation of a product.

Dimension A measure of the shape of product that specifies a relationship between two geometric elements of the shape definition of a product or a parameter implicit within a geometric element. The numerical value of the dimension is implicit within the model geometry or explicitly called out in an implicit feature.

Feature Feature is some characteristic of an object or an object representation which can be uniquely identified. The same term is defined more completely within the ANSI standard.

Object Representation Object representation refers to the form in which the shape of a real or conceived object is defined.

Design Model A Design Model is the complete definition of a product, typically at the point of "release" to manufacturing, such as an engineering drawing or product model.

SECTION 3: SHAPE VARIATION TOLERANCES

3.5 Subject Reference Model

3.5.1 Entity Pool

This is a list of entities contained in this model: (Underlined entity numbers indicate a diagram page for the entity)

Number		Name
<u>603</u>	-	Angle Dimension
611	-	Angle Size Characteristic
609	-	Angle Size Dimension
610	-	Angle Size Parameter
4013	-	Angle Tolerance Range
<u>406</u>	-	Angularity
1023	-	Angul-Proj-Tol-Zone
506	-	Angul-Tol-Ent
5061	-	Angul-Tol-Ent-Seam
5062	-	Angul-Tol-Ent-Area
5063	-	Angul-Tol-Ent-FOS
INT-8	-	Area
<u>311</u>	-	Center of Symmetry
3111	-	Center of Symmetry-Size
3112	-	Center of Symmetry-Angle
508	-	Circ-Tol-Ent
5081	-	Circ-Tol-Ent-Seam
5082	-	Circ-Tol-Ent-Area
5083	-	Circ-Tol-Ent-FOS
<u>407</u>	-	Circular Runout
<u>408</u>	-	Circularity
<u>409</u>	-	Concentricity
509	-	Conc-Tol-Ent
5091	-	Conc-Tol-Ent-Seam
5092	-	Conc-Tol-Ent-Area
5093	-	Conc-Tol-Ent-FOS
<u>302</u>	-	Conditioned Datum
<u>600</u>	-	Coordinate Dimension
<u>401</u>	-	Coordinate Tolerance Range
INT-20	-	Corner
507	-	Crun-Tol-Ent

Entity Pool in Alphabetic Order

Number		Name
5071	-	Crun-Tol-Ent-Seam
5072	-	Crun-Tol-Ent-Area
5073	-	Crun-Tol-Ent-FOS
6022	-	Curvi-linear Dim
410	-	Cylindricity
510	-	Cyl-Tol-Ent
5102	-	Cyl-Tol-Ent-Area
5103	-	Cyl-Tol-Ent-FOS
301	-	Datum
6102	-	Derivable Angle Size Dimension
6042	-	Derivable Size Parameter
109	-	Derived Geometry
GEO14	-	Direction
4151	-	Directrix
<u>202</u>	-	DT Area
<u>201</u>	-	DT Corner
<u>300</u>	-	DT Feature
<u>304</u>	-	DT Form Feature
<u>203</u>	-	DT Seam
<u>200</u>	-	DT Shape Element
<u>306</u>	-	Feature of Size
<u>411</u>	-	Flatness
511	-	Flat-Tol-Ent
FF001	-	Form Feature
3061	-	Form Feature of Size
110	-	GD-Inputs
111	-	GD-Inputs-GD
112	-	GD-Inputs-SE
113	-	GD-Parms
<u>108</u>	-	Geometric Derivation
<u>402</u>	-	Geometric Tolerance
GEO1	-	Geometry
FF002	-	Implicit Form Feature
6101	-	Independent Angle Size Dimension
6041	-	Independent Size Parameter
6021	-	Linear Dimension
<u>602</u>	-	Location Dimension

Entity Pool in Alphabetic Order - (Continued)

Number		Name
4012	-	Location Tolerance Range
412	-	Parallelism
1021	-	Parl-Proj-Tol-Zone
512	-	Parl-Tol-Ent
5121	-	Parl-Tol-Ent-Seam
5122	-	Parl-Tol-Ent-Area
5123	-	Parl-Tol-Ent-FOS
413	-	Perpendicularity
1022	-	Perp-Proj-Tol-Zone
513	-	Perp-Tol-Ent
5131	-	Perp-Tol-Ent-Seam
5132	-	Perp-Tol-Ent-Area
5133	-	Perp-Tol-Ent-FOS
515	-	Plin-Tol-Ent
5151	-	Plin-Tol-Ent-Seam
5152	-	Plin-Tol-Ent-Area
414	-	Position
1024	-	Pos-Proj-Tol-Zone
514	-	Pos-Tol-Ent
415	-	Profile of a Line
416	-	Profile of a Surface
102	-	Projected_Tolerance_Zone
516	-	Psrf-Tol-Ent
608	-	Related Angle Dimension
INT-14	-	Seam
3031	-	SF-Components
INT-2	-	Shape_Element
400	-	Shape_Tolerance
605	-	Size Characteristic
601	-	Size Dimension
303	-	Size Feature
604	-	Size Parameter
4011	-	Size Tolerance Range
4171	-	Straight-Direction
417	-	Straightness
517	-	Strght-Tol-Ent

Entity Pool in Alphabetic Order - (Continued)

Number		Name
5171	-	Strght-Tol-Ent-Seam
5172	-	Strght-Tol-Ent-Area
5173	-	Strght-Tol-Ent-FOS
418	-	Total Runout
518	-	Trun-Tol-Ent
5182	-	Trun-Tol-Ent-Area
5183	-	Trun-Tol-Ent-FOS
310	-	Unconditioned Datum

Entity Pool in Alphabetic Order - (Continued)

Number		Name
101	-	Direction
102	-	Projected Tolerance_Zone
1021	-	Parl-Proj-Tol-Zone
1022	-	Perp-Proj-Tol-Zone
1023	-	Angul-Proj-Tol-Zone
1024	-	Pos-Proj-Tol-Zone
108	-	Geometric Derivation
109	-	Derived Geometry
110	-	GD-Inputs
111	-	GD-Inputs-GD
112	-	GD-Inputs-SE
113	-	GD-Parms
200	-	DT Shape_Element
201	-	DT Corner
202	-	DT Seam
203	-	DT Area
300	-	DT_Feature
301	-	Datum
302	-	Conditioned Datum
303	-	Size Feature

Entity Pool in Numeric Order

SECTION 3: SHAPE VARIATION TOLERANCES

Number		Name
304	-	DT Form Feature
3031	-	SF-Components
306	-	Feature of Size
3061	-	Form Feature of Size
310	-	Unconditioned Datum
311	-	Center of Symmetry
3111	-	Center of Symmetry-Size
3112	-	Center of Symmetry-Angle
400	-	Shape_Tolerance
401	-	Coordinate Tolerance Range
4011	-	Size Tolerance Range
4012	-	Location Tolerance Range
4013	-	Angle Tolerance Range
402	-	Geometric Tolerance
406	-	Angularity
407	-	Circular Runout
408	-	Circularity
409	-	Concentricity
410	-	Cylindricity
411	-	Flatness
412	-	Parallelism
413	-	Perpendicularity
414	-	Position
415	-	Profile of a Line
4151	-	Directrix
416	-	Profile of a Surface
417	-	Straightness
4171	-	Straight-Direction
418	-	Total Runout
506	-	Angul-Tol-Ent
5061	-	Angul-Tol-Ent-Seam
5062	-	Angul-Tol-Ent-Area
5063	-	Angul-Tol-Ent-FOS
507	-	Crun-Tol-Ent
5071	-	Crun-Tol-Ent-Seam
5072	-	Crun-Tol-Ent-Area
5073	-	Crun-Tol-Ent-FOS

Entity Pool in Numeric Order - (Continued)

Number		Name
508	-	Circ-Tol-Ent
5081	-	Circ-Tol-Ent-Seam
5082	-	Circ-Tol-Ent-Area
5083	-	Circ-Tol-Ent-FOS
509	-	Conc-Tol-Ent
5091	-	Conc-Tol-Ent-Seam
5092	-	Conc-Tol-Ent-Area
5093	-	Conc-Tol-Ent-FOS
510	-	Cyl-Tol-Ent
5102	-	Cyl-Tol-Ent-Area
5103	-	Cyl-Tol-Ent-FOS
511	-	Flat-Tol-Ent
512	-	Parl-Tol-Ent
5121	-	Parl-Tol-Ent-Seam
5122	-	Parl-Tol-Ent-Area
5123	-	Parl-Tol-Ent-FOS
513	-	Perp-Tol-Ent
5131	-	Perp-Tol-Ent-Seam
5132	-	Perp-Tol-Ent-Area
5133	-	Perp-Tol-Ent-FOS
514	-	Pos-Tol-Ent
515	-	Plin-Tol-Ent
5151	-	Plin-Tol-Ent-Seam
5152	-	Plin-Tol-Ent-Area
516	-	Psrf-Tol-Ent
517	-	Strght-Tol-Ent
5171	-	Strght-Tol-Ent-Seam
5172	-	Strght-Tol-Ent-Area
5173	-	Strght-Tol-Ent-FOS
518	-	Trun-Tol-Ent
5182	-	Trun-Tol-Ent-Area
5183	-	Trun-Tol-Ent-FOS
600	-	Coordinate Dimension
601	-	Size Dimension
602	-	Location Dimension
6021	-	Linear Dimension
6022	-	Curvi-linear Dim

Entity Pool in Numeric Order - (Continued)

SECTION 3: SHAPE VARIATION TOLERANCES

Number		Name
603	-	Angle Dimension
604	-	Size Parameter
6041	-	Independent Size Parameter
6042	-	Derivable Size Parameter
605	-	Size Characteristic
608	-	Related Angle Dimension
609	-	Angle Size Dimension
610	-	Angle Size Parameter
6101	-	Independent Angle Size Dimension
6102	-	Derivable Angle Size Dimension
611	-	Angle Size Characteristic
FF001	-	Form Feature
FF002	-	Implicit Form Feature
GEO1	-	Geometry
GEO14	-	Direction
INT-2	-	Shape Element
INT-8	-	Area
INT-14	-	Seam
INT-20	-	Corner

Entity Pool in Numeric Order - (Continued)

3.5.2 Entity Definitions

The entity definitions which constitute this model are presented (more or less) in the IDEF subject-entity diagram and page-pair format with additional formatting as follows:

Entity Number and Name:

The entity number is local to this model (i.e. do not correspond to any other models.)

Entity Definition:

The definition of the entity is relative to its use in the model.

Express Definition of Entity:

The (more-or-less) equivalent Express definitions for the IDEF1X model have been provided in this model. This includes those entities which were defined as parts of other modelling efforts (i.e. fall within the scope of other reference models).

Definition of Attributes:

Where attributes have been defined for entities (not including all cases of migrated keys), a definition is provided for each attribute.

Definition of Constraints:

Where specific constraints on the value of an attribute or existance of a relationship are known, an explanation of the constraint is provided to support the statements in the WHERE portion of the Express definition of the entity.

Propositions (a.k.a. Business Rules):

Propositions are statements of fact about the subject entity and its relationships to other entities. They are English-language statements of the relationships defined in the model. Sometimes propositions contain knowledge about the entity that cannot be captured in the IDEF1X or Express definitions.

Subject Entity Diagram:

The IDEF1X model of the entity which is being defined.

Declarations:

A number of attribute types and constraints are specified more than several times throughout the following entity definitions. The ones which occur most frequently are explained here:

```
TYPE

   Tol_MLSN : ENUMERATION OF (MAXMC, LEASTMC, REGARDLESS, NONE);

   Tol_IBO  : ENUMERATION OF (INSIDE, BILATERAL, OUTSIDE);

CONSTRAINTS

Tol_Ent <> [];
```

Tol-Ent is a SET containing the entities to which a tolerance applies. This constraint specifies that that set must not be empty. This is true for all tolerance entities which use the SET except for Profile of a Surface, where the set may be empty if the tolerance is a default tolerance.

```
IF SYMMETRIC(object) THEN
  Material_Condition = M OR
  Material_Condition = L OR
  Material_Condition = S;                -- Default condition
 ELSE
  Material_Condition = N;
```

This contraint states that if an "object" (an entity, or members of an input LIST, SET, or ARRAY) is Symmetric about a point, curve or surface, then an associated Material-Condition modifier must have a value M, L or S. If the object is not symmetric, then a Material-Condition modifier is not applicable and should be N.

```
Tolerance > 0.0;
```

The meaning of this constraint is self-evident.

Entity Name: Direction

Entity Number: GEO-14

A sequence of three values that define a unit vector which specifies a direction in cartesain space. The Euclidean norm is exactly 1.

This entity falls within the scope of the Geometry model, but is included here for completeness. The definition provided implies the requirements that the Tolerance Model has of the entity.

EXPRESS Definition

```
ENTITY Direction SUBTYPE OF (Wire_Frame_Geometry);
    X : Number;
    Y : Number;
    Z : Optional Number;
  WHERE
    (X**2 + Y**2 + Z**2) = 1.0;
    END_ENTITY;
```

Propositions:

Each Direction(GEO-14)

- defines the direction of 0,1, or more Projected-Tolerance-Zone(102).
- defines 0,1 or more Directrix's (4151) which are the normals for the planes which define Profile-Line(415) tolerances.
- defines 0, 1 or more directions (4171) of application for Straightness(417) tolerances.
- establishes the right hand rule for 0,1, or more Related Angle Dimension (608).

Entity Name: Projected-Tolerance-Zone

Entity Number: 102

A Projected-Tolerance-Zone is a direction and a length value which establishes the extent of the projected tolerance zone.

EXPRESS Definition

```
        ENTITY Projected_Tolerance_Zone;
            Direction     : Direction;
            Extent        : Number;
          WHERE
            MEMBER(Position,1,1) OR MEMBER(Angularity,1,1) OR
              MEMBER(Parallelism,1,1) OR MEMBER(Perpendicularity,1,1);
(*          Parallel(Direction,{Curve or Surface of Symmetry of
              Toleranced Entity}); *)
            Extent > 0.0;
          END_ENTITY;
```

Attribute Definition:

Direction
: The direction from the tolerance zone defined by the tolerance entity that the additional tolerance zone is projected. This direction must be parallel to the curve or surface of symmetry of the toleranced entity (if it is a Feature of Size) or the toleranced entity itself (if not a Feature of Size).

Extent
: A real value that specifies the length of the projected tolerance zone.

Constraint:

```
        MEMBER(Position,1,1) OR MEMBER(Angularity,1,1) OR
        MEMBER(Parallelism,1,1) OR MEMBER(Perpendicularity,1,1);
```

For the existence of a Projected-Tolerance-Zone (PTZ) to be valid, it must be related to a Position(414), Angularity(406), Parallelism(412), or Perpendicularity(413) Tolerance.

```
  Parallel(Direction,{Curve or Surface of Toleranced Entity})
```

The direction of the PTZ must be parallel to the curve or surface of symmetry if the toleranced entity is a Feature of Size, or parallel to the toleranced entity itself.

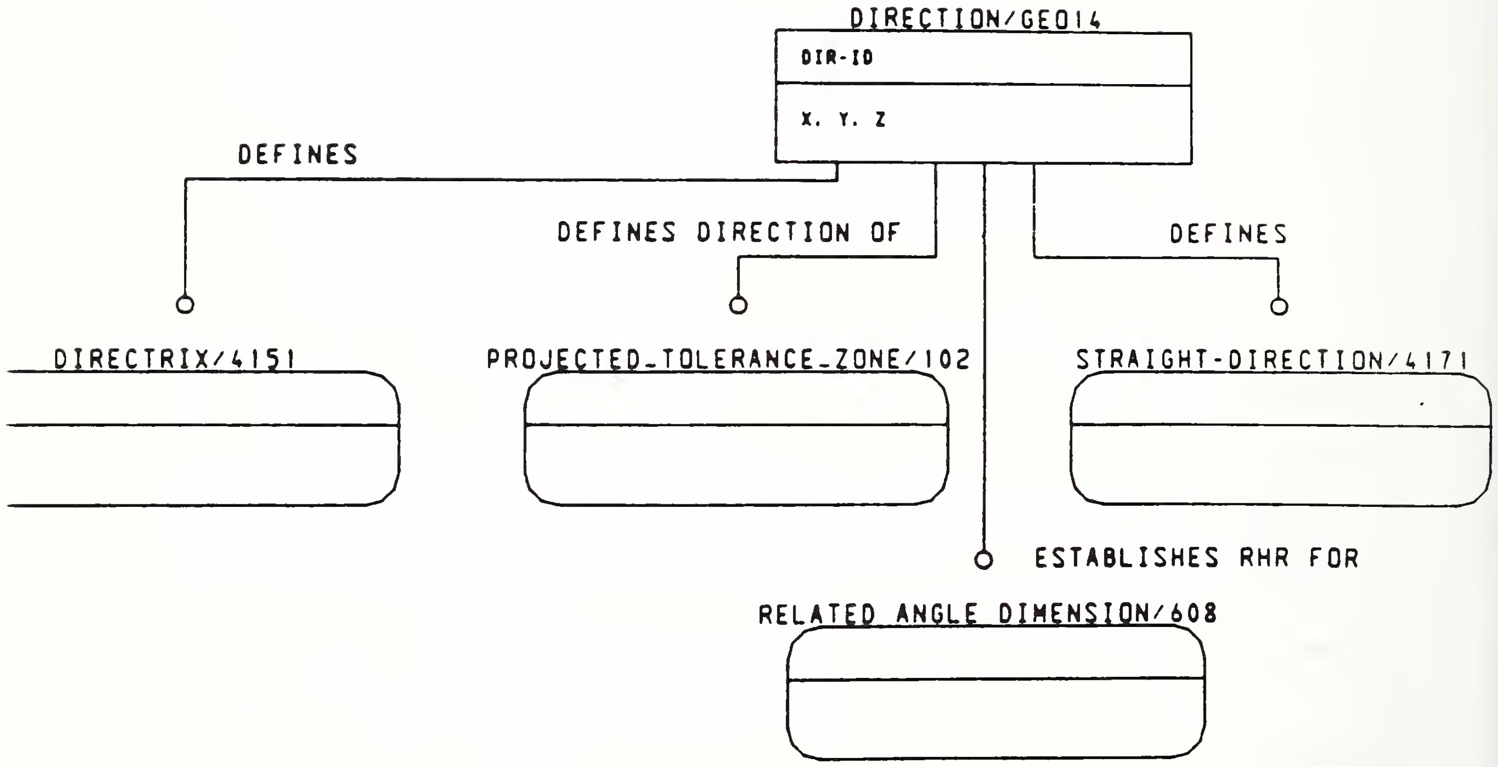


Figure D-1: DIRECTION IDEF1X Diagram

Propositions:

Each Project-Tolerance-Zone(102)

- is directed by exactly one Direction(GEO-14).
- defines the projected tolerance zone for 0 or 1 Perpendicularity(413) tolerance.
- defines the projected tolerance zone for 0 or 1 Angularity(406) tolerance.
- defines the projected tolerance zone for 0 or 1 Position(414) tolerance.
- defines the projected tolerance zone for 0 or 1 Parallelism(412)
- must define a projected tolerance zone for a tolerance.

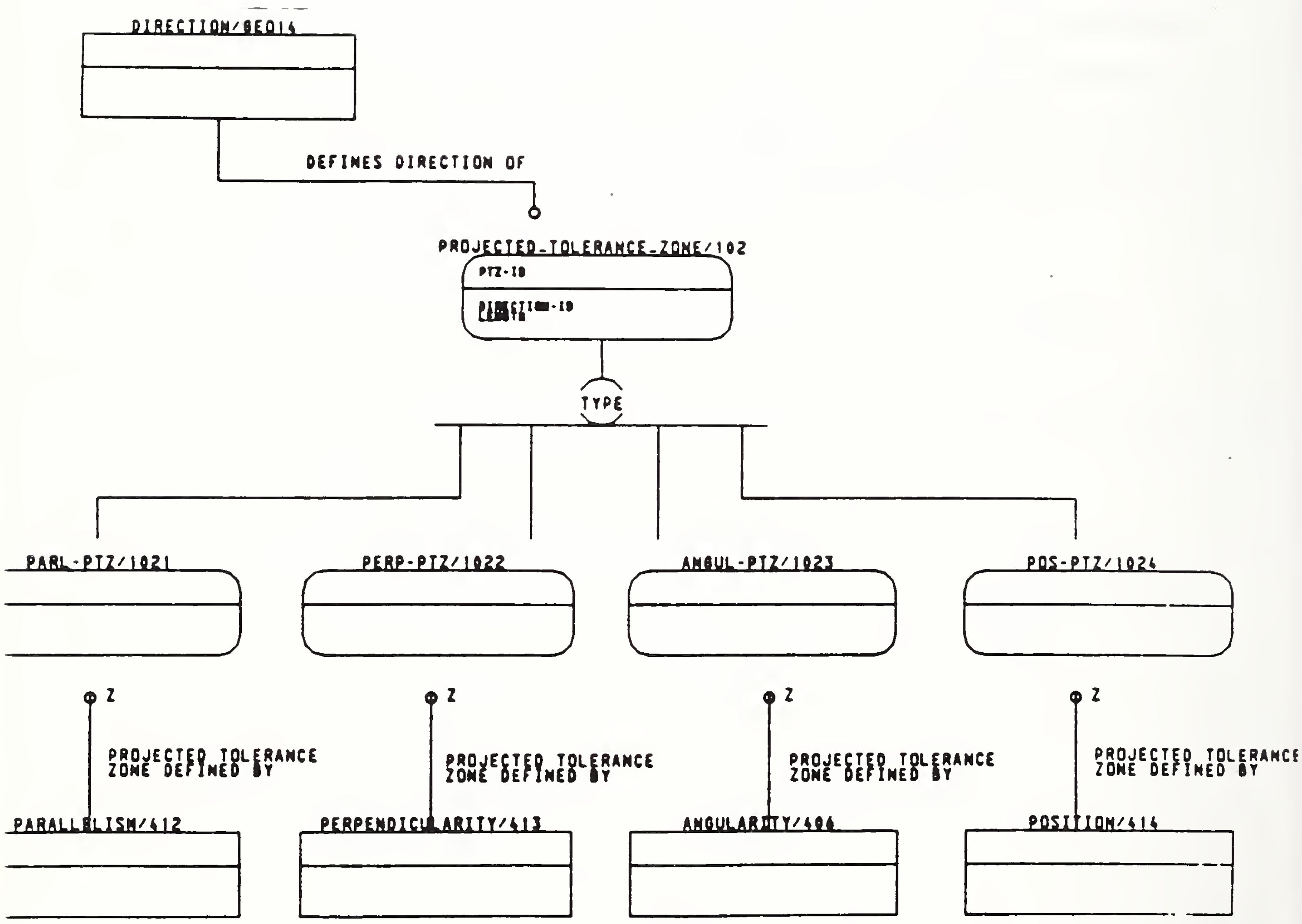


Figure D-2: DIRECTION IDEF1X Diagram

Entity Name: **Geometric Derivation**

Entity Number: **108**

A Geometric Derivation is a geometric entity which is derived from shape representation elements. An actual entity corresponding to this geometric derivation may or may not be included in the design model. The key distinction is that the geometric derivation is not a definitional element of the shape of an object, but is determined from shape elements or other geometric derivations. On an actual physical object the geometric derivation is virtual geometry that is calculated from reference to "hard points" on the object (faces, edges and vertices on the physical object which correspond to the areas, seams and corners in the object representation). Examples include: centerlines and centerplanes; breakout tangency planes; spacial intersection of two surfaces.

A Geometric Derivation is a feature which may be used as the target or the origin of a tolerance/dimension.

A Geometric Derivation consist primarily of the shape elements of other Geometric Derivations used to determine the derived geometry, and a type designation indicating the type of derivation. A reference to the derived geometry may optionally be included.

EXPRESS Definition

```
ENTITY Geometric_Derivation SUBTYPE OF (DT_Feature);
    Type             : Undefined;
    Parameters       : LIST OF SELECT(Shape_Element,
                                      Geometric_Derivation);
    Derived_Geometry : Optional Geometry;
    END_ENTITY;
```

Attribute Definition:

Type
: A (to be) enumerated list of operations that result in specified types of geometry which are derived from the input parameters. Each operation would consist of an input list of parameters, the anticipated type of result, and an algorithmic description of the operation.

Parameters
: The inputs to the derivation operation. Most typically the parameters will be shape element entities from which the geometry is derived.

Derived-Geometry
: The evaluated form of the Geometric Derivation may be included for completeness. The result of the derivation operation, however, takes precedence over a predefined result that is included in the definition of the entity.

Entity Name: DT-Shape-Element

Entity Number: 200

Shape elements or entities, within the scope of this model, are constructs that define touchable or viewable portions of a part. Shape elements are defined in various ways depending the type of shape representation method used. A DT-Shape-Element is a subset of Shape Element which is defined for the purposes of this model.

Shape Element entity is outside the scope of the tolerance model but is included for integration reasons; it falls within the scope of the work of the PDES Integration Committee.

EXPRESS Definition

```
        ENTITY DT_Shape_Element SUPERTYPE OF (Area, Seam, Corner);
         END_ENTITY;
```

Propositions:

Each DT-Shape-Element(200)

- must be of one Shape-Element type.
- may be a Corner(INT-20).
- may be a Seam(INT-14).
- may be a Area(INT-8).
- may be a component of the Size Feature(303).
- is a DT Feature(300).

Constraint Definition

A Corner may not be a component of a Size Feature(303).

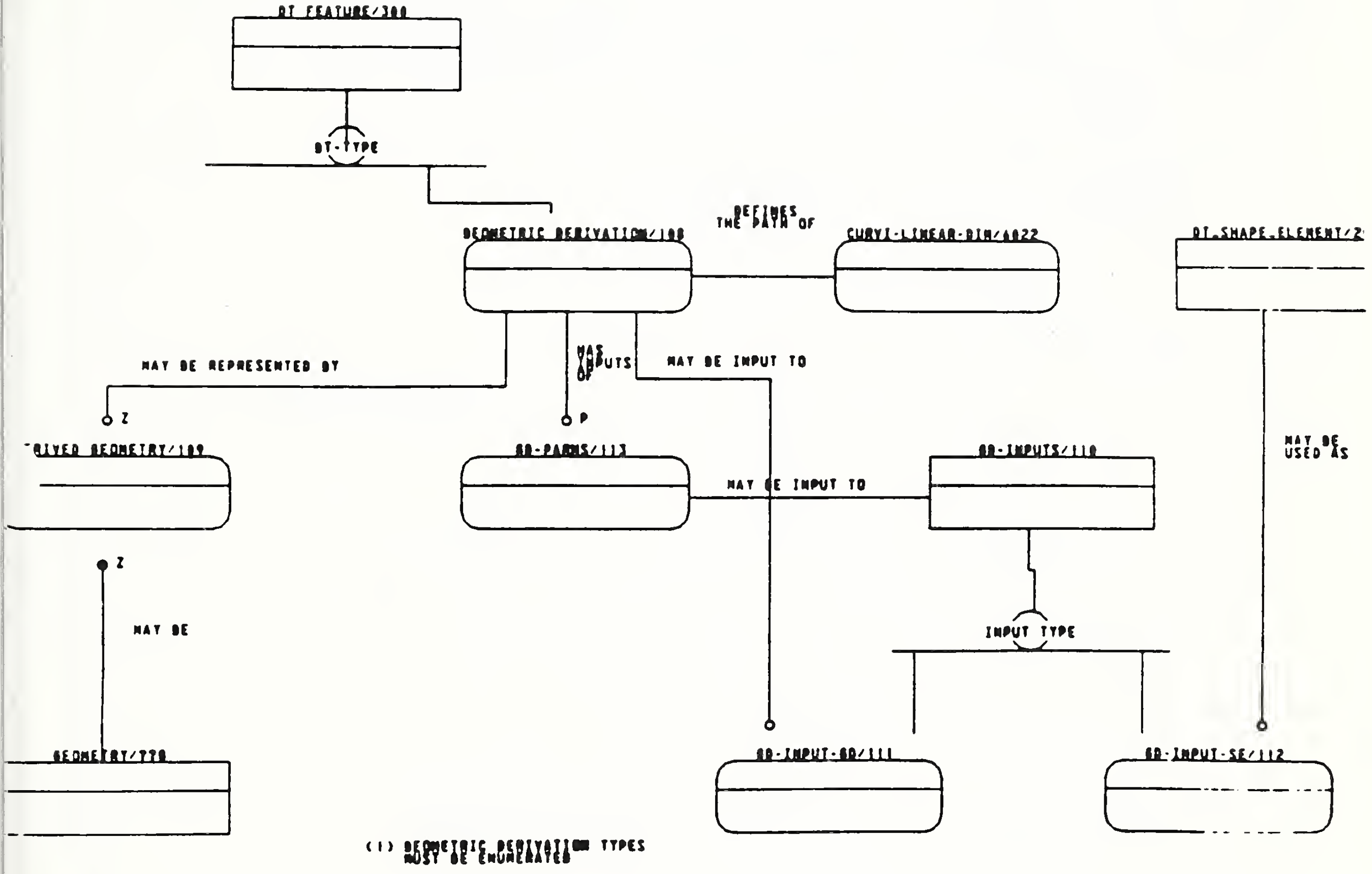


Figure D-3: GEOMETRIC DERIVATION IDEF1X Diagram

Entity Name: Corner (formerly Vertex)

Entity Number: INT-200

A corner defines a unique, zero-dimensional location on the shape of the product.

Corner is outside the scope of the Tolerance Model, but is included for completeness and integration reasons. It properly falls within the scope of the work of the Integration Committee; see that work for a complete definition of this entity. The definition here is incomplete with respect to the work of the Integration Committee, but is sufficient for the purposes of this model.

EXPRESS Definition

```
ENTITY Corner SUBTYPE OF (DT_Shape_Element);
  END_ENTITY;
```

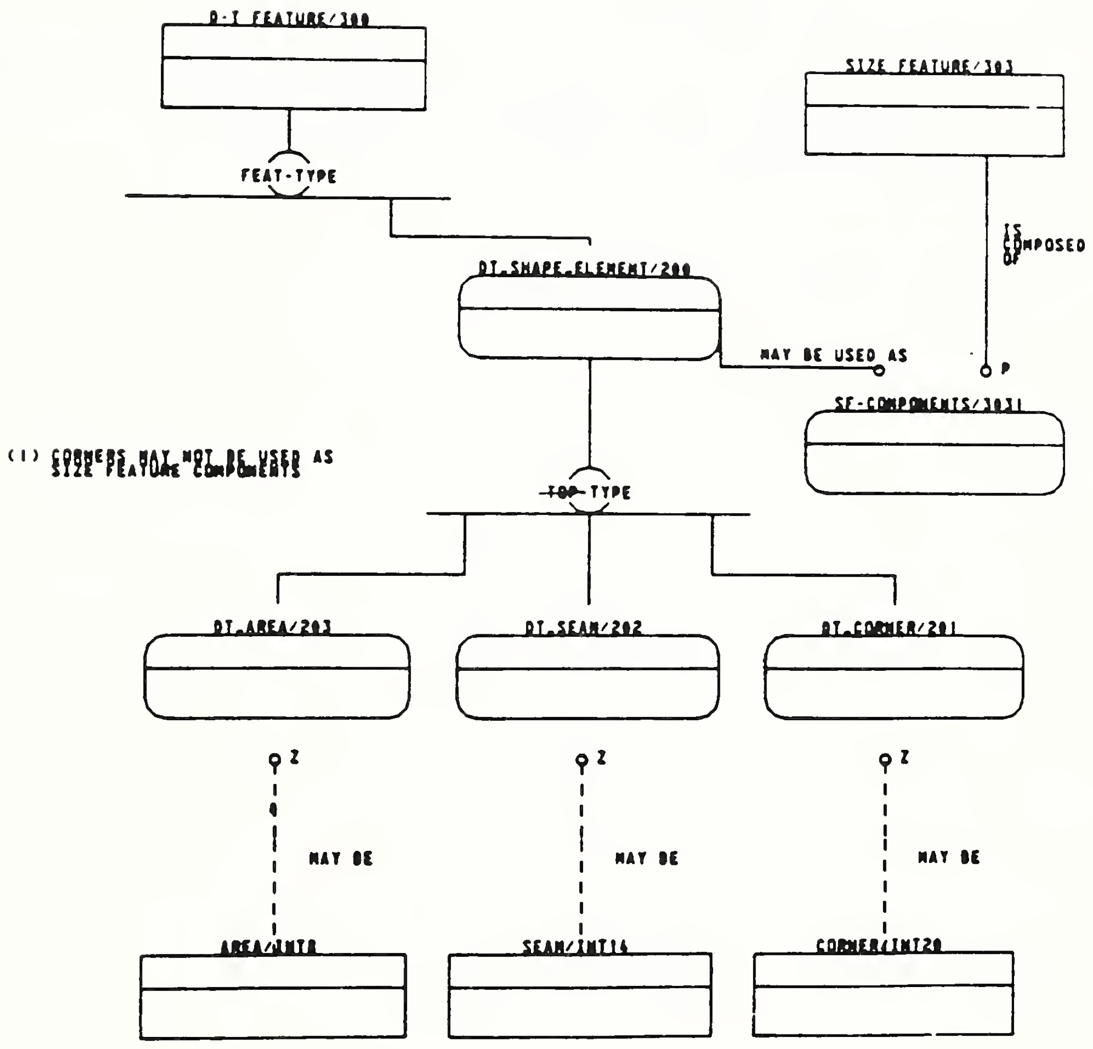


Figure D-4: DT SHAPE ELEMENT IDEF1X Diagram

Entity Name: Seam

Entity Number: 104

A seam is a one-dimensional characteristic of the shape of a product, typically defined by the intersection of two areas and bounded by two corners.

Seam is outside the scope of the Tolerance Model, but is included for completeness and integration reasons. It properly falls within the scope of the work of the Integration Committee; see that work for a complete definition of this entity. The definition here is incomplete with respect to the work of the Integration Committee, but is sufficient for the purposes of this model.

EXPRESS Definition

```
ENTITY Seam SUBTYPE OF (DT_Shape_Element);
  END_ENTITY;
```

Propositions:

Each Seam(INT-14)

- is a Shape-Element(200).
- can be toleranced by 0 or 1 Angularity(406) tolerance.
- can be toleranced by 0 or 1 Circularity(408) tolerance.
- can be toleranced by 0 or 1 Circular-Runout(407) tolerance.
- can be toleranced by 0 or 1 Concentricity(409) tolerance.
- can be toleranced by 0 or 1 Parallelism(412) tolerance.
- can be toleranced by 0 or 1 Perpendicularity(413) tolerance.
- can be toleranced by 0 or 1 Profile-Line(415) tolerance.
- can be toleranced by 0 or 1 Straightness(417) tolerance.

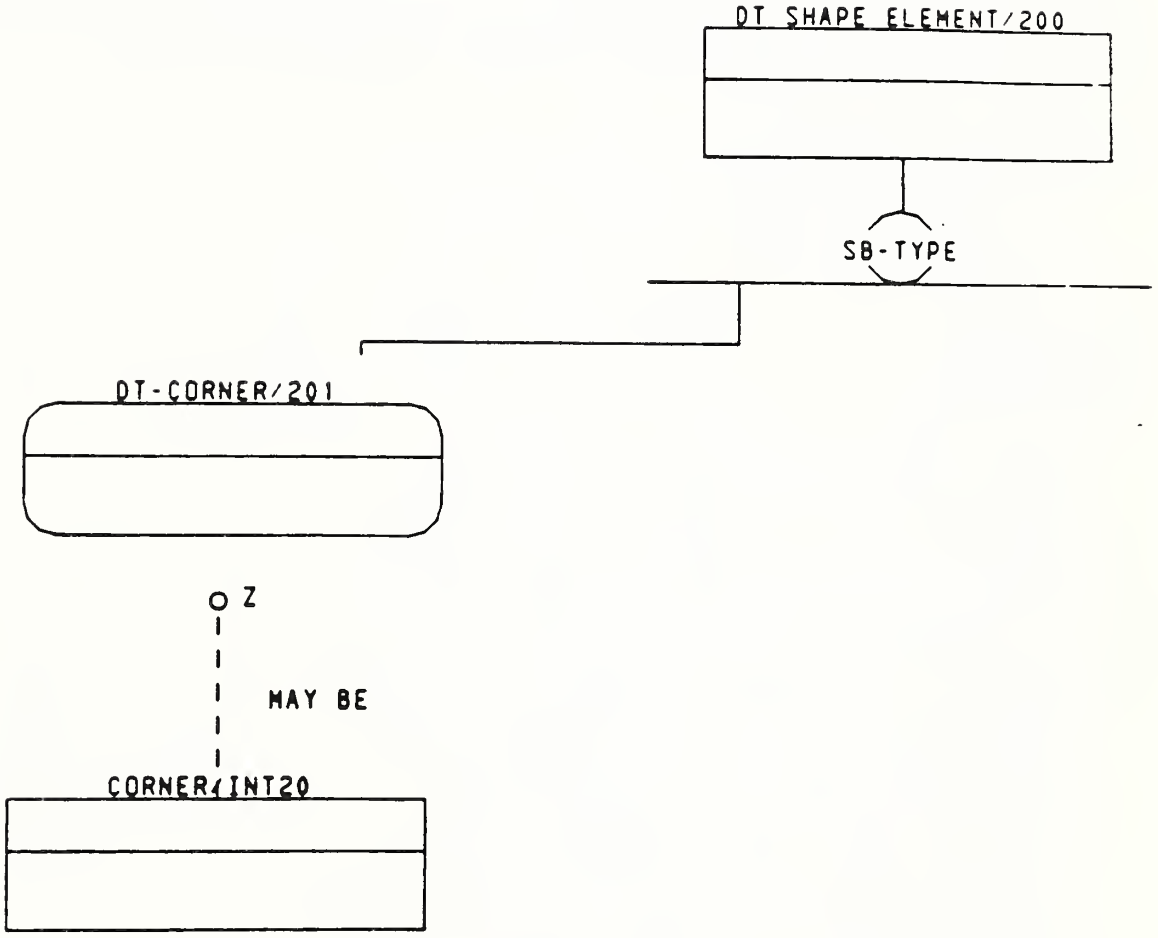


Figure D-5: DT CORNER / CORNER IDEF1X Diagram

Entity Name: **Area**

Entity Number: **INT-8**

An area is a two-dimensional characteristic of the shape of a product, and is a bounded portion of a geometric surface.

Area is outside the scope of the Tolerance Model, but is included for completeness and integration reasons. It properly falls within the scope of the work of the Integration Committee; see that work for a complete definition of this entity. The definition here is incomplete with respect to the work of the Integration Committee, but is sufficient for the purposes of this model.

EXPRESS Definition

```
ENTITY Area SUBTYPE OF (DT_Shape_Element);
  END_ENTITY;
```

Proposition:

Each Area(INT-8)

- is a Shape-Element(INT-8).
- can be toleranced by 0 or 1 Angularity(406) tolerance.
- can be toleranced by 0 or 1 Circularity(407) tolerance.
- can be toleranced by 0 or 1 Circular-Runout(408) tolerance.
- can be toleranced by 0 or 1 Concentricity(409) tolerance.
- can be toleranced by 0 or 1 Cylindricity(410) tolerance.
- can be toleranced by 0 or 1 Flatness(411) tolerance.
- can be toleranced by 0 or 1 Parallelism(412) tolerance.
- can be toleranced by 0 or 1 Perpendicularity(413) tolerance.
- can be toleranced by 0 or 1 Profile-Line(415) tolerance.
- can be toleranced by 0 or 1 Profile-Surface(416) tolerance.
- can be toleranced by 0 or 1 Straightness(417) tolerance.
- can be toleranced by 0 or 1 Total-Runout(418) tolerance.

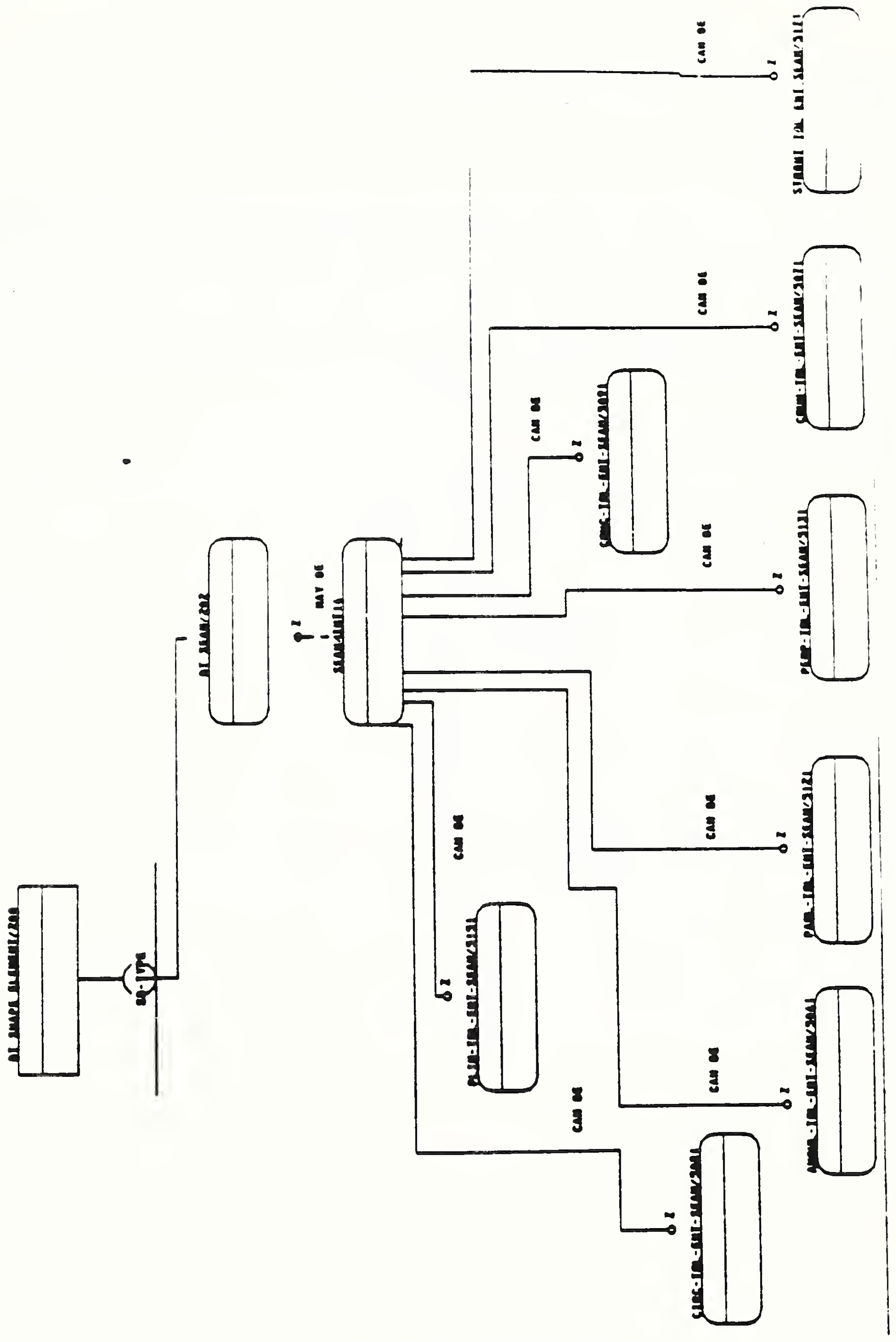


Figure D-6: DT SEAM / SEAM IDEF1X Diagram

Entity Name: **DT-Feature (formerly Feature)**

Entity Number: **300**

A Dimension/Tolerance Feature is a categorization of things which may be the target or origin of dimension/tolerances and corresponds to the term "feature" as used in the ANSI Y14.5 standard. It is some characteristic of the shape of a product that can be uniquely identified. Categories of a DT Feature include: Shape Elements (Area, Seam, Corner), Form Features, Features of Size (a subset of which are Form Features), and Geometric Derivations. Angle and Location Dimensions reference DT Features and Size Dimensions reference Features of Size. It is an artificial classification defined for the purposes of the Tolerance Model.

EXPRESS Definition

```
ENTITY DT_Feature SUPERTYPE OF (DT_Shape_Element, DT_Form_Feature,
      Feature_of_Size, Geometric_Derivation);
    END_ENTITY;
```

Propositions:

A DT-Feature(300)

- may be the target of a Location Dimension (602).
- may be the origin of a Location Dimension (602).
- may be the target of a Related Angle Dimension (608).
- may be the origin of a Related Angle Dimension (608).
- may be used as a Datum(301).
- must be a DT-Shape-Element(200), DT-Form-Feature(304), Feature-of-Size(306), or a Geometric-Derivation(108).

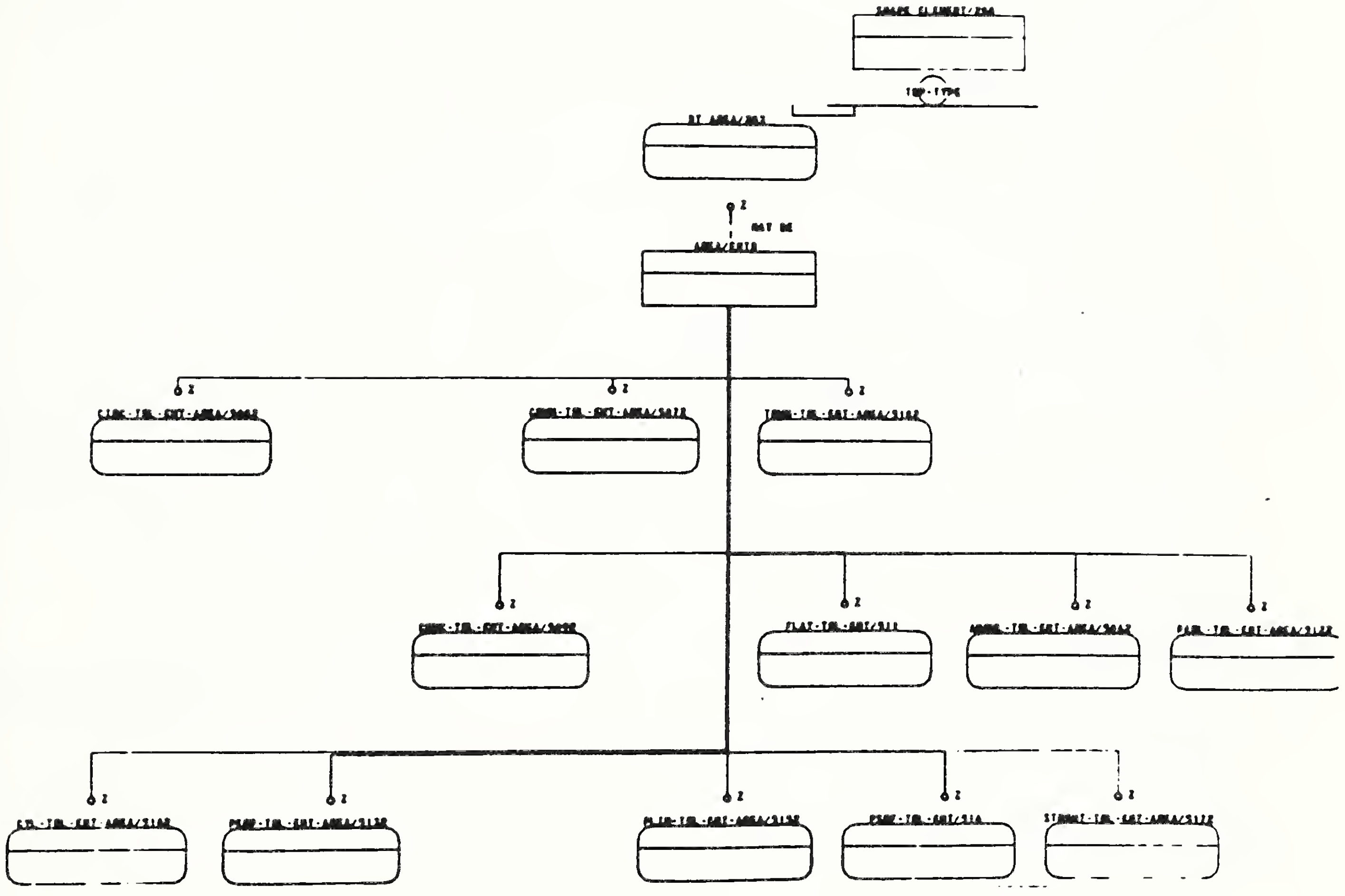


Figure D-7: DT AREA / AREA IDEF1X Diagram

Entity Name: Datum

Entity Number: 301

A theoretically exact geometric reference to which toleranced features are related.

EXPRESS Definition

```
ENTITY Datum;
   Reference    : DT_Feature;
   Name         : String(2);
 WHERE
   (* Note constraint on Name A..Z, AA..ZZ Except I, O, Q *)
 END_ENTITY;
```

Attribute Definitions:

Reference
An entity which serves as the exact definition of the datum.

Name
An alphabetic string that provides a unique designation for the datum (range: A ... Z, AA ... ZZ, excluding I, O, and Q)

Proposition:

Each Datum(301)

- is defined by a DT-Feature(300).
- may be a Conditioned-Datum(302).
- may be an Unconditioned-Datum(310).

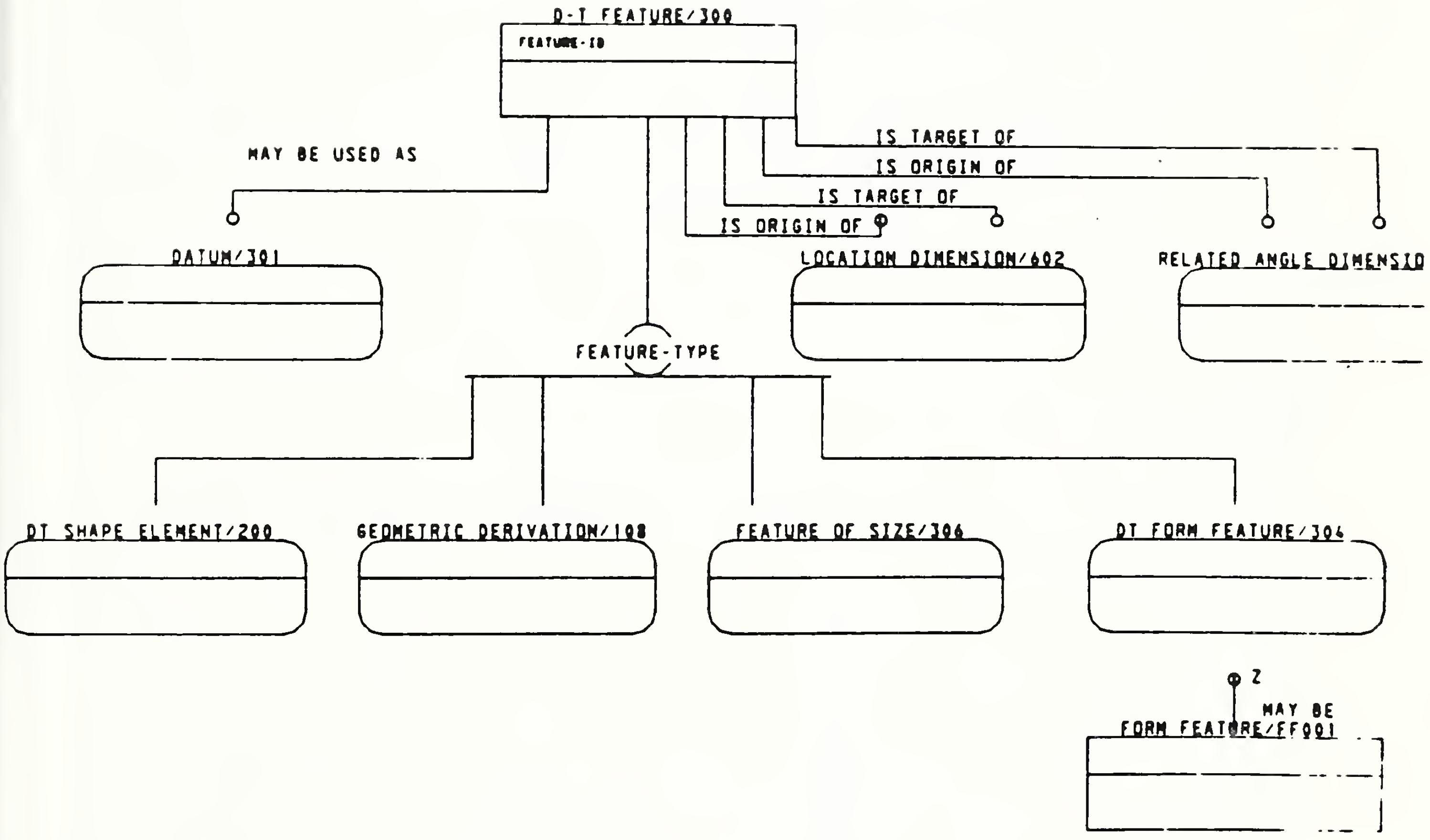


Figure D-8: DIMENSION/TOLERANCE IDEF1X Diagram

Entity Name: Conditioned Datum

Entity Number: 302

A conditioned datum is a datum to which a material condition modifier may apply (if the datum is defined by a Feature of Size).

EXPRESS Definition

```
ENTITY Conditioned_Datum SUBTYPE OF (Datum);
    Material_condition   : Tol_MLSM;
  WHERE
    IF (SYMMETRIC(Datum.Reference) THEN
      Material_Condition = M OR
      Material_Condition = L OR
      Material_Condition = S;
     ELSE
      Material_Condition = N;
  END_ENTITY;
```

Attribute Definitions:

Material-condition
An enumerated list that indicates the material condition at which the tolerance applies: M - maximum material condition; L - least material condition; or S - regardless of feature size; N - not applicable.

Propositions:

Each Conditioned Datum(302)

- is a Datum(301).
- is the primary datum for 0, 1, or more Angularity(406) Tolerances.
- is the secondary datum for 0, 1, or more Angularity(406) Tolerances.
- is the tertiary datum for 0, 1, or more Angularity(406) Tolerances.
- is the primary datum for 0, 1, or more Profile-Line(415) Tolerances.
- is the secondary datum for 0, 1, or more Profile-Line(415) Tolerances.
- is the tertiary datum for 0, 1, or more Profile-Line(415) Tolerances.
- is the primary datum for 0, 1, or more Parallelism(412) Tolerances.

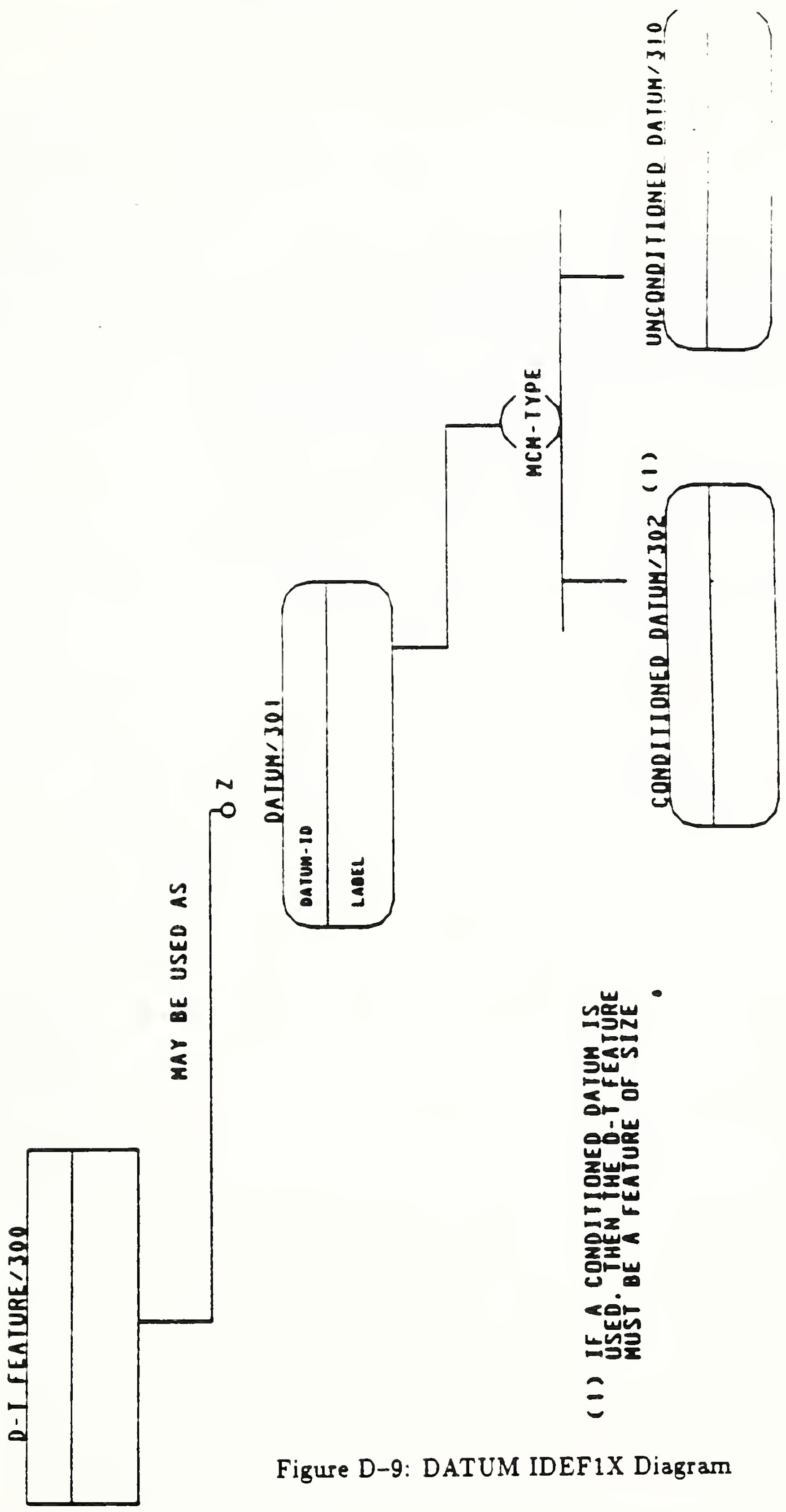

D-T FEATURE/300
MAY BE USED AS
Z
DATUM/301
DATUM-ID
LABEL
MCM-TYPE
CONDITIONED DATUM/302 (1)
UNCONDITIONED DATUM/310
(1) IF A CONDITIONED DATUM IS USED, THEN THE D-T FEATURE MUST BE A FEATURE OF SIZE.

Figure D-9: DATUM IDEF1X Diagram

- is the primary datum for 0, 1, or more Perpendicularity(413) Tolerances.
- is the secondary datum for 0, 1, or more Perpendicularity(415) Tolerances.
- is the primary datum for 0, 1, or more Position(414) Tolerances.
- is the secondary datum for 0, 1, or more Position(414) Tolerances.
- is the tertiary datum for 0, 1, or more Position(414) Tolerances
- is the Primary datum for 0, 1, or more Profile-Surface(416) Tolerances.
- is the secondary datum for 0, 1, or more Profile-Surface(416) Tolerances.
- is the tertiary datum for 0, 1, or more Profile-Surface(416) Tolerances.

Entity Name: **Size Feature**

Entity Number: **303**

A collection of Areas which has a tolerancable geometric location that is derived from physical feature geometry and is symmetrical about that geometric location (e.g. point, axis, curve or surface.) This entity exists because a set of Form Features has not been fully defined. A subset of Form Features can be classified as Features-of-Size (e.g. Hole, Tab, Slot) and the concept of Feature-of-Size is required for tolerancing. This construct will allow the application of tolerances to shape definitions which to not included Form Features.

NOTE: The number of Areas used to define a Size-Feature depends on the particular implementation of the shape representation. In some, a single surface which wraps around to form a cylinder and joins itself at a seam would be an appropriate single component of a Size-Feature. The assumption here is that it would take at least two semi-cylindrical surfaces to define a hole Size-Feature.

EXPRESS Definition

```
       ENTITY Size_Feature SUBTYPE OF (Feature_of_Size);
           SF_Components : LIST [2 to #] of SELECT(Area, Seam);
          WHERE
              SYMMETRIC(SF_Components);
    (*        All members of LIST must be of same type.       *)
         END_ENTITY;
```

Propositions:

Each Size Feature(303)

- is a type of Feature-of-Size(306).
- is composed of 2 or more Areas(INT-8) or 2 or more Seams(INT-14).

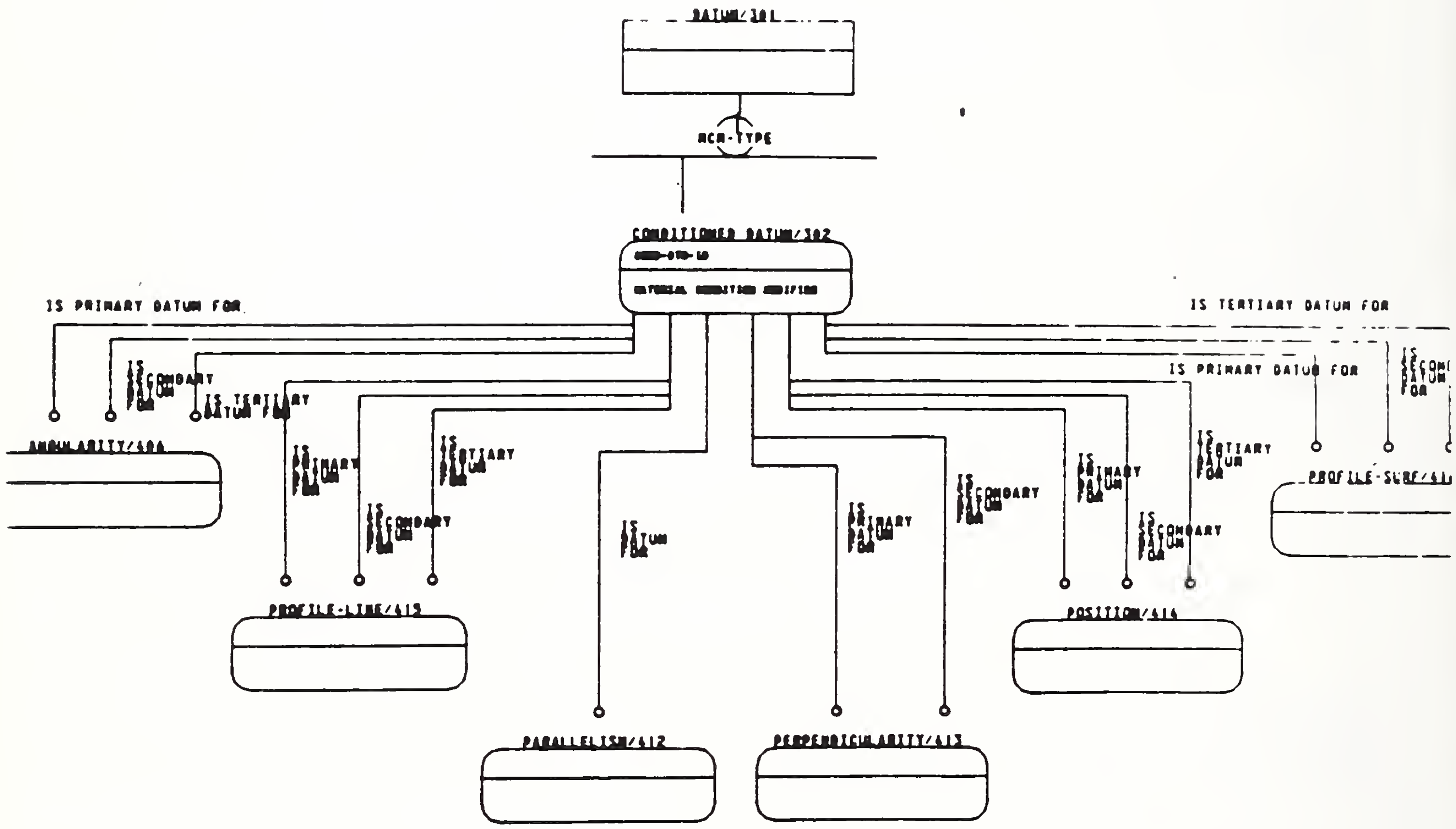


Figure D-10: CONDITIONED DATUM IDEF1X Diagram

Entity Name: **DT-Form-feature, Implicit Form Feature, Form Feature**

Entity Number: **304,FF-002,FF-001**

A referencable collection of shape elements whose name implies some stereotypical configuration.

Form Feature and Implicit Form Feature entity are outside the scope of the Tolerance Model, but are included for integration reasons. The definition of the entity is with respect to and from the viewpoint of the Tolerance Model and is incomplete with respect to the Form Features model.

The inclusion of the this entity within the Tolerance Model should be regarded as a Planning Level View. That is, the relationship between Implicit Form Feature and the tolerance entities within the Tolerance Model will correspond to relationships between tolerance entities and Specific Implicit Features (e.g. Implicit-Thru-Hole) in the Form Features Model.

EXPRESS Definition

```
ENTITY DT_Form_Feature SUBTYPE OF (DT_Feature);
    Ref_Feature      : Form_Feature;
    END_ENTITY;
```

Propositions:

Each DT Form Feature(304)

- is a DT Feature.
- may be a Form Feature (FF-001).
- can be used as Form Feature of Size (3061).

Each Implicit Form Feature (FF-002)

- is defined by 0, 1, or more Size Parameters (604).
- is defined by 0, 1, or more Angle Size Parameter (610).

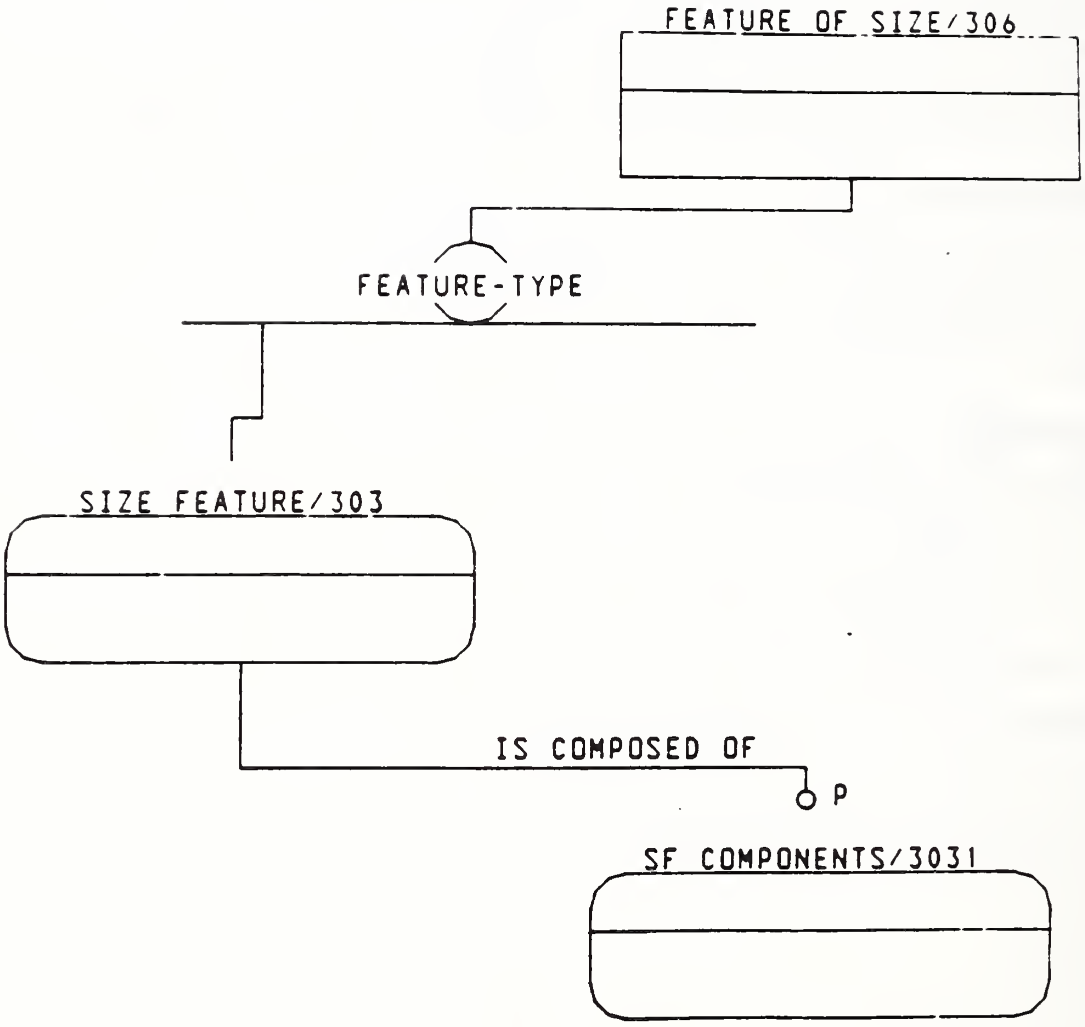


Figure D-11: SIZE FEATURE IDEF1X Diagram

Entity Name: **Feature-of-Size**

Entity Number: **306**

A Feature of Size is a grouping of Areas or Seams which are characterized by a set of opposing Areas or Seams and a point, curve (or axis), or surface of symmetry. It has two subsets: 1) all defined Size Features(303) are Features of Size(306); 2) all Form Features which have been defined as Features of Size(306) (e.g. hole, tab, slot).

EXPRESS Definition

```
ENTITY Feature_of_Size SUBTYPE OF (DT_Feature);
    Type              : Enumeration of (Form_Feature, Size_Feature);
    FF                : Optional DT_Form_Feature;
  WHERE
    SYMMETRIC(FF);
    IF (Type = Form_Feature) THEN FF <> NULL;
    IF (Type = Size_Feature_ THEN FF = NULL;
  END_ENTITY.
```

Attribute Definition:

Type

A Feature of Size is either a Size Feature or a Form Feature which is a symmetric about a point, curve or surface.

FF

If a Form Feature is a Feature of Size, then it must be identified as such.

Constraint Definition:

```
SYMMETRIC(FF)
```

If the Form Feature is a Feature of Size, then it must be symmetric.

```
IF (Type = Form-Feature) THEN FF <> NULL;
IF (Type = Size-Feature) THEN FF = NULL;
```

If the Feature of Size is a Form Feature, then the FF attribute must reference some Form Feature. If it isn't, if it is a Size Feature, the the FF attribute must be NULL.

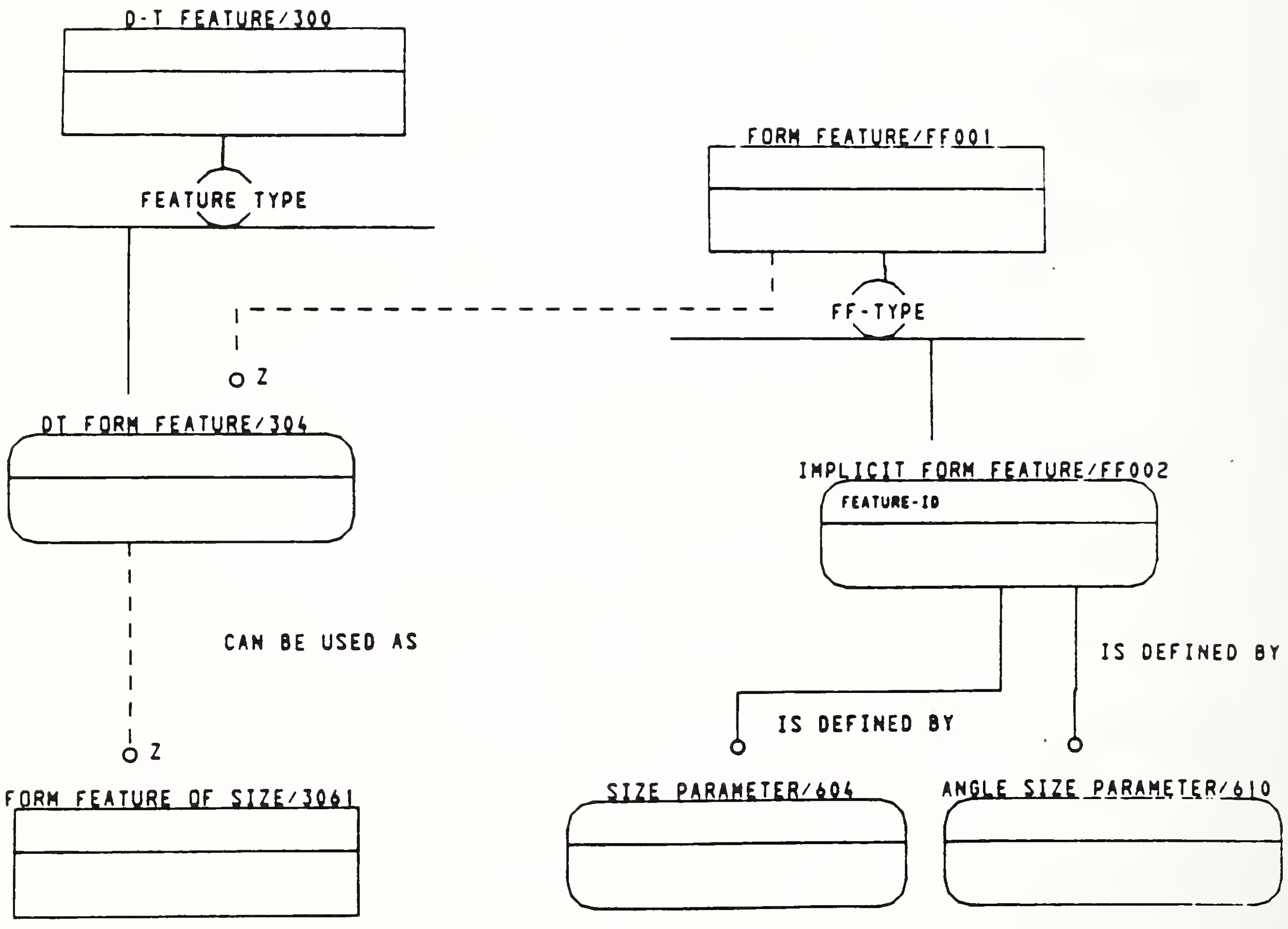


Figure D-12: DT FORM FEATURE IDEF1X Diagram

Propositions:

Each Feature-of-Size(306)

- is a DT Feature (300).
- may be a Size-Feature(303).
- may be a DT Form Feature (304).
- can be toleranced by 0 or 1 Angularity Tolerance (406).
- can be toleranced by 0 or 1 Circular Runout Tolerance (407).
- can be toleranced by 0 or 1 Circularity Tolerance (408).
- can be toleranced by 0 or 1 Concentricity Tolerance (409).
- can be toleranced by 0 or 1 Cylindricity Tolerance (410).
- can be toleranced by 0 or 1 Parallelism Tolerance (412).
- can be toleranced by 0 or 1 Perpendicularity Tolerance (413)
- can be toleranced by 0 or 1 Position Tolerance (414)
- can be toleranced by 0 or 1 Straightness Tolerance (417).
- can be toleranced by 0 or 1 Total Runout Tolerance (418).
- has 0,1, or more Size Characterisitic (605).
- has 0, 1, or more Angle Size Characteristic (611).
- must have at least one Size (605) or Angle Size Characteristic (611).

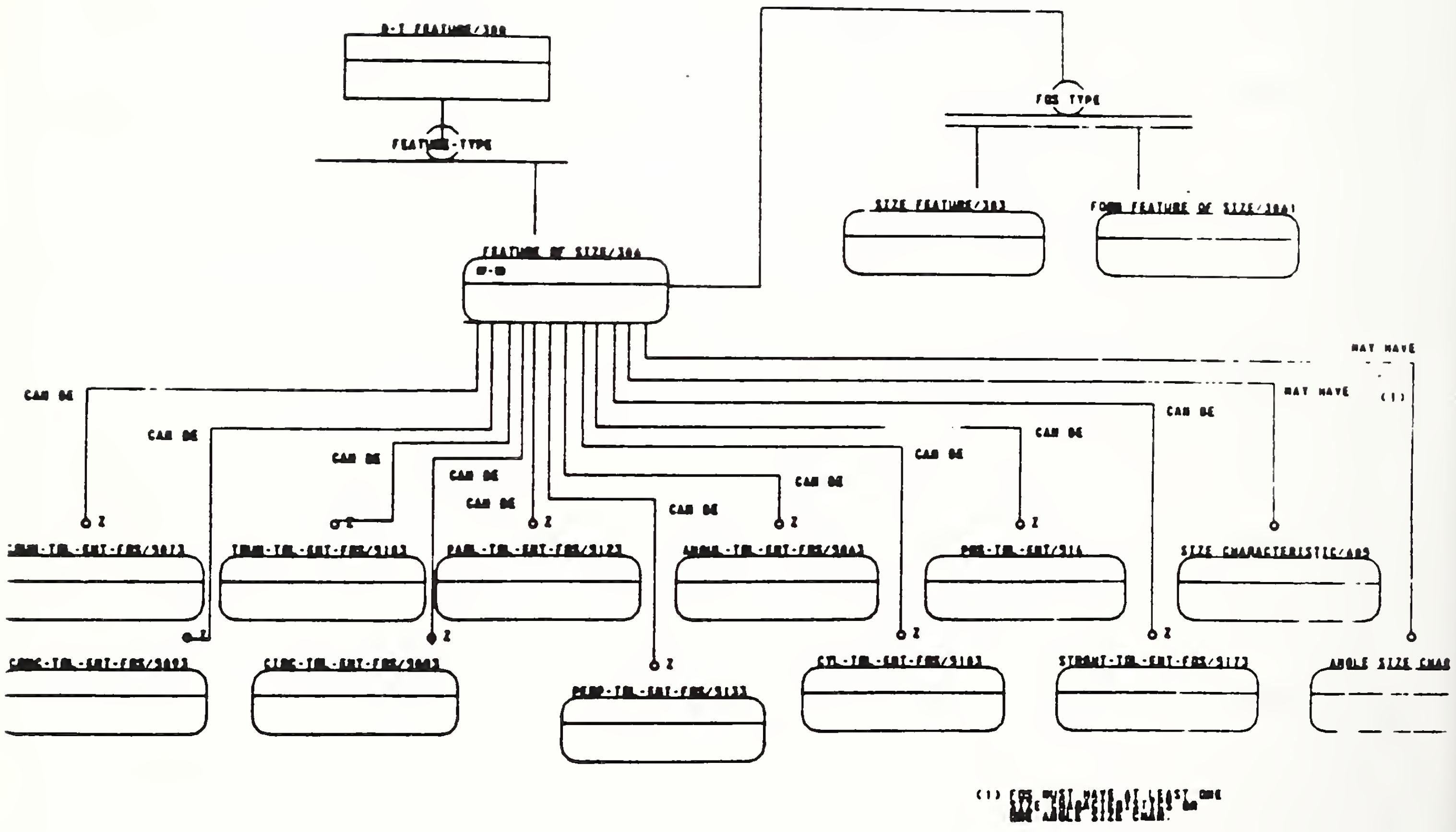


Figure D-13: FEATURE OF SIZE IDEF1X Diagram

Entity Name: Unconditioned Datum

Entity Number: 310

An Unconditioned Datum is a Datum to which a Material Condition Modifier (MCM: MMC, LMC, RFS) does not apply.

EXPRESS Definition

```
ENTITY Unconditioned_Datum SUBTYPE OF (Datum);
  END_ENTITY;
```

Propositions:

Each Unconditioned Datum(310)

- is a Datum(301).
- is the primary datum for 0, 1, or more Total-Runout(418) Tolerances.
- is the co-datum for 0, 1, or more Total-Runout(418) Tolerances.
- is the primary datum for 0, 1, or more Circular-Runout(407) Tolerances.
- is the co-datum for 0, 1, or more Circular-Runout(407) Tolerances.
- is the primary datum for 0, 1, or more Concentricity(409) Tolerances.
- is the co-datum for 0, 1, or more Concentricity(409) Tolerances.

Entity Name: **Center-of-Symmetry**

Entity Number: **311**

Features of Size are characterized by a center of symmetry. The center of symmetry may be a point, curve, axis or surface about which the elements of the Feature of Size are symmetric.

This is an IDEF1X intersection entity and does not manifest itself as an Express Entity. Center of Symmetry is a role (attribute name) that a geometric entity plays with respect to a Size Dimension and an Angle Size Dimension.

Propositions:

Each Center of Symmetry(311)

- is defined by exactly one Geometry (GEO-1).
- is part of 1 or more Size Characteristic (605)
- is part of 1 or more Angle Size Characteristic (611)
- must be part of one Size Characteristic OR one Angle Size Characteristic.

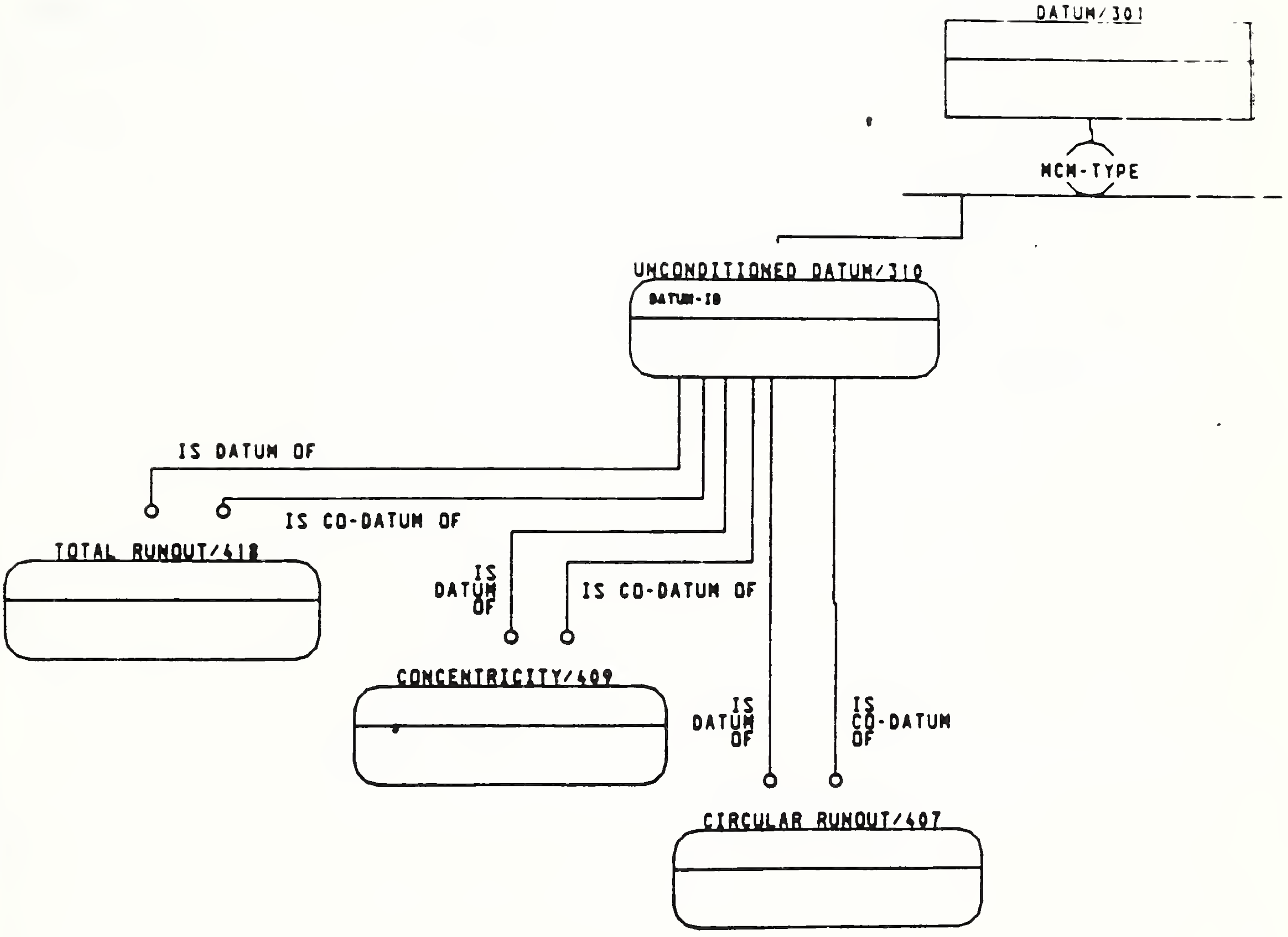


Figure D-14: UNCONDITIONED DATUM IDEF1X Diagram

Entity Name: **Shape_Tolerance**

Entity Number: 400

The allowable deviation of a geometric aspect of a product from its design nominal geometry.

EXPRESS Definition:

```
ENTITY Shape_Tolerance SUBTYPE OF (Tolerance);
  END_ENTITY;
```

Propositions:

Each Shape_Tolerance(400)

- may be a Geometric_Tolerance(402).
- may be a Coordinate_Tolerance_Range(401).
- must be a Geometric Tolerance or a Coordinate Tolerance Range.
- is a Tolerance.

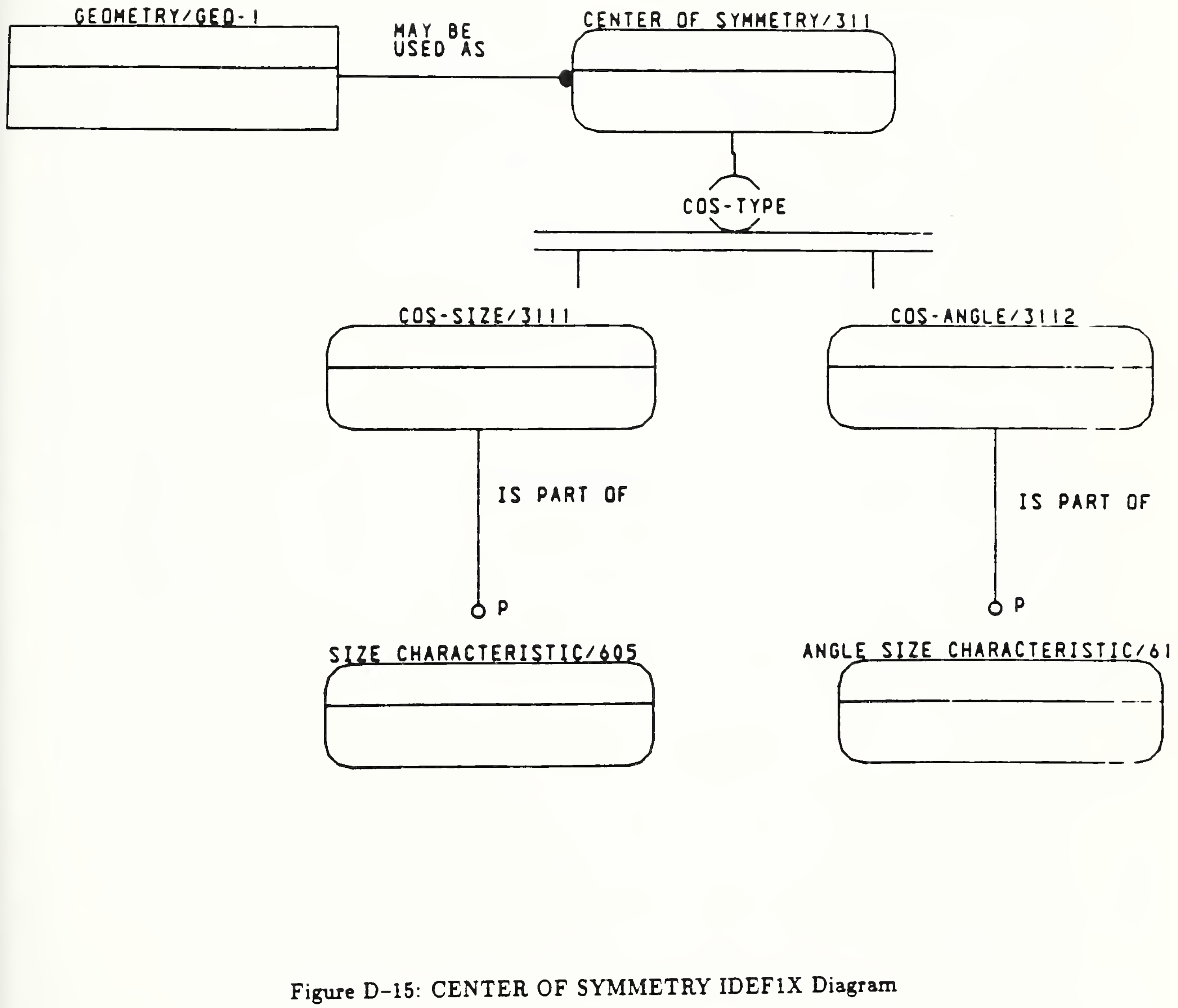


Figure D-15: CENTER OF SYMMETRY IDEF1X Diagram

Entity Name: Coordinate_Tolerance_Range

Entity Number: 401

A Coordinate_Tolerance_Range is the numeric values added to and subtracted from the nominal dimensional value calculate from the shape definition of a product. Coordinate_Tolerance_Range represent the traditional plus/minus tolerances found on dimensions on drawings.

EXPRESS Definition:

```
ENTITY Coordinate_Tolerance_Range SUBTYPE OF (Shape_Tolerance);
     Plus_Tol     : Number;
     Minus_Tol    : Number;
  WHERE
     Plus_Tol > 0.0;
     Minus_Tol >0.0;
     NOT ((Plus_Tol = 0.0) AND (Minus_Tol = 0.0));
     MEMBER(Size_Dimension,1,#) OR MEMBER(Location_Dimension,1,#)
       OR MEMBER(Angle_Dimension,1,#);
  END_ENTITY;
```

Attribute Definitions:

Plus_Tol
: The absolute value of the tolerance that is added to the nominal dimension value to establish the maximum allowable deviation of the toleranced entity from the nominal.

Minus_Tol
: The absolute value of the tolerance that is subtracted from the nominal dimension value to establish the minimum allowable deviation of the toleranced entity from the nominal.

Propositions:

Each Coordinate_Tolerance_Range(401)

- is a Shape_Tolerance(400).
- may tolerance 0, 1 or more Location Dimensions (602).
- may tolerance 0, 1 or more Angle Dimension (603).
- may tolerance 0, 1, or more Size Dimension (601).
- must tolerance a Location, Angle or Size Dimension.

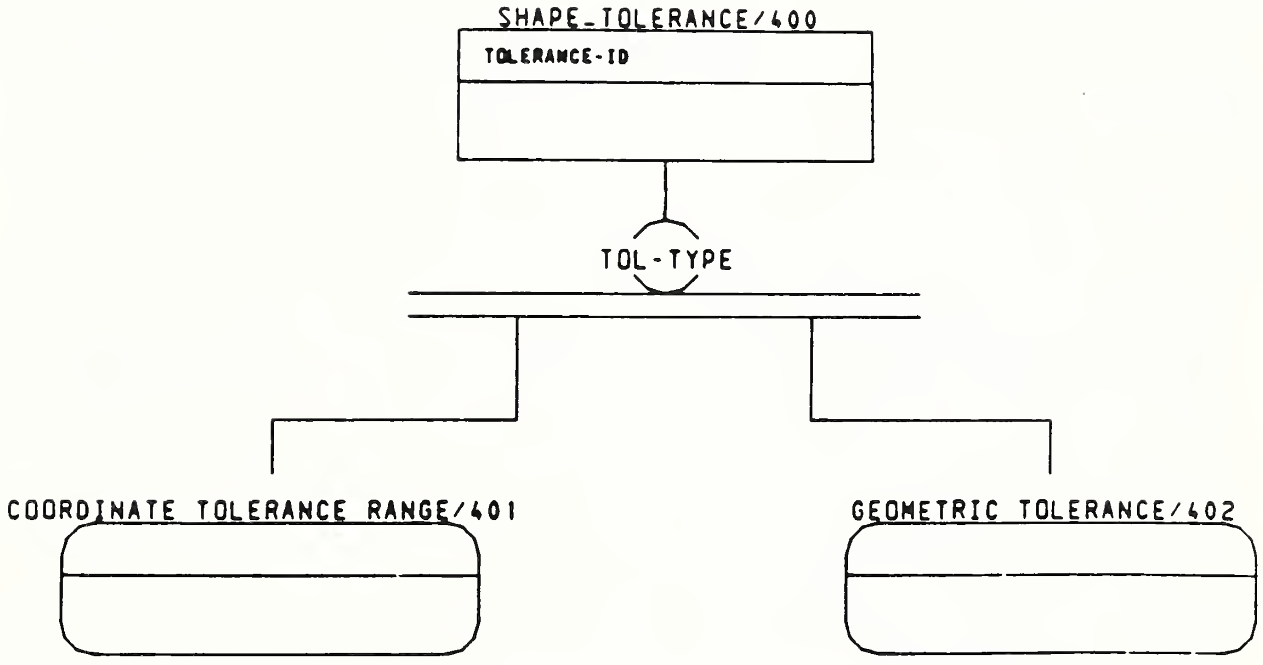


Figure D-16: SHAPE TOLERANCE IDEF1X Diagram

Entity Name: Geometric_Tolerance

Entity Number: 402

A Geometric_Tolerance is a class of entities. Geometric tolerances as defined by ANSI Y14.5M 1982 tolerance the deviation of form, orientation, location, and runout, of a produced feature from its design nominal.

EXPRESS Definition:

```
        ENTITY Geomtric_Tolerance SUBTYPE OF (Shape_Tolerance);
          END_ENTITY;
```

Propositions:

Each Geometric_Tolerance(402)

- is a Shape_Tolerance(400).
- may be an Angularity(406) tolerance.
  may be a Circular_Runout(407) tolerance.
  may be a Circularity(408) tolerance.
  may be a Concentricity(409) tolerance.
  may be a Cylindricity(410) tolerance.
  may be a Flatness(411) tolerance.
  may be a Parallelism(412) tolerance.
  may be a Perpendicularity(413) tolerance.
  may be a Position(414) tolerance.
  may be a Profile_Line(415) tolerance.
  may be a Profile_Surface(416) tolerance.
  may be a Straightness(417) tolerance.
  may be a Total_Runout(418) tolerance.
- must be one of the listed tolerances (406-418).

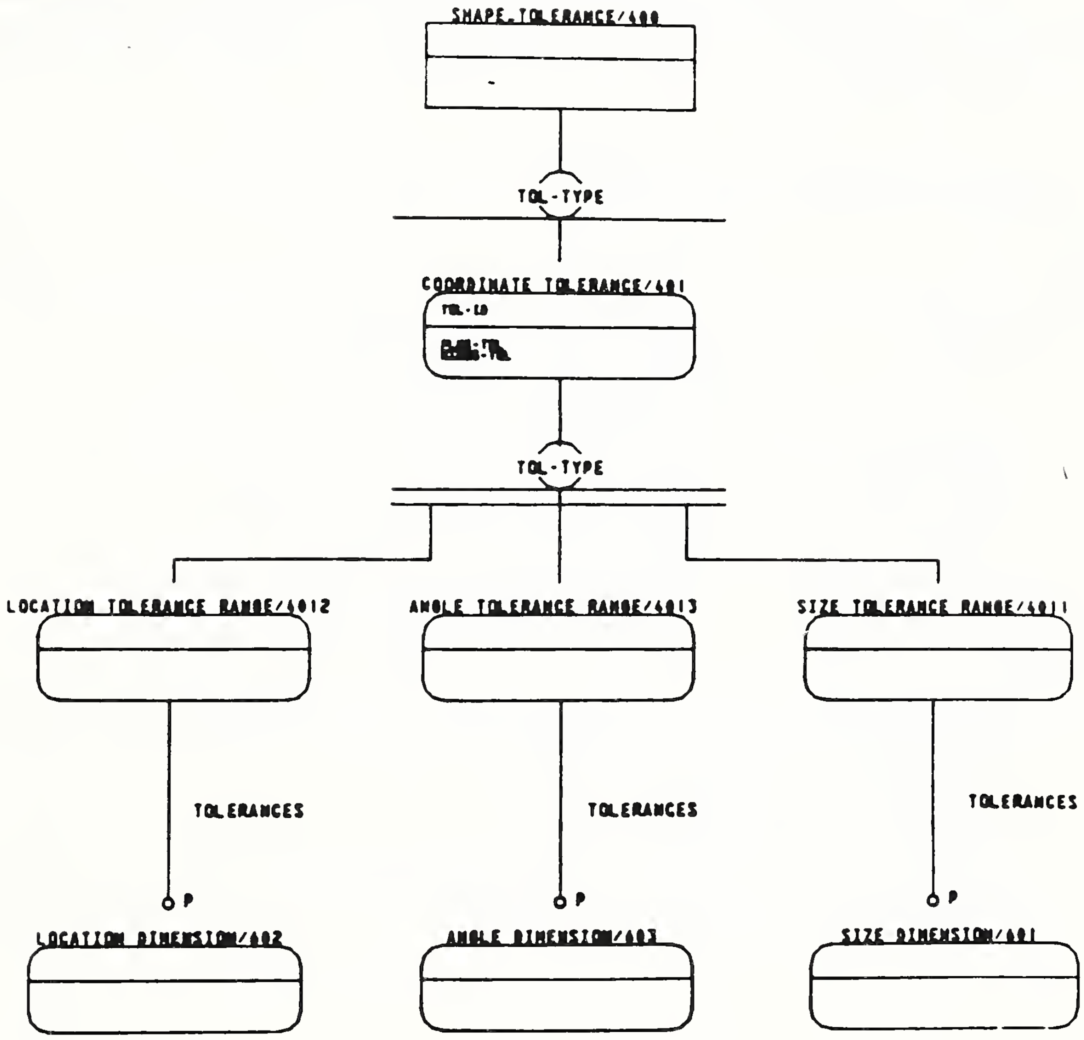


Figure D-17: COORDINATE RANGE IDEF1X Diagram

Entity Name: Angularity Tolerance

Entity Number: 406

Angularity is the condition of a surface or axis at a specified angle (other than 90 degrees) from a datum plane or axis. An Angularity tolerance specifies a tolerance zone defined by two parallel planes at the specified basic angle from the datum plane or axis within which the surface or axis of the considered feature must lie.

See ANSI Y14.5M 1982, page 106, section 6.6.2
See ISO 1101, pages 18-19, section 5.9

EXPRESS Definition:

```
        ENTITY Angularity SUBTYPE OF (Geometric_Tolerance);
             Tol_Ent              : SET OF SELECT (Seam,Area,
                                        Feature_of_Size);
             Tolerance            : Number;
             Material_condition   : Tol_MLSN;
             Projection           : Optional Projected_Tolerance_Zone;
             Primary_datum        : Conditioned_datum;
             Secondary_datum      : Optional Conditioned_datum;
             Tertiary_datum       : Optional Conditioned_datum;
          WHERE
             Tol_Ent <> [];
             Tolerance > 0;
   (*        IF SYMMETRIC(Toleranced_Entity) THEN
                Material_Condition = M    OR
                Material_Condition = L    OR
                Material_Condition = S;           -- Default Condition
             ELSE
                Material_Condition = N;      *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced Entity
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Material_condition
An enumerated list that indicates the material condition at which the tolerance applies:

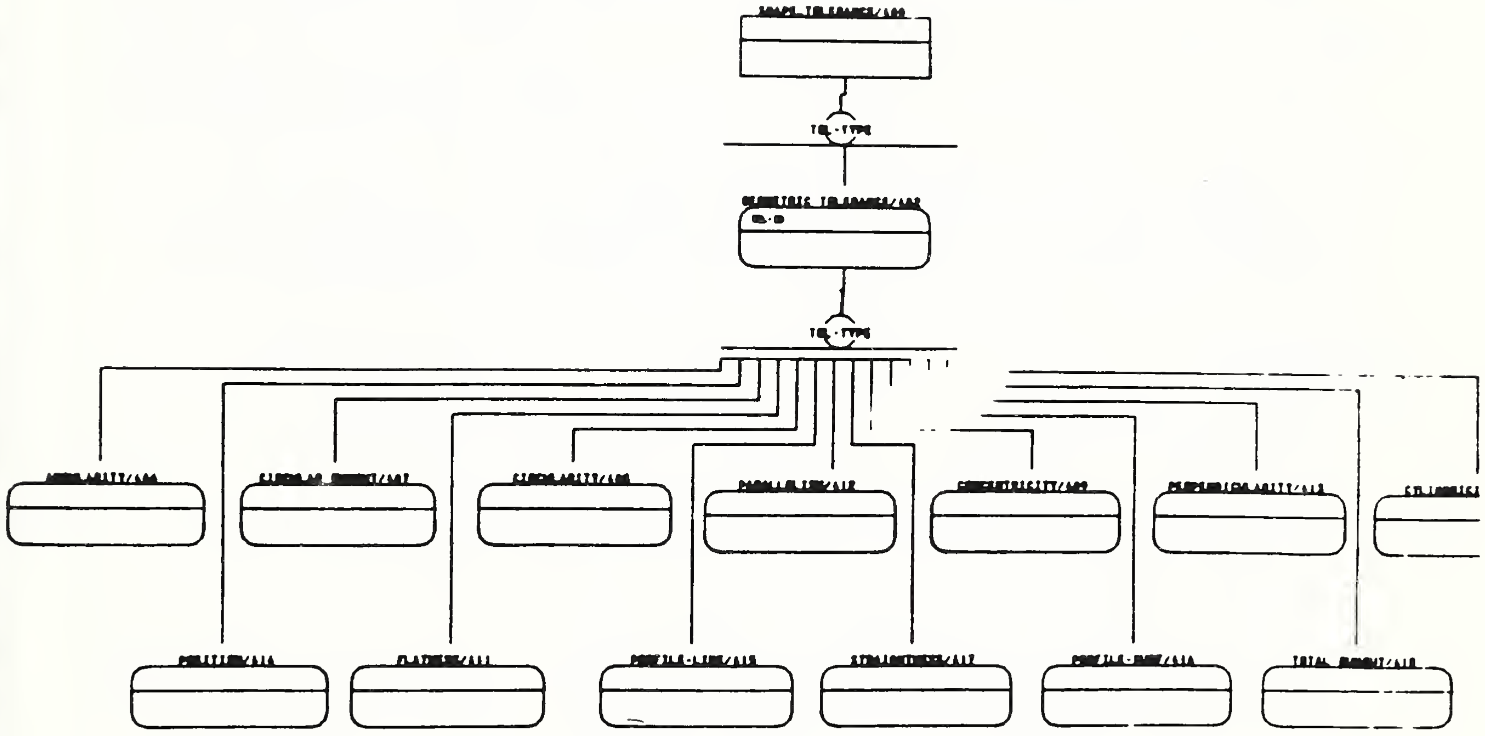


Figure D-18: GEOMETRIC TOLERANCE IDEF1X Diagram

M - maximum material condition; L - least material condition; or S - regardless of feature size; N - Not Applicable.

Projection
A Projected_Tolerance Zone which specifies the additional height and direction of the projected tolerance zone outside the feature boundary.
Note: Must be parallel to the toleranced features. Length of vector determines the extent of the zone.

Primary_datum
A conditioned datum entity from which the dimension is measured. This datum is the most important datum relative to the tolerance.

Secondary_datum
A conditioned datum entity which is the second most important datum relative to the tolerance.

Tertiary_datum
A conditioned datum entity which is the third most important datum relative to the tolerance. With the primary and secondary datums, it establishes a datum reference frame that exactly locates the toleranced feature.

Propositions:

Each Angularity(406) tolerance

- is a Geometric_Tolerance(402).
- has a projected tolerance zone defined by 0 or 1 Projected_Tolerance_Zone(102).
- has a primary datum of exactly one Conditioned_Datum(302).
- may have a secondary datum of one Conditioned_Datum(302).
- may have a tertiary datum of one Conditioned_Datum(302).
- tolerances 1 or more Seam(INT-14), Area(INT-8), or Feature_of_Size(306).

Entity Name: Circular Runout Tolerance

Entity Number: 407

Circular runout tolerance defines the maximum allowable deviation of position of a point on the toleranced feature during one complete revolution of the feature about the datum axis, without relative axial displacement of the measuring position. Where applied to surfaces constructed around a datum axis, it is used to to control the cumulative variations of circularity and coaxiality. Where applied to surfaces constructed at right angles to the datum axis, circular runout controls circular elements of a planar surface.

See ANSI Y14.5M 1982, page 109, section 6.7.2.1
See ISO 1101, page 22-23, section 5.12

EXPRESS Definition:

```
        ENTITY Circular_Runout SUBTYPE OF (Geometric_Tolerance);
             Tol_Ent             : SET OF SELECT(Area,Feature_of_Size);
             Tolerance           : Number;
             Primary_datum       : Unconditioned_Datum;
             Co-primary_datum    : Optional Unconditioned_Datum;
          WHERE
             Tol_Ent <> [];
             Tolerance > 0;
   (*        For each member in Toleranced_Entity
                 ((CIRCULAR(member) = TRUE) OR
                   (DISK(member) = TRUE));         *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Primary_datum: A datum entity from which the dimension is measured. The primary datum is the most important datum relative to the tolerance.

Co-primary_datum
An additional datum entity which establishes an axis with the primary datum.

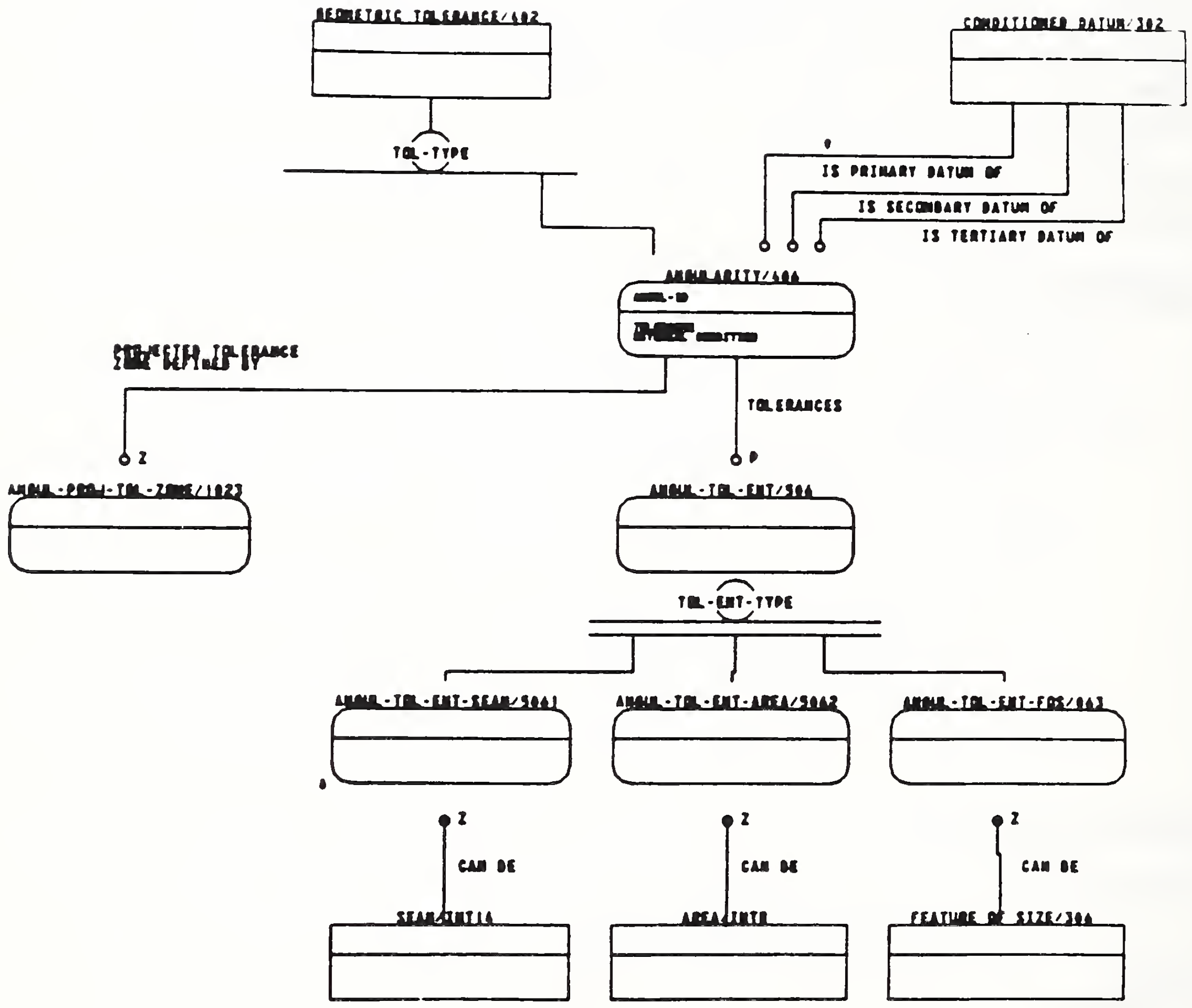


Figure D-19: ANGULARITY IDEF1X Diagram

Constraint Definitions:

For each member in Toleranced Entity

```
        ((CIRCULAR(member) = TRUE) OR (DISK(member) = TRUE))
```

CIRCULAR is a function which returns the value TRUE if cross sections of the input entity (or each member of a list of entities) in a plane normal to the axis are circular. DISK is a function which returns a value TRUE of the input entity (or each member of a list of entities) is normal to the axis of rotation, planar, and has a circular boundary.

Propositions:

Each Circular_Runout(407) tolerance

- is a Geometric_Tolerance(402).
- has a datum of exactly one Unconditioned_Datum(310).
- may have a co-datum of one Unconditioned_Datum(310).
- tolerances 1 or more Seam(INT-14), Area(INT-8) or Feature_of_Size(306).

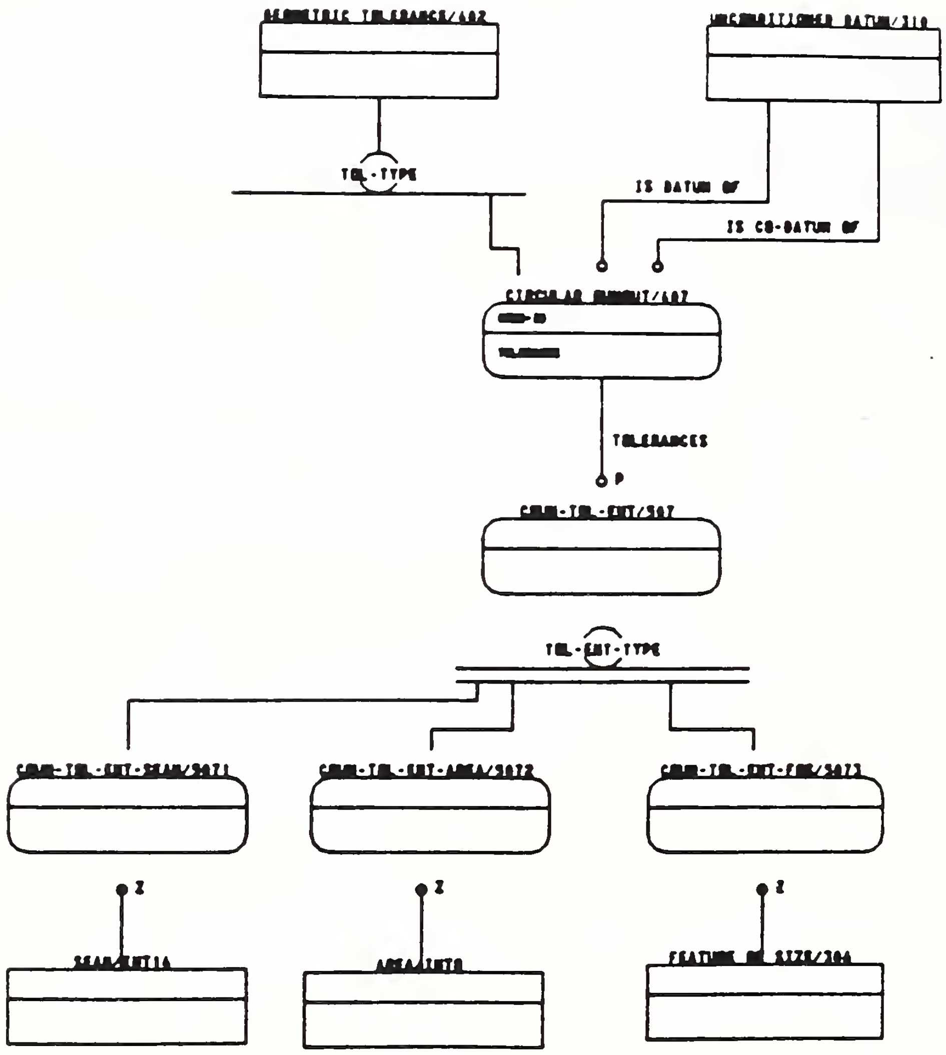


Figure D-20: CIRCULAR RUNOUT IDEF1X Diagram

Entity Name: Circularity Tolerance

Entity Number: 408

Circularity is a condition of a surface of revolution such that all points of the surface intersected by a plane perpendicular to the axis or center point are equidistant from the intersection point of the plane and the axis or center point. A Circularity tolerance defines the distance between two concentric circles within which the coordinates of the toleranced feature must lie. These circles are perpendicular to and centered on the axis of the toleranced feature.

See ANSI Y14.5M 1982, page 95, section 6.4.3
See ISO 1101, page 14, section 5.3

EXPRESS Definition:

```
        ENTITY Circularity SUBTYPE OF (Geometric_Tolerance);
             Tol_Ent    : SET OF SELECT (Seam,Area,Feature_of_Size);
             Tolerance  : Number;
          WHERE
             Tol_Ent <> [];
             Tolerance > 0;
   (*        CIRCULAR(Tol_Ent) = TRUE;   *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity
   A set of entities to which the tolerance applies.

Tolerance
   The allowable deviation of the measured dimensional value from the design nominal.

Constraint Definitions:

```
        CIRCULAR(Tol_Ent) = TRUE;
```

The asserts that the entity(ies) to which this tolerance applies must circular (see Circular Runout for definition of function).

Propositions:

Each Circularity(408) tolerance

- is a Geometric_Tolerance(402).
- tolerances 1 or more Seam(INT-14), Area(INT-8), Feature_of_Size(306);

Entity Name: Concentricity Tolerance

Entity Number: 409

Concentricity tolerance specifies the diameter of cylinder centered on a datum point or axis within which the center or axis of the toleranced circular or cylindrical feature must lie. The specified tolerance and datum reference apply only on a Regardless-of-Feature-Size basis.

See ANSI Y14.5M 1982, page 84, section 5.11.3
See ISO 1101, page 21, section 5.11.1

EXPRESS Definition:

```
        ENTITY Concentricity SUBTYPE OF (Geometric_Tolerance);
             Tol_Ent               : SET OF SELECT (Area,Feature_of_Size);
             Tolerance             : Number;
             Cylindrical_zone      : Logical;
             Primary_datum         : Unconditioned_Datum;
             Co-primary_datum      : Optional Unconditioned Datum;
          WHERE
             Tol_Ent <> [];
             Tolernace > 0;
   (*        CIRCULAR(Tol_Ent) = TRUE;  *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Cylindrical_zone
A boolean (true/false) flag that indicates that the tolerance value is the diameter of a cylindrical zone within which the axis or line must lie. If false, the zone is parallelepipedic or the space between two parallel lines or planes.

Primary_datum
A datum entity from which the dimension is measured. The primary datum is the most important datum relative to the tolerance.

Co_primary_datum
An additional datum entity which establishes an axis with the primary datum.

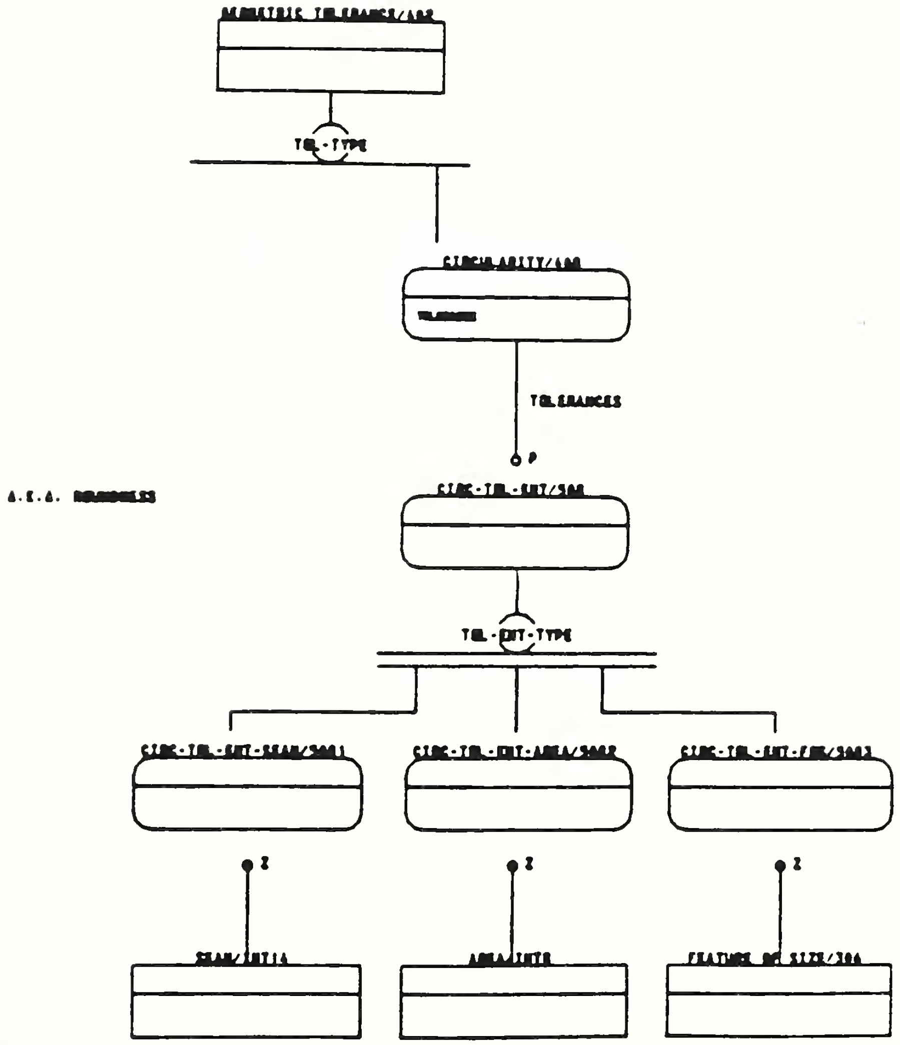


Figure D-21: CIRCULARITY IDEF1X Diagram

Constraint Description:

```
        CIRCULAR(Tol_Ent) = TRUE;
```

Asserts that the entity(ies) to which this tolerance applies must be circular (see Circular Runout for definition of function).

Propositions:

Each Concentricity(409) tolerance

- is a Geometric_Tolerance(402).
- has a datum of one Unconditioned_Datum(310).
- has a co-datum of 0 or 1 Unconditioned_Datum(310).
- tolerances 1 or more Seam(INT-14), Area(INT-8), or Feature_of_Size(306).

Entity Name: Cylindricity Tolerance

Entity Number: 410

Cylindricity tolerance defines the distance between two coaxial cylinders within which the toleranced cylindrical feature must lie. Unlike circularity, the tolerance applies simultaneously to both circular and longitudinal elements of the surface.

See ANSI Y14.5M 1982, page 96, section 6.4.4.
See ISO 1101, page 14, section 5.4

EXPRESS Definition:

```
        ENTITY Cylindricity SUBTYPE OF (Geometric_Tolerance);
            Tol_Ent   : SET OF SELECT (Area,Feature_of_Size);
            Tolerance : Number;
          WHERE
            Tol_Ent <> [];
            Tolerance > 0;
   (*       CYLINDRICAL(Tol_Ent) = TRUE;         *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced Entity
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Constraint Definitions:

```
CYLINDRICAL(Tol_Ent) = TRUE;
```

The CYLINDRICAL function returns a value TRUE if the input entity (or each member from a list of entities) is cylindrical.

Propositions:

Each Cylindricity(410) tolerance

- is a Geometric_Tolerance(402).
- tolerances 1 or more Area(INT-8) or Feature_of_Size(306).

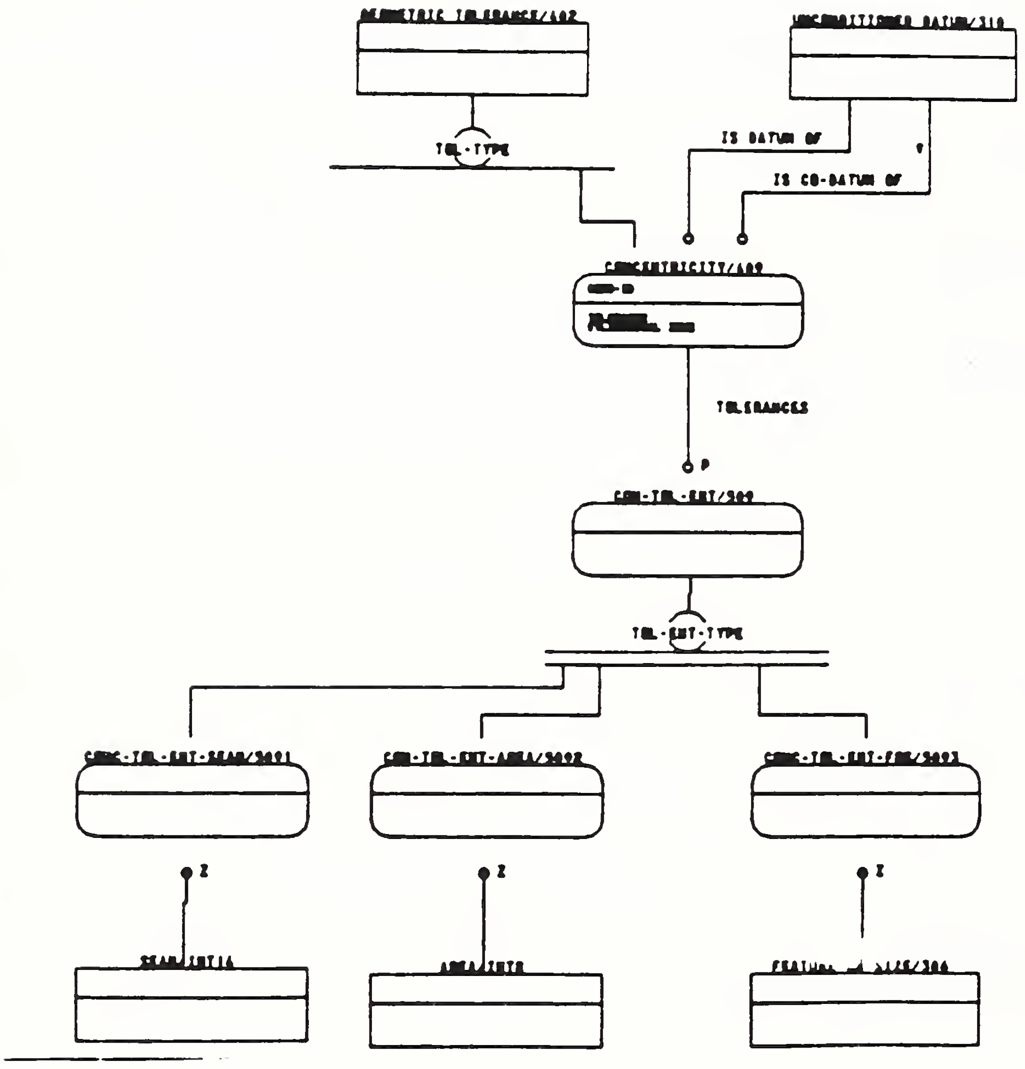


Figure D-22: CONCENTRICITY IDEF1X Diagram

Entity Name: Flatness Tolerance

Entity Number: 411

Flatness tolerance defines the distance between two parallel planes between which the toleranced surface must lie. The tolerance may be applied on a unit basis as a means of preventing abrupt surface variation within a small area of the feature.

See ANSI Y14.5M 1982, page 94, section 6.4.2
See ISO 1101, page 13, section 5.2

EXPRESS Definition:

```
        ENTITY Flatness SUBTYPE OF (Geometric_Tolerance);
             Tol_Ent              : SET OF Area;
             Tolerance            : Number;
             Per_unit_square      : Optional Number;
          WHERE
             (Per_unit_Square > 0.0);
             Tol_Ent <> [];
             Tolerance > 0;
          (* PLANAR(Tol_Ent) = TRUE;  *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Per unit square
Specifies the side of square region on the Toleranced_Entity over which the tolerance value applies. Used to prevent abrupt surface variations in a relatively small area of the feature.

Constraint Definitions:

```
        PLANAR(Tol_Ent) = TRUE
```

The PLANAR function returns a value TRUE if the input entity (or each member from a list of entities) is planar.

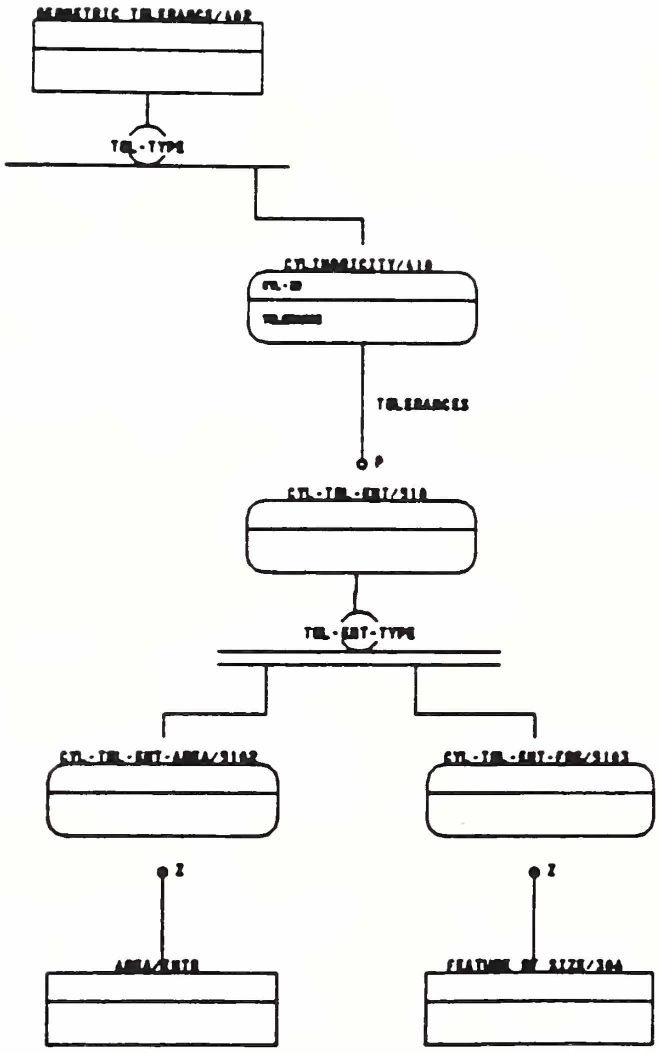


Figure D-23: CYLINDRICITY IDEF1X Diagram

Propositions:

Each Flatness(411) tolerance

- is a Geometric_Tolerance(402).
- tolerances 1 or more Area(INT-8).

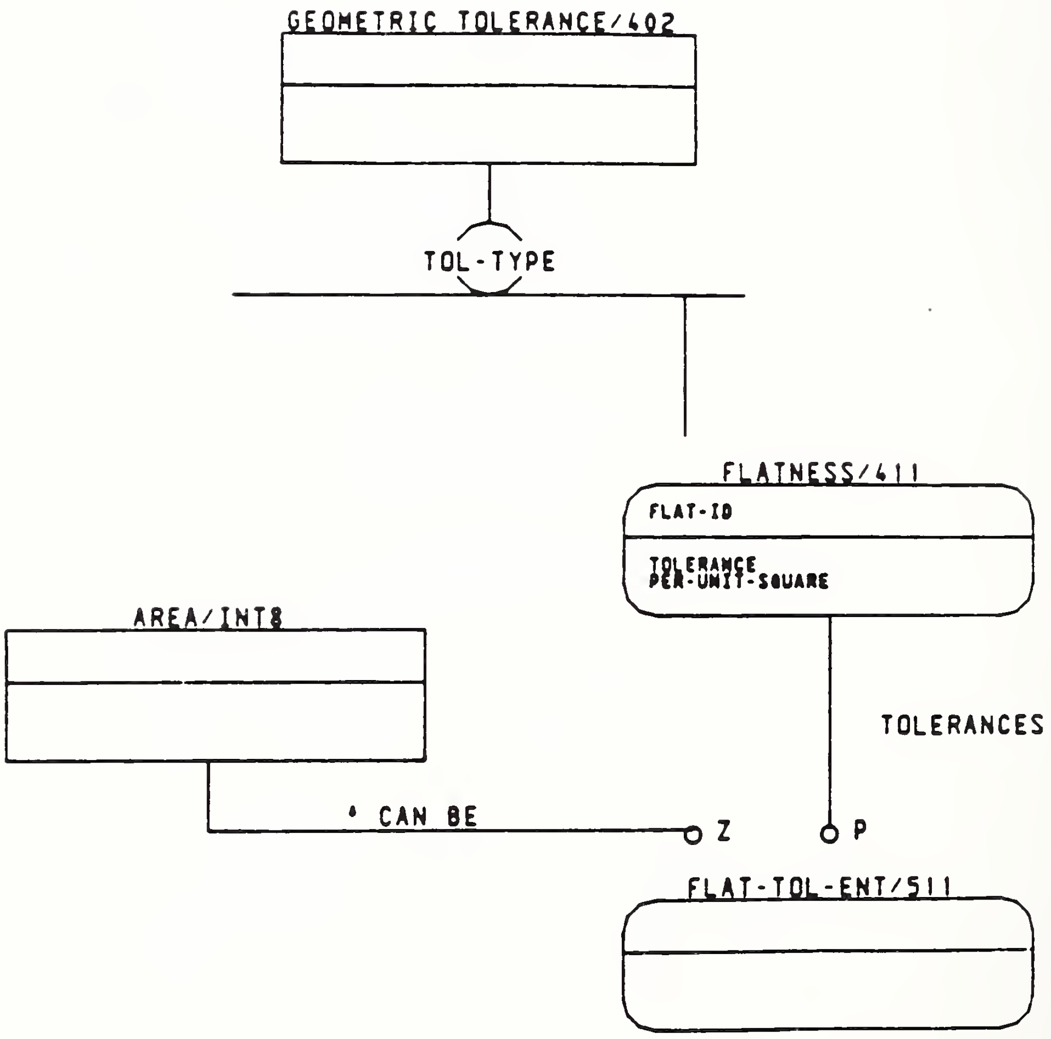


Figure D-24: FLATNESS IDEF1X Diagram

Entity Name: **Parallelism Tolerance**

Entity Number: **412**

Parellelism is the condition of a surface equidistant at all points from a datum plane or an axis equidistant along the length from the datum axis. Parallelism tolerance specifies the distance between two planes or lines parallel to a datum plane or axis within which the line elements of the surface or axis of the considered feature must lie, or a cylindrical tolerance zone whose axis is parallel to the datum axis, within which the axis of the considered feature must lie. The allowable feature position zone may be cylindrical(fig 45), parallelepipedic (fig 51) or planar (fig 47,54) for line features and is similar to a flatness tolerance zone for surface features (fig 57,60). These figure references are to the ISO 1101 standard.

See ANSI Y14.5M 1982, page 106, section 6.6.3
See ISO 1101, page 15-17, section 5.7

EXPRESS Definition:

```
        ENTITY Parallelism SUBTYPE OF (Geometric_Tolerance);
            Tol_Ent               : SET OF SELECT(Seam,Area,
                                     Feature_of_Size);
            Tolerance             : Number;
            Material_condition    : Tol_MLSN;
            Cylindrical_zone      : Logical;
            Projection            : Optional Projected_Tolerance_Zone;
            Primary_datum         : Conditioned_datum;
          WHERE
            Tol_Ent <> [];
            Tolerance > 0;
(*          IF SYMMETRIC(Tol_Ent) THEN
              Material_Condition = M    OR
              Material_Condition = L    OR
              Material_Condition = S;           -- Default Condition
            ELSE
              Material_Condition = N;       *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Material_condition

An enumerated list that indicates the material condition at which the tolerance applies: M - maximum material condition; L - least material condition: S - regardless of feature size; N - Not applicable.

Cylindrical_zone

A boolean (true/false) flag that indicates that the tolerance value is the diameter of a cylindrical zone within which the axis or line must lie. If false, the zone is parallelepipedic or the space between two parallel lines or planes.

Projection

A point, a direction, and an extent which specify the additional height and direction of the projected tolerance zone outside the feature boundary.
Note: Must be parallel to the toleranced features.

Primary_datum

A conditioned datum entity from which the dimension is measured.

Propositions:

Each Parallelism(412) tolerance

- is a Geometric_Tolerance(402).
- has exactly one datum of Conditioned_Datum(302).
- has a project tolerance zone defined by 0 or 1 Projected Tolerance_Zone(102).
- tolerances 1 or more Seam(INT-14), Area(INT-8), or Feature_of Size(306).

Entity Name: Perpendicularity Tolerance

Entity Number: 413

Perpendicularity tolerance defines the allowable linear deviation from a true right angle of line or surface features with respect to line or surface datums. Several interpretations of the exact tolerance zone are possible for line features with respect to surface datums.

See figures 65,67 and 69 in ISO 1101, page 17.
See ANSI Y14.5M 1982, page 106, section 6.6.4
See ISO 1101, page 17-18, section 5.8

EXPRESS Definition:

```
       ENTITY Perpendicularity SUBTYPE OF (Geometric_Tolerance);
            Tol_Ent              : SET OF SELECT(Seam,Area,
                                      Feature_of_Size);
            Tolerance            : Number;
            Material_condition   : Tol_MLSN;
            Cylindrical_zone     : Logical;
            Projection           : Optional Projected_Tolerance_Zone;
            Primary_datum        : Conditioned_datum;
            Secondary_datum      : Optional Conditioned_datum;
         WHERE
            Tol_Ent <> [];
            Tolerance > 0;
(*          IF SYMMETRIC(Toleranced_Entity) THEN
               Material_Condition = M    OR
               Material_Condition = L    OR
               Material_Condition = S;          -- Default Condition
            ELSE
               Material_Condition = N;      *)
         END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Material_condition
An enumerated list that indicates the material condition at which the tolerance applies:

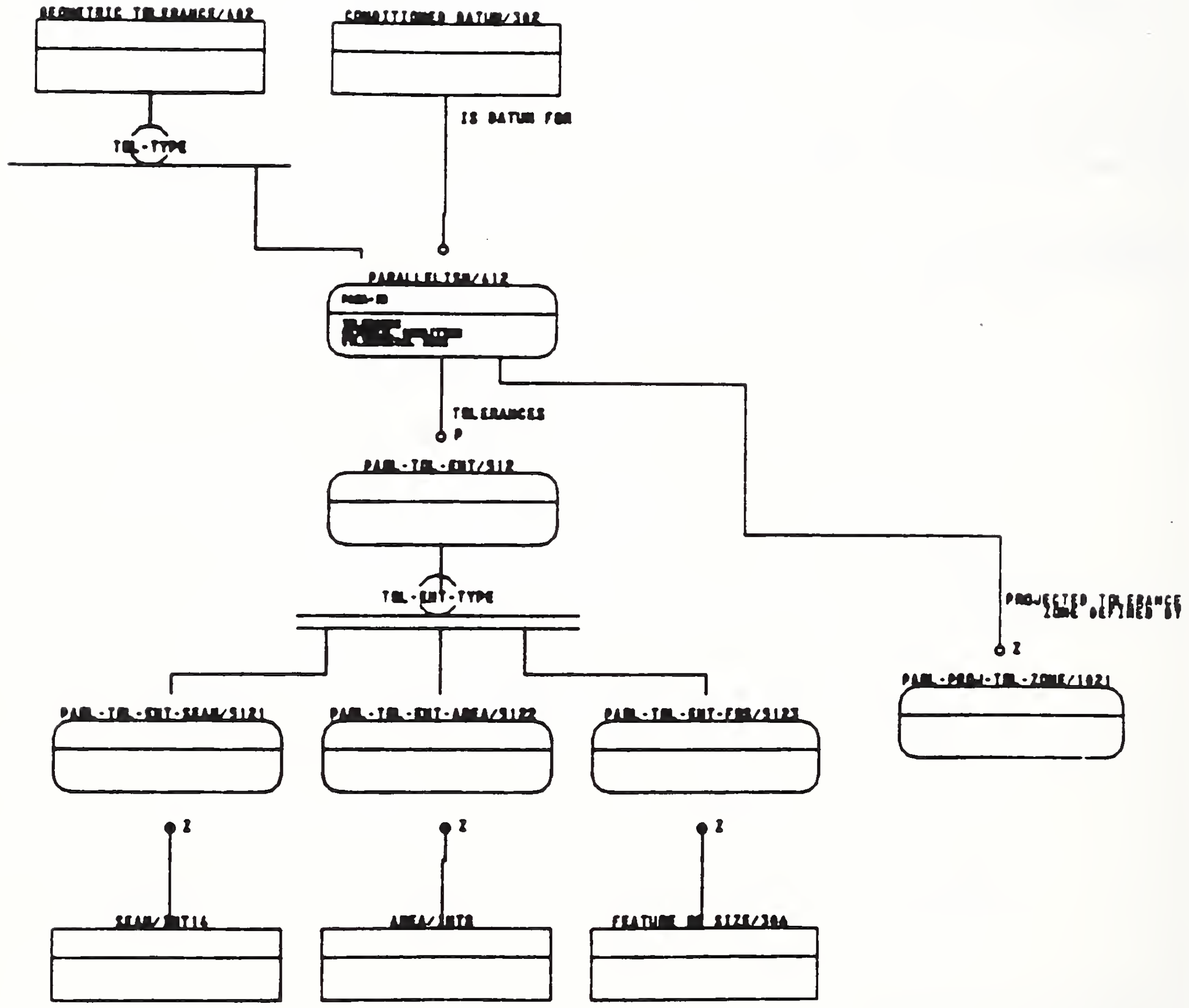


Figure D-25: PARALLELISM IDEF1X Diagram

M - maximum material condition; L - least material condition: S - regardless of feature size; N - Not Applicable.

Cylindrical_zone
A boolean (true/false) flag that indicates that the tolerance value is the diameter of a cylindrical zone within which the axis or line must lie. If false, the zone is parallelepipedic or the space between two parallel lines or planes.

Projection
A point, a direction and an extent which specify the additional height and direction of the projected tolerance zone outside the feature boundary.
Note: Must be parallel to the toleranced features. Length of vector determines the extent of the zone.

Primary_datum
A conditioned_Datum entity from which the dimension is measured. This primary datum is the most important datum relative to the tolerance.

Secondary datum
A conditioned_Datum entity which is the second most important datum relative to the tolerance.

Propositions:

Each Perpendicularity(413) tolerance

- is a Geometric_Tolerance(402).
- has Primary datum of exactly one Conditioned Datum(302).
- may have a secondary datum of one Conditioned_Datum(302).
- has a projected tolerance zone defined by 0 or 1 Projected_Tolerance_Zone(102).
- tolerances 1 or more Seam(INT-14), Area(INT-8), or Feature_of_Size(306).

Entity Name: Position Tolerance

Entity Number: 414

Position tolerance defines the allowable deviation of position of the center point axis or center plane of a feature of size. A center point tolerance defines the diameter of a spherical or circular zone, an axis tolerance defines the measure of a cylindrical, parallelepipedic or planar zone and a center plane tolerance defines a zone specified by the distance between two bounding parallel planes. Each zone is considered to contain the true position of the toleranced feature.

See ANSI Y14.5M 1982, page 53-89, section 5.2
See ISO 1101, page 19-20, section 5.10

EXPRESS Definition:

```
        ENTITY Position SUBTYPE OF (Geometric Tolerance);
             Tol_Ent              : SET OF Feature_of_Size;
             Tolerance            : Number;
             Material_condition   : Tol_MLSN;
             Cylindrical_zone     : Logical;
             Projection           : Optional Projected_Tolerance_Zone;
             Primary_datum        : Conditioned_datum;
             Secondary_datum      : Optional Conditioned_datum;
             Tertiary_datum       : Optional Conditioned_datum;
          WHERE
             Tol_Ent <> [];
             Tolerance > 0;
   (*        IF SYMMETRIC(Toleranced_Entity) THEN
                Material_Condition = M    OR
                Material_Condition = L    OR
                Material_Condition = S;           -- Default Condition
             ELSE
                Material_Condition = N;      *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Material_condition
An enumerated list that indicates the material condition at which the tolerance applies:

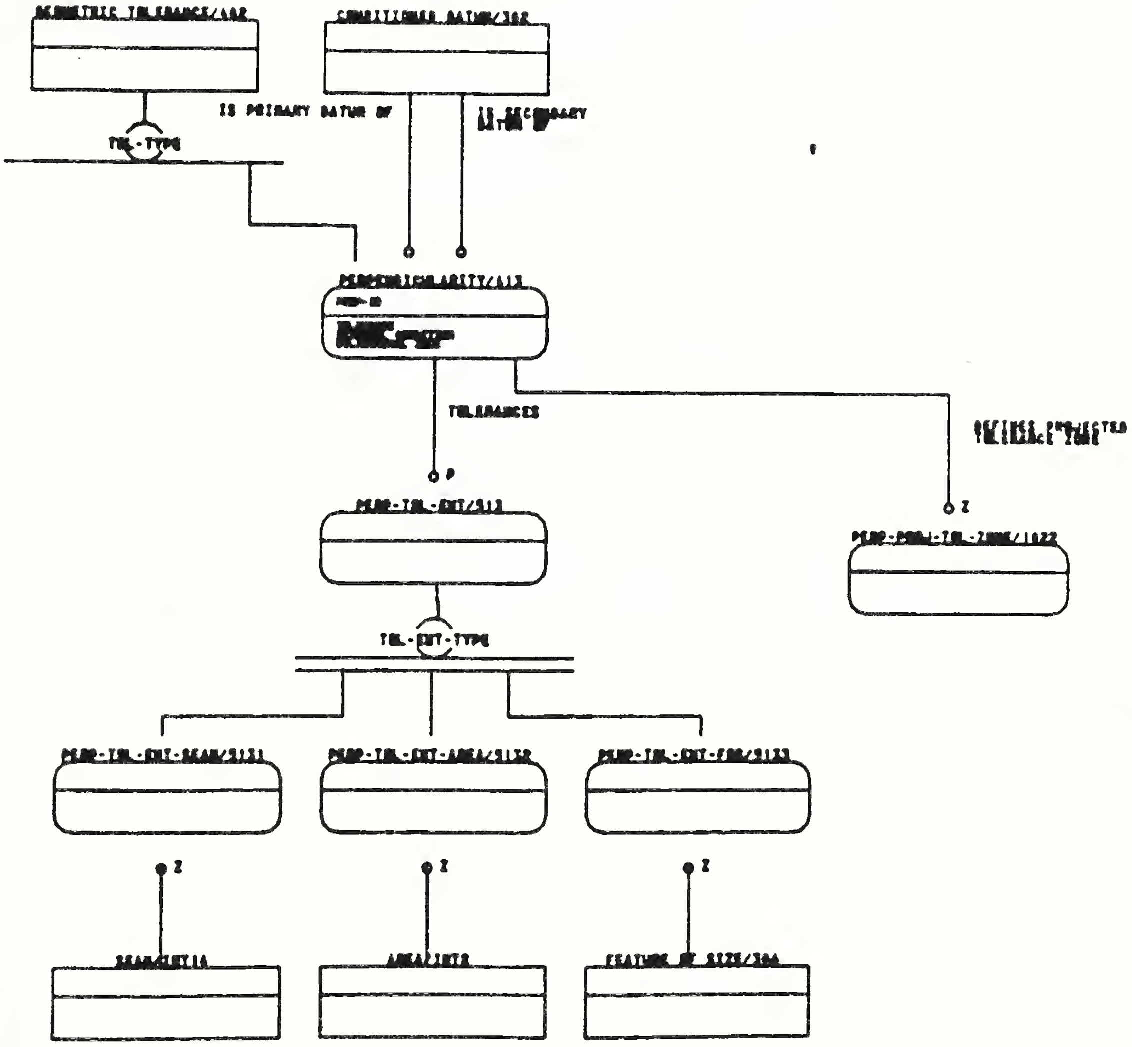


Figure D-26: PERPENDICULARITY IDEF1X Diagram

M - maximum material condition; L - least material condition: S - regardless of feature size; N - not applicable.

Cylindrical_zone
A boolean (true/false) flag that indicates that the tolerance value is the diameter of a cylindrical zone within which the axis or line must lie. If false, the zone is parallelepipedic or the space between two parallel lines or planes.

Projection
A point, a direction and an extent which specify the additional height and direction of the Projected_Tolerance_Zone outside the feature boundary.
Note: Must be parallel to the toleranced features.

Primary_datum
A conditioned_Datum entity from which the dimension is measured. This primary datum is the most important datum relative to the tolerance.

Secondary_datum
A conditioned_Datum entity which is the second most important datum relative to the tolerance.

Tertiary_datum
A conditioned datum entity which is the third most important datum relative to the tolerance. With the primary and secondary datums, it establishes a datum reference frame that exactly located the toleranced feature.

Propositions:

Each Position(414) tolerance

- is a Geometric_Tolerance(402)
- has a primary datum of exactly one Conditioned_Datum(302).
- may have a secondary datum of one Conditioned_Datum(302).
- may have a tertiary datum of one Conditioned_Datum(302).
- has a projected tolerance zone defined by 0 or 1 Projected_Tolerance_Zone(102).
- tolerances 1 or more Feature of_Size(306).

Entity Name: **Profile of a Line Tolerance**

Entity Number: **415**

Profile of a line tolerance specifies the diameter of a circle which when its center or one tangent moves along the design nominal curve feature, sweeps the region in which the feature must lie. The tolerance is two dimensional and applies normal (perpendicular) to the true profile at all points. Where a sharp corner is included, the tolerance zone extends to the intersection of the boundary lines.

See ANSI Y14.5M 1982, page 97-104, section 6.5.1
See ISO 1101, page 14, section 5.5

EXPRESS Definition:

```
        ENTITY Profile_Line SUBTYPE OF (Geometric_Tolerance);
             Tol_Ent             : SET OF SELECT (Seam, Area);
             Tolerance           : Number;
             Directrix           : Optional Direction;
             Application         : Tol_IBO;
             Primary_datum       : Optional Conditioned_datum;
             Secondary_datum     : Optional Conditioned_datum;
             Tertiary_datum      : Optional Conditioned_datum;
          WHERE
             Tol_Ent <> [];
             Tolerance > 0;
  (*         NOT ((Tol_Ent = Edge) AND NOT PLANAR(Tol_Ent));
             IF (Tol_Ent = Edge) THEN Directrix = NUL;  *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity
A set of entities to which the the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Application
An enumerated list that specifies the tolerance application to be I - inside, B - bilateral, O - Outside.

Primary_datum
A conditioned_Datum entity from which the dimension is measured. This primary datum is the most important datum relative to the tolerance.

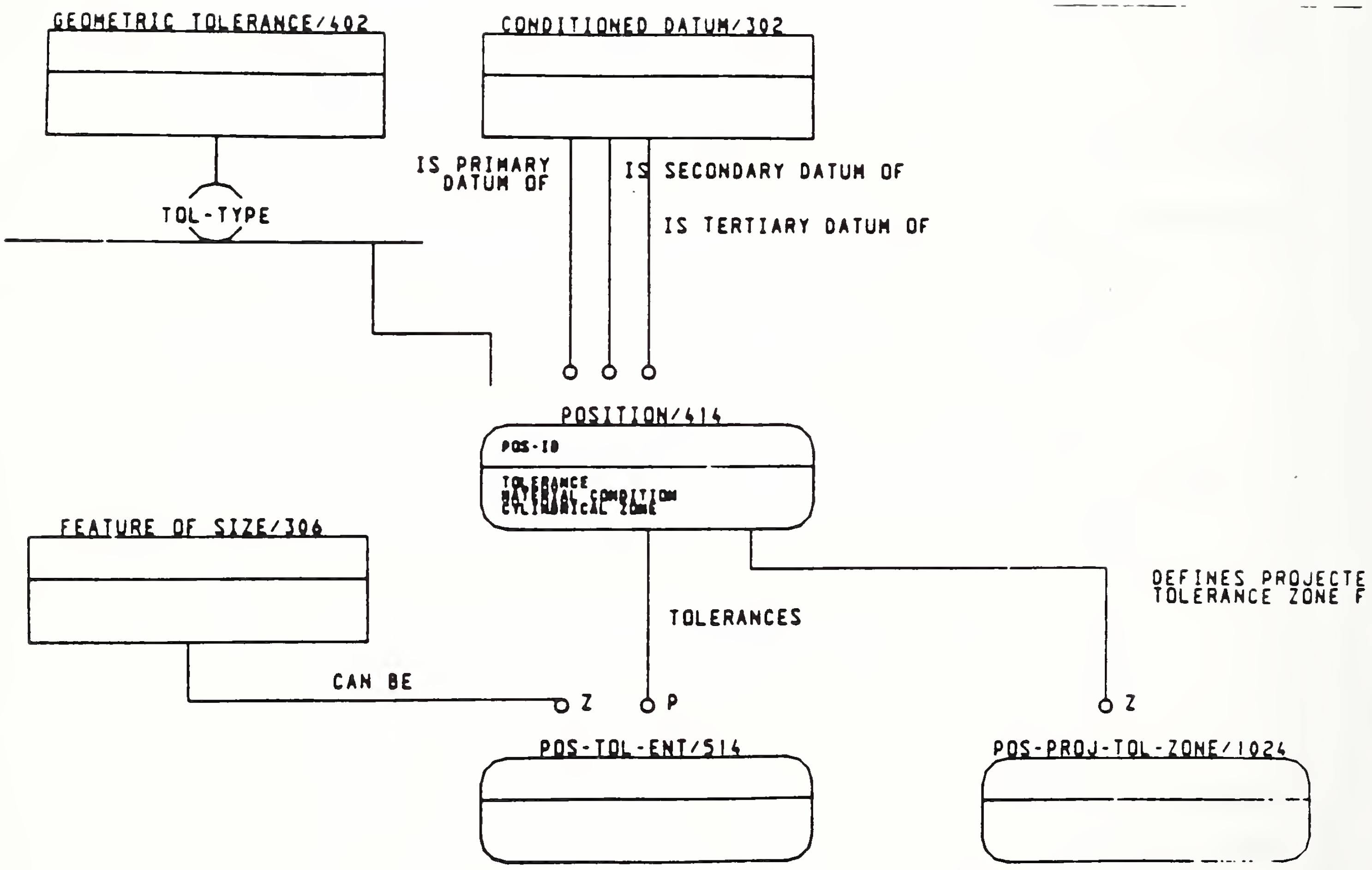


Figure D-27: POSITION IDEF1X Diagram

Secondary_datum
A conditioned_Datum entity which is the second most important datum relative to the tolerance.

Tertiary_datum
A conditioned datum entity which is the third most important datum relative to the tolerance. With the primary and secondary datums, it establishes a datum reference frame that exactly located the toleranced feature.

Directrix
Cross sections of the toleranced face taken in planes normal to the directix establish the line profile that is toleranced. The directrix is required only if a datum is not included in the line tolerance entity.

Constraint Definitions:

```
(Tol_Ent = Edge) AND PLANAR(Tol_Ent));
IF (Tol_Ent = Edge) THEN Directrix = NULL;
```

This clause asserts that if the entity to which the tolerance applies is an Seam, the underlying curve of the Seam must be defined within a plane. (see Flatness for definition of PLANAR). It further asserts that the Directrix is meaningless and should be null if the Tol_Ent is an Seam (A value for the Directrix may be assigned if there are entities in the list which are Areas).

Propositions:

Each Profile of a Line(415) tolerance

- is a Geometric_Tolerance(402).
- may have a primary datum of one Conditioned_Datum(302).
- may have a secondary datum of one Conditioned_Datum(302).
- may have a tertiary datum of one Conditioned_Datum(302).
- may have profile determined in planes normal to one Direction(GEO-14).
- tolerances 1 or more Seam(INT-14) or Area(INT-8).

Entity Name: **Profile of a Surface Tolerance**

Entity Number: **416**

A profile of a surface tolerance specifies the distance between two "ball-offset" surfaces located equally on either side, or totally on one side of the design nominal feature. The toleranced feature must lie between these surfaces. The tolerance is three-dimensional and applies normal (perpendicular) to the true profile at all points. Where a sharp corner is included, the tolerance zone extends to the intersection of the boundary.

See ANSI Y14.5M 1982, page 97-104, section 6.5.1
See ISO 1101, page 14, section 5.5

EXPRESS Definition:

```
      ENTITY Profile_Surface SUBTYPE OF (Geometric_Tolerance);
           Tol_Ent             : SET OF Area;
           Tolerance           : Number;
           Default             : Logical;
           Application         : Tol_IBO;
           Primary_datum       : Optional Conditioned_datum;
           Secondary_datum     : Optional Conditioned_datum;
           Tertiary_datum      : Optional Conditioned_datum;
   (* WHERE
           Tolerance >= 0;
           EMPTY(Toleranced_Entity) = Default;
           UNIQUE(Default = TRUE);           *)
      END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Default
A Boolean flag used to denote the instance of the Profile_Surface_Tolerance that is used as the default tolerance within the Product Model. Only one instance of this entity may have this attribute set to TRUE, and this one may not reference any toleranced entity (hence, a cardinality of 0 is allowed for this entity).

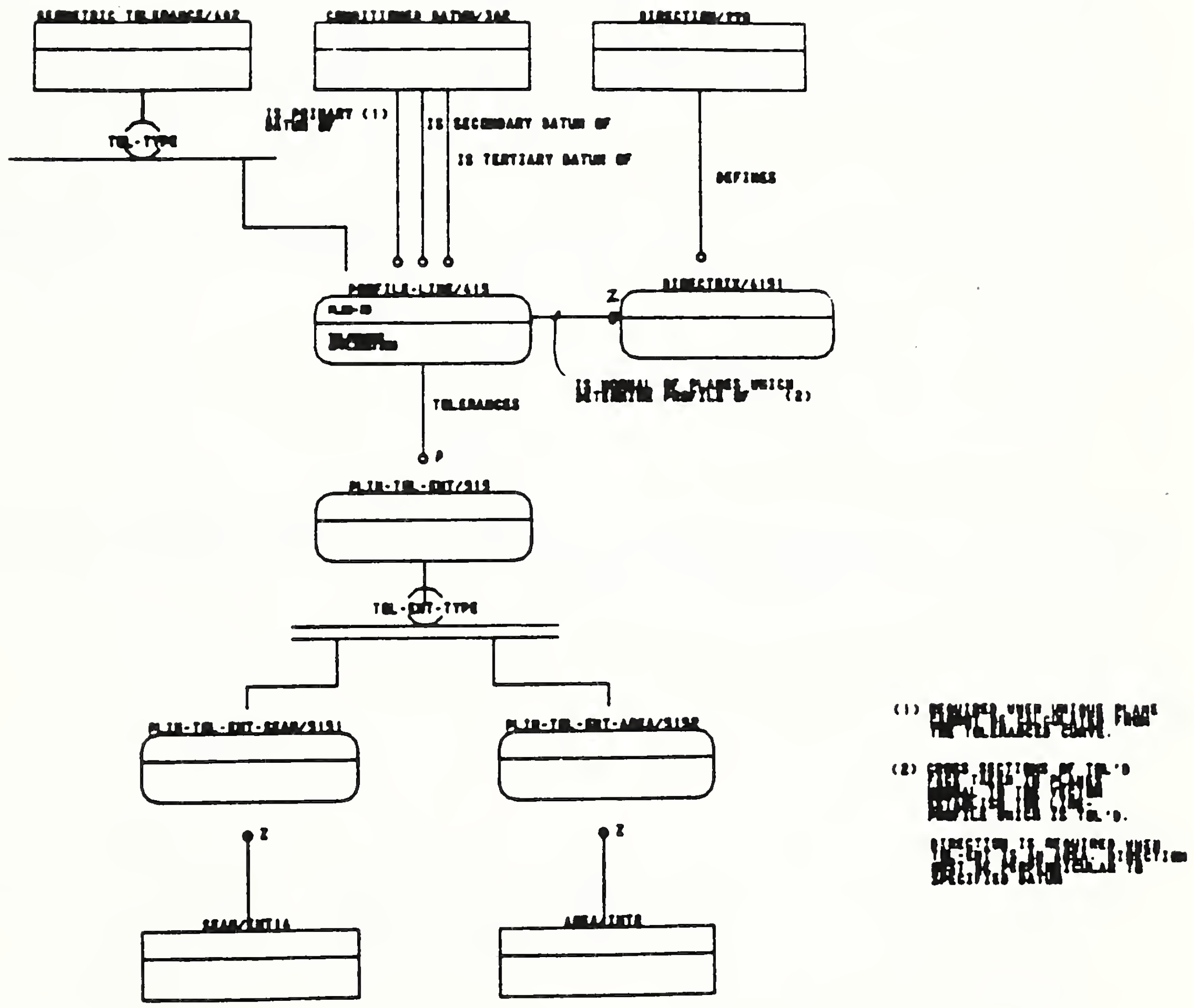


Figure D-28: PROFILE OF A LINE IDEF1X Diagram

Application

An enumerated list that specifies the tolerance application to be I - inside, B - bilateral O - Outside.

Primary datum

A conditioned_Datum entity from which the dimension is measured. This primary datum is the most important datum relative to the tolerance.

Secondary_datum

A conditioned_Datum entity which is the second most important datum relative to the tolerance.

Tertiary_datum

A conditioned datum entity which is the third most important datum relative to the tolerance. With the primary and secondary datums, it establishes a datum reference frame that exactly located the toleranced feature.

Constraint Definitions:

```
EMPTY(Tol_Ent) = Default;
UNIQUE(Default = TRUE);
```

This constraint asserts that if the Tol_Ent set is EMPTY, then the Default flag must be TRUE. In addition, the instance of the entity where this condition is true must be UNIQUE (i.e. there is only one entity which has a default flag set to TRUE.)

Propositions:

Each Profile_of a_Surface(416) tolerance

- is a Geometric_Tolerance(402).
- may have a primary datum of one Conditioned_Datum(302).
- may have a secondary datum of one Conditioned_Datum(302).
- ..ay have a tertiary datum of one Conditioned_Datum(302).
- tolerances 1 or more Area (INT-8).

Entity Name: Straightness Tolerance

Entity Number: 417

Straightness tolerance defines the allowable deviation of a line or of line elements of a surface feature. The tolerance zones for line features are cylindrical, parallelepipedic and parallel planes. Straightness tolerance for surface features specify the distance between two parallel lines within which a linear element of the surface in a specified direction, must lie. The linear elements is a cross section of the surface in a plane parallel to the direction vector and normal to the surface.

See figures 27,29 and 31 in the ISO 1101 standard, page 17.
See ANSI Y14.5M 1982, page 91-94. section 6.4.1
See ISO 1101, page 13, section 5.1

EXPRESS Definition:

```
ENTITY Straightness SUBTYPE OF (Geometric_Tolerance);
    Tol_Ent              : SET OF SELECT(Seam,Area,
                              Feature_of_Size);
    Tolerance            : Number;
    Direction            : Optional Direction;
    Material_condition   : Tol_MLSN;
    Cylindrical_zone     : Logical;
    Per_unit_length      : Number;
  WHERE
    (per_unit_length > 0.0);
    Tol_Ent <> [];
    Tolerance > 0;
(*  IF SYMMETRIC(Tol_Ent) THEN
        Material_Condition = M    OR
        Material_Condition = L    OR
        Material_Condition = S;          -- Default Condition
    ELSE
        Material_Condition = N;
    IF (Tol_Ent <> Edge) THEN LINEAR_SECTIONS(Direction, Tol_Ent);
    IF (Tol_Ent = Edge) THEN Direction = NULL:  *)
  END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

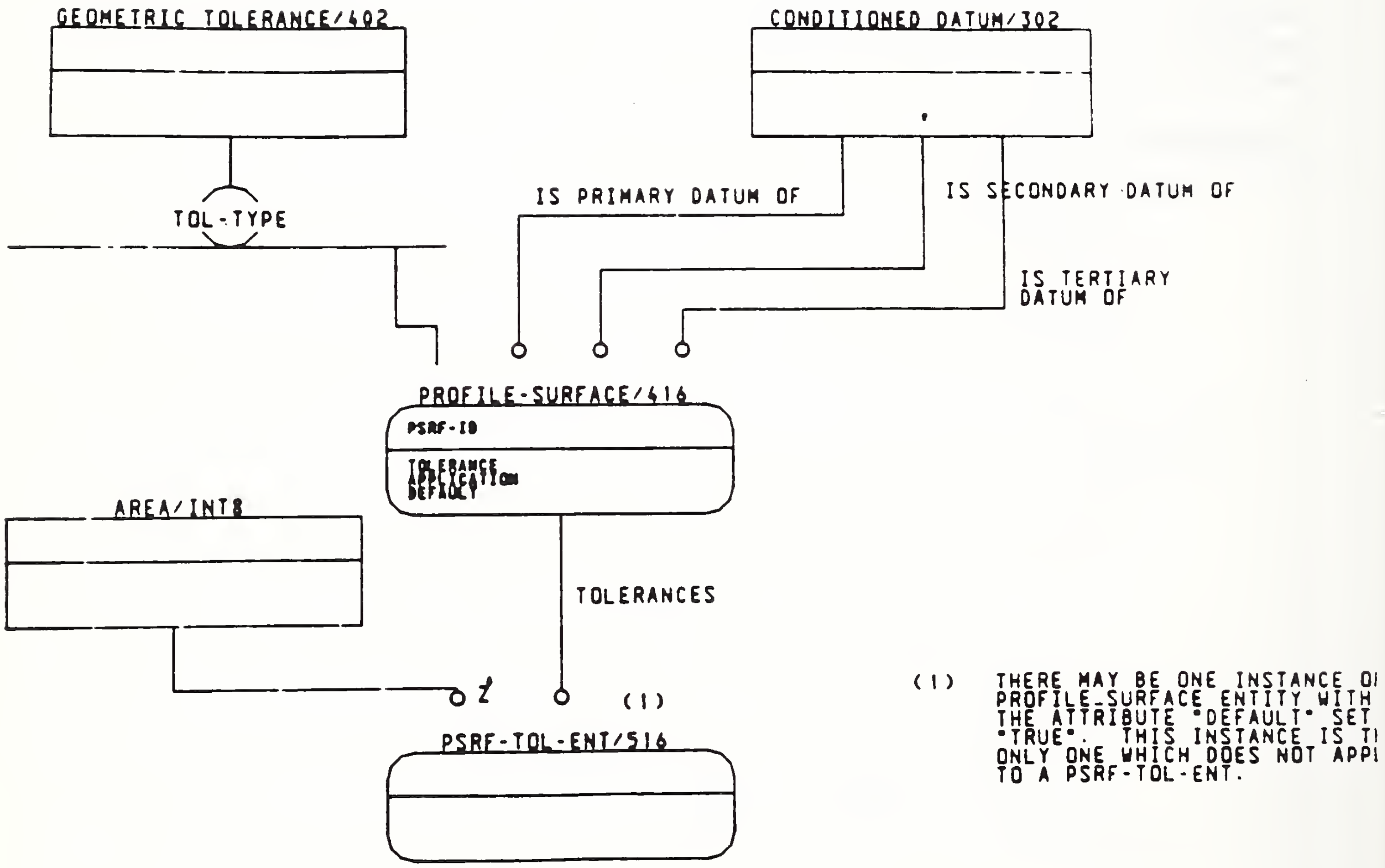


Figure D-29: PROFILE OF A SURFACE IDEF1X Diagram

Direction
A direction that specifies the straightness tolerance for linear surface elements Required when the toleranced entity is a surface. It must be parallel to the surface

Material.condition
An enumerated list that indicates the material condition at which the tolerance applies: M - maximum material condition; L - least material condition: S - regardless of feature size; N - Not applicable.

Cylindrical zone
A boolean (true/false) flag that indicates that the tolerance value is the diameter of a cylindrical zone within which the axis or line must lie. If false, the zone is parallelepipedic or the space between two parallel lines or planes.

Per_unit_length
Specifies the linear distance within which the tolerance value applies. Used to prevent abrupt changes in the direction of the toleranced entity.

Constraint Definitions:

```
IF (Tol_Ent <> Edge) THEN LINEAR_SECTIONS(Direction, Tol_Ent);
IF (Tol_Ent = Edge) THEN Direction = NULL:  *)
```

LINEAR SECTIONS is a function which returns a value TRUE if all cross sections of the toleranced surface (or members of a list of entities) taken in planes tangent to the direction are straight lines. If the Tol_Ent contains a Seam, then the Direction does not apply. If the Toleranced_Entity list contains only Seams, then Direction must be Null.

Propositions:

Each Straightness(417) tolerance

- is a Geometric_Tolerance(402).
- may have a direction of application defined by one Direction(GEO-14).
- tolerances 1 or more Seam(INT-14), Area(INT-8), Feature_of_Size(306).

Entity Name: **Total Runout Tolerance**

Entity Number: **418**

A total runout tolerance specifies the maximum allowable deviation of position for all points on the toleranced feature during one complete revolution of the feature about the datum axis, with relative axial displacement of the measuring position. Where applied to surfaces constructed around a datum axis, it is used to control the cumulative variations of circularity, straightness, angularity, taper, profile of surface, and coaxiality. Where applied to surfaces constructed at right angles to the datum axis, total runout controls perpendicularity and flatness.

See ANSI Y14.5M 1982, page 109, section 6.7.2.2
See ISO 1101, page 22-23, section 5.12
Note that ANSI and ISO do not explicitly define total runout for non-cylindrical surfaces. It is assumed that this is due to mechanical measurement limitations.

EXPRESS Definition

```
        ENTITY Total_Runout SUBTYPE OF (Geometric_Tolerance);
             Tol_Ent              : SET OF SELECT(Area,Feature_of_Size);
             Tolerance            : Number;
             Primary_datum        : Unconditioned_Datum;
             Co-primary_datum     : Optional Unconditioned_Datum;
          WHERE
             Tol_Ent <> [];
             Tolerance > 0;
   (*        FOR EACH member IN Tol_Ent
                 ((CIRCULAR(member) OR DISK(member));      *)
          END_ENTITY;
```

Attribute Definitions:

Toleranced_Entity:
A set of entities to which the tolerance applies.

Tolerance
The allowable deviation of the measured dimensional value from the design nominal.

Primary_datum
A datum entity from which the dimension is measured. The primary datum is the most important datum relative to the tolerance.

Co-primary_datum
An additional datum entity which establishes an axis with the primary datum.

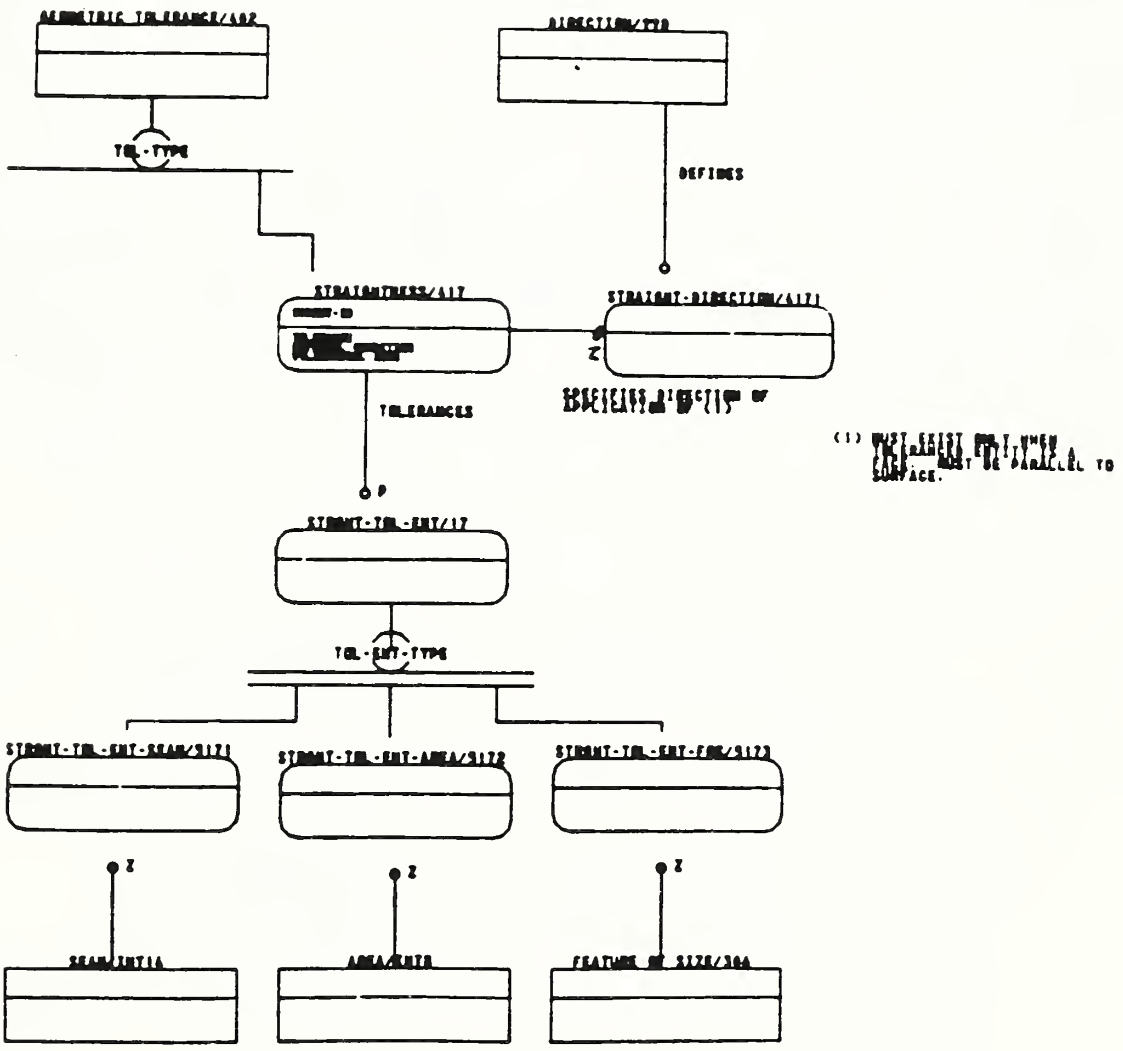


Figure D-30: STRAIGHTNESS IDEF1X Diagram

Constraint Definitions:

```
FOR EACH member IN Tol_Ent ((CIRCULAR(member) OR DISK(member))
```

Asserts that each member in the Tol_Ent list must be either Cylindrical or a Disk. (See Circular_Runout for definition).

Propositions:

Each Total_Runout(418) tolerance

- is a Geometric_Tolerance(402).
- has datum of exactly one Unconditioned_Datum(310).
- may have a co-datum of one Unconditioned Datum(310).
- tolerance 1 or more Area(INT-8), Feature of Size(306).

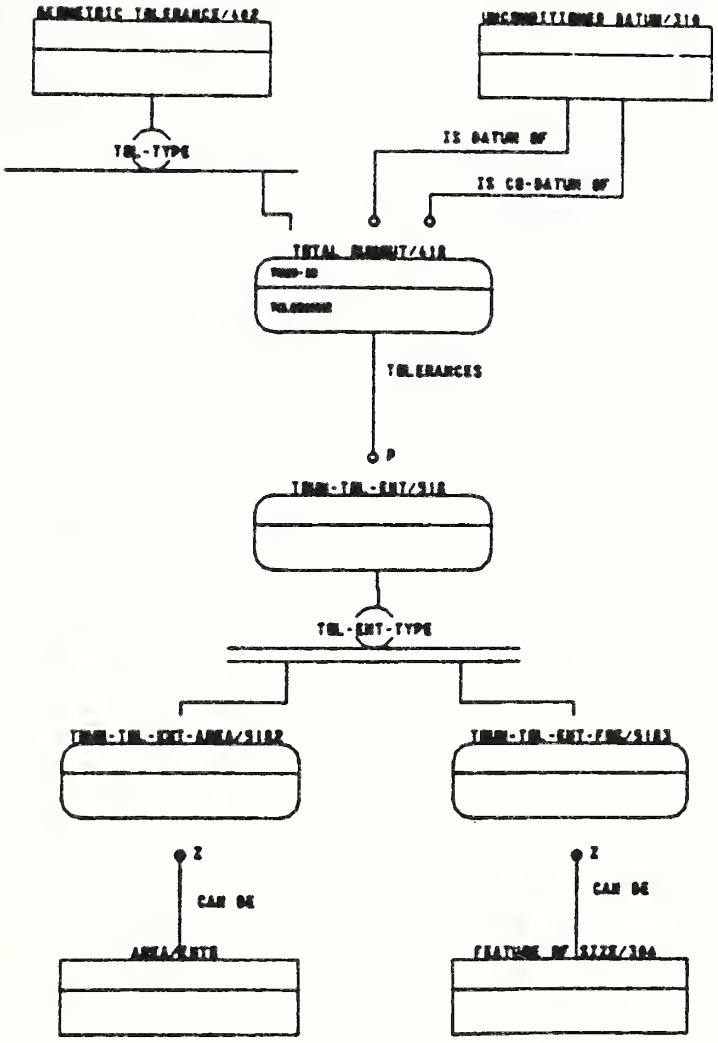


Figure D-31: TOTAL RUNOUT IDEF1X Diagram

DIMENSIONS OVERVIEW

The analysis of dimensions brought out some very subtle aspects of the meaning of dimensions placed on engineering drawings. Ostensibly, the dimensions define the theoretically exact shape of the modelled object. However, further analysis reveals meaning imbedded within the plane of the paper in which the dimension is drawn, within the witness lines and even in the shape of the dimension leaders. The aspect of the dimension with the least meaning is the dimensional value. All of these characteristics are added together with a tolerance value(s) to communicate the allowable shape deviations of the physical object produced from the design model to the design analysts, machinists and inspectors who use them.

For example, one distinction that was implicitly made in earlier versions of the tolerance model and is more explicitly dealt with in these extensions is the difference between the thing which is toleranced versus the thing controlled by the tolerance (for the Location and Angle tolerances). The plane of the paper of a drawing represents a series of section cuts (parallel to the plane of the paper) through the object representation and each dimension is placed within one of these section cuts. Witness lines or leader arrowheads indicate the lines or planar curves within a section cut that are the origin and target for the dimension. The toleranced thing is the line or a point on the planar curve while the surface being controlled by the dimension/tolerance combination is the surface that intersects the plane of the section cut to form the line or curve. Another example is the location of a hole from a plane: the thing to which the tolerance applies is the centerline of the hole, but he thing being controlled by the tolerance is the surface of the hole.

NOTE: Unlike previous entity definitions, the Propositions of the dimension entities contain information that is not captured in either the IDEF or the Express entity definitions. These propositions are part of the entity definition.

Entity Name: **Coordinate Dimension**

Entity Number: **600**

A coordinate dimension corresponds to dimensions typically found on engineering drawings. This is a classification of Location, Size and Angle dimensions.

EXPRESS Definition

```
ENTITY Coordinate_Dimension SUPERTYPE OF (Size_Dimension,
  .      Angle_Dimension, Location_Dimension);
  END_ENTITY;
```

Entity Name: **Size Dimension**

Entity Number: **601**

A Size Tolerance is a numeric range that constrains the value of a Size Dimension. A Size Dimension is a measure of an individual feature of the shape of an object. There are three characteristics of a Size Dimension:

1. the dimensional value (implicitly defined within the representation geometry or explicitly called out in a feature definition);
2. the shape representation elements which define the feature of interest; and
3. the center of symmetry of the elements of the feature.

The value of a Size Dimension is expressed as a magnitude and is independent of the location of the feature. The feature of interest must be a Feature of Size (see - ANSI Y14.5) which are characterized by a point, curve or surface of symmetry. The value of the Size Dimension is determined by measuring in a straight line from a point on the feature through the center of symmetry (normal to the curve or surface of symmetry) to another point on the feature opposite the first. In most cases, the determination of th dimensional value is trivial, as in the diameter of a hole or the width of a slot.

EXPRESS Definition

```
ENTITY Size_Dimension SUBTYPE OF (Coordinate_Dimension);
     Tolerance     : Coordinate_Tolerance_Range;
  END_ENTITY;

ENTITY Size_Parameter SUBTYPE OF (Size_Dimension);
     Parameter_Value    : Optional Number;
  WHERE
     MEMBER(Form_Feature,1,1);
  END_ENTITY;

ENTITY Size_Characteristic SUBTYPE OF (Size_Dimension);
     Dimensioned_Entity : Feature_of_Size;
     Center_of_Symmetry : Geometry;
  END_ENTITY;
```

Attribute Definitions:

Size_Dimension
   Size_Dimension is an entity that specifies a tolerance range for a dimensional aspect of a product feature.

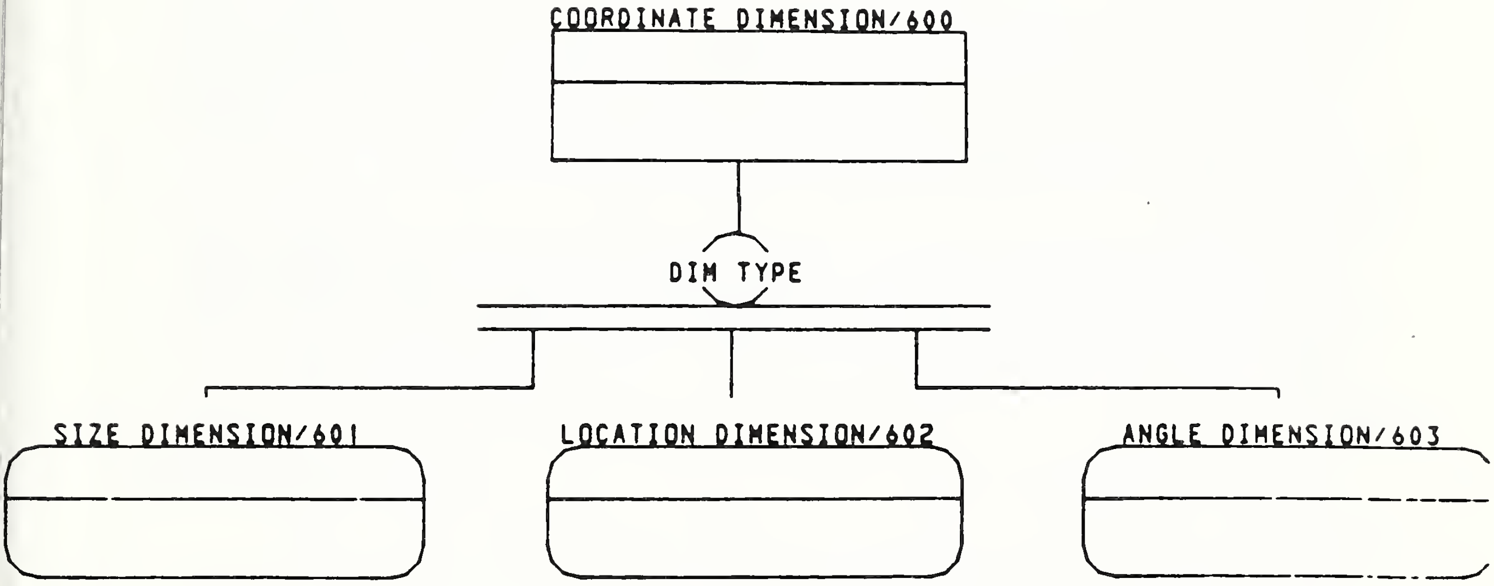


Figure D-32: COORDINATE DIMENSION IDEF1X Diagram

Tolerance
The numeric range that defines the allowable deviation of the size dimension.

Size_Parameter
Implicit Form Features typically call out size parameters in the definition of the Feature, such as the diameter of a Hole. A Size_Parameter is a type of Size_Dimension that specifies that value of the parameter and a tolerance on the parameter (through its supertype Size_Dimension). For the existence of this entity to be valid it must be referenced by some Implicit Form Feature.

Parameter_Value
The numeric value of the size parameter for a characteristic of a Implicit Form Feature. In some cases, this value may be derivable from other parameters of the Implicit Form Features, therefore this value is left optional; thus Size Parameter is categorized as independent or derivable. This implies the restriction that Derivable Size Parameters (i.e. specifies no explicit value) must be DERIVEd in an Implicit Form Feature.

Size Characteristic
Explicit shape elements may have dimensional characteristic to which a Size_Dimension may be applied. Since a Size_Dimension only applies to Features_of_Size, the shape element must be defined as a Feature_of_Size and associated with its Center_of_Symmetry. The Tolerance Range then applies across the dimensioned surfaces through the Center_of_Symmetry.

Dimensioned_Entity
The explicit feature of the product shape to which the Size Dimension Tolerance applies. It must be a Feature_of_Size.

Center_of_Symmetry
Features_of_Size are characterized by a Center of Symmetry and the the dimension and tolerance apply across the center of symmetry.

Propositions:

- A Size Tolerance Range (403) applies to a Size Dimension (601)
- A Size Dimension (601) may be an explicit parameter (604) (attribute) or may be a calculated characteristic (605) of a Feature of Size.
- An Implicit Form Feature may have 0, 1, or more Size Parameters.
- A Size Parameter may be either independent or derivable.
- A Feature of Size may have 0, 1 or more Size Characteristics.
- A Size Characteristic of a FOS has one center of symmetry (COS).
- Some Form Features are Features of Size.
- A Size Feature is a Feature of Size.

Entity Name: Location Dimension

Entity Number: 602

A Location Tolerance is a numeric range that constrains the value of a Location Dimension. A Location Dimension is the measurement of the location of one feature with respect to another feature. It is either directed (i.e. there is a distinction between the origin and the target of the dimension) or a bi-directional. The value of the Location Dimension is the distance between two parallel shape representation elements or things derived from shape representation elements (any combination of planar areas, linear seam or corners, or two elements separated by a constant distance). Each feature within a Location Dimension consists of two characteristics: the thing to which the tolerance applies (or is the origin of the dimension) and the actual shape representation element (surface/area, curve/seam or point/corner) on the object which is being controlled (or is the controlling surface of) the dimension and tolerance. These components may be the same thing, i.e. there does not have to be two distinct entities (in fact, the thing being controlled may be implied through the thing being toleranced.)

The value of the dimension is typically measured in along a linear path, although arc length and "true" dimensions require that a path be specified to determine the actual value to which the tolerance applies.

This is not to imply that location tolerances may apply only to linear, planar and offset curves and surfaces. A complex (shape representation elements that are not planar, linear or cylindrical) Area or Seam (the thing which is being controlled by the tolerance) may be algorithmically resolved (through a Geometric Derivation) to a plane or line (the thing which is toleranced), thereby satisfying the stipulations above.

EXPRESS Definition

```
ENTITY Location_Dimension SUBTYPE OF (Coordinate_Dimension);
     Tolerance    : Coordinate_Tolerance_Range;
     Target       : DT_Feature;
     Origin       : DT_Feature;
     Directed     : Logical;
     Linear       : Logical
     Path         : Optional Geometric_Derivation;
  WHERE
     IF Linear THEN Path = NULL;
     IF NOT Linear THEN PATH <> NULL;
  END_ENTITY;
```

Attribute Definitions:

Tolerance
  The numeric range that defines the allowable deviation of the location dimension.

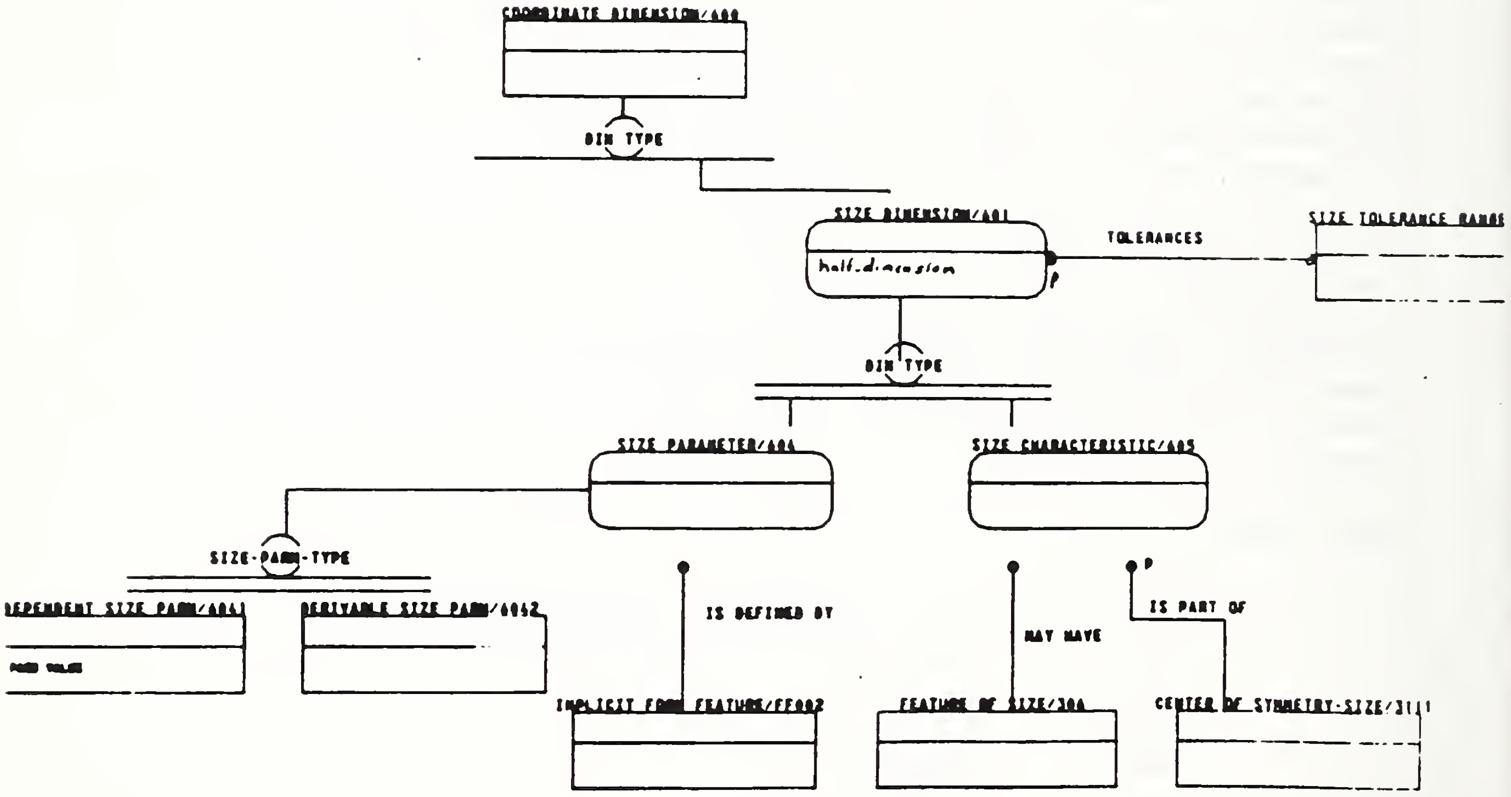


Figure D-33: SIZE DIMENSION IDEF1X Diagram

Target
In a directed dimension, the Target is the feature of the product shape that represents the "to" entity of the dimension.

Origin
In a directed dimension, the Origin is the feature of the product shape that represents the "from" entity of the dimension.

Directed
A true or false value that indicates whether the Location_Dimension should be viewed as a "from"/"to" dimension or whether no such distinction should be made. "True" means that the dimension should be interpreted "from" the origin "to" the target. "False" means that there is no precedence between the entities involved in the dimension.

Linear
In most cases, a Location_Dimension will be a linear measurement between the two specified entities. "Linear" will be "true" in these instances. When the measurement follows some non-linear path, such as an "arc length" or "true" dimension, then a measurement path must be specified and "linear" will be false.

Path
In non-linear dimensional measurements, a Path for the measurement must be specified.

Constraint Definitions:

If the dimension is linear, then no path is specified. If non-linear, then a path must be specified.

The target and origin entities called out by a Location_Dimension must be planar, linear or a point, OR they must be offset from one another by a uniform distance. (see propositions)

Propositions:

- A Location Tolerance applies to a Location Dimension.
- A Location Dimension may be a linear measurement of the distance between two parallel shape elements. ("Parallel" is a single valued function; points are parallel to everything.)
- A Location Dimension may be a curvi-linear measurement between shape elements.
- The Path of a curvi-linear measurement must be specified.
- A Path is a Geometric Derivation which specified a curve.
- The target and origin of a Location Dimension must:
  1. be planar, linear or a point;
  2. be a Geometric Derivation which resolves to a plane, line or point;
  3. be parallel to one another (offset, curvi-linear surfaces);
  4. the origin may be reference geometry.

Entity Name: **Angle Dimension**

Entity Number: **603**

An Angle Tolerance is the numeric range that constrains the value of an Angle Dimension. An Angle Dimension is the measure of the orientation of one feature with respect to another feature. An Angle Dimension is either directed in the same sense as a Location Dimension, or bi-directional in the same sense as a Size Dimension (in that it applies to a single feature). The value of the dimension is the angle between two straight shape representation elements or the thing derived from a shape representation element (planar areas, linear seams or elements which have a constant angular relationship to one another).

Each feature within a directed Angle Dimension consists of two characteristics, as in the Location Dimension:

1. the thing to which the tolerance applies (or is used as the origin for the dimension); and
2. the actual element which is being controlled (or is the controlling element for the dimension and tolerance).

These characteristics may be embodied within the same shape element, or may be separate elements in the case of complex features.

The feature within a bi-directional angle (angle size) dimension is a Feature of Size and must be composed of linear elements equally disposed about the center of symmetry.

A directed Angle Dimension must consist of two additional pieces of information in order to determine the dimensional value:

1. an orientation vector (parallel to area features and normal to seam features) to establish a right-hand-rule for
2. a flag that indicates the CW or CCW sense of measurement.

A bi-directional angle (angle size) dimension requires one additional piece of information to determine the toleranced angle value: a flag indicating that the angle of interest is the one less than 180 degrees or greater that 180 degrees.

EXPRESS Definition

```
ENTITY Angle_Dimension SUBTYPE OF (Coordinate_Dimension);
    Tolerance    : Coordinate_Tolerance_Range;
  END_ENTITY;

ENTITY Related_Angle_Dimension SUBTYPE OF (Angle_Dimension);
    Target       : DT_Feature;
    Origin       : DT_Feature;
    Sense        : Logical;
    Orientation  : Direction;
  WHERE
```

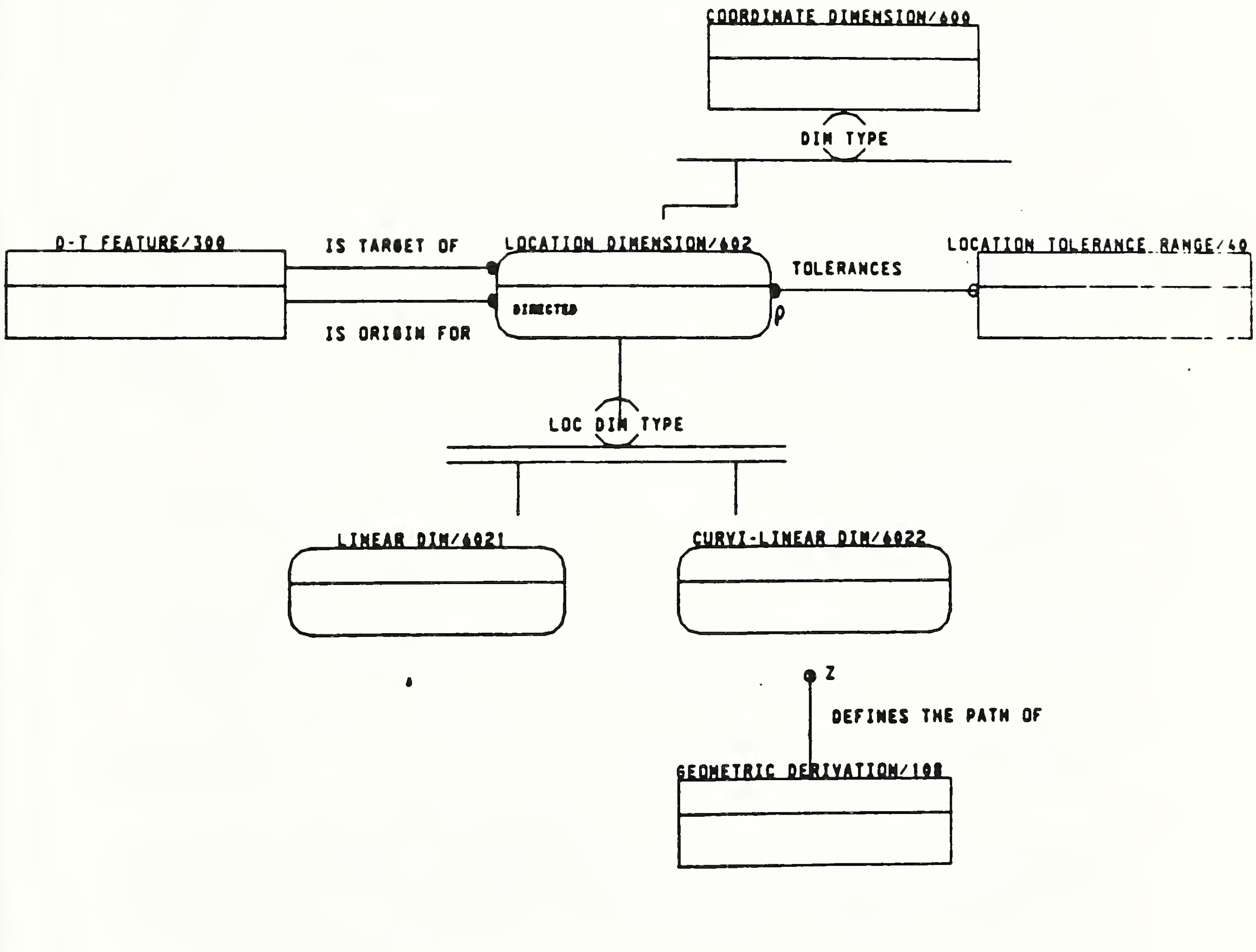


Figure D-34: LOCATION DIMENSION IDEF1X Diagram

```
      ((Target <> Corner) AND (Origin <> Corner));
   END_ENTITY;

 ENTITY Angle_Size_Parameter SUBTYPE OF (Angle_Dimension);
      Angle_Value  : Optional Number;
   WHERE
      MEMBER(Form_Feature,1,#);
   END_ENTITY;

 ENTITY Angle_Size_Characteristic SUBTYPE OF (Angle_Dimension);
      Dimensioned_Entity      : Feature_of_Size;
      Center_of_Symmetry      : Geometry;
      Characteristic_Angle    : Logical;
   END_ENTITY;
```

Attribute Definitions:

Angle Dimension
: Angle_Dimension is an entity that specifies a tolerance range for an angular dimensional aspect of a product feature.

Tolerance
: The numeric range that defines the allowable deviation of the Angle_Dimension.

Related_Angle_Dimension
: For explicit features of a product shape, a Related Angle Dimension specified the "from" and "to" entities of an Angle_Dimension.

Target
: As in a directed Location_Dimension, the Target is the feature of the product shape which is the "to" feature in a directed angle dimension.

Origin
: As in a directed Location_Dimension, the Origin is the feature of the product shape that represents the "from" entity of the dimension.

Sense
: Sense is a Logical value that indicates whether the measurement of the dimension is to be taken in a clockwise (TRUE) or counterclockwise (FALSE) direction for the Related_Angle_Dimension. This attribute must be used in conjunction with the orientation vector, otherwise it is ambiguous.

Orientation
: The Orientation Direction (vector) defines the Right-Hand-Rule to be used in determining the direction of measurement for the Angle Dimension. This is to be used in conjunction with the Sense flag.

Angle_Size_Parameter

Implicit Form Features may angle size parameters in the definition of the Feature, such as the angle of a V-groove. An Angle_Size.Parameter is a type of Angle.Dimension that specifies that value of the parameter and a tolerance on the parameter (through its supertype Angle.Dimension). For the existence of this entity to be valid it must be referenced by some Form Feature.

Angle_Value

The numeric value of the angle parameter for a characteristic of a Form Feature. As is the case of the size parameter value, this value may be derivable from other parameters of the Implicit Form Features, therefore this value is left optional; thus Angle Size Parameter is categorized as independent or derivable. This implies the restriction that Derivable Angle Size Parameters (i.e. specifies no explicit value) must be DERIVEd in an Implicit Form Feature.

Angle_Size_Characteristic

Explicit shape elements may have dimensional characteristic to which a Angle_Size_Dimension may be applied. Since an Angle_Size_Dimension only applies to Features_of_Size, the shape element must be defined as a Feature_of_Size and associated with its Center_of_Symmetry. The Tolerance Range then applies across the Center_of_Symmetry.

Dimensioned_Entity

The explicit feature of the product shape to which the Angle Size Dimension Tolerance applies. It must be a Feature_of_Size.

Center_of_Symmetry

Features_of_Size are characterized by a Center of Symmetry and the the dimension and tolerance apply across the center of symmetry.

Characteristic_Angle

Characteristic_Angle is a flag indicating whether it is the angle with a measure of less than 180 degree (TRUE) which is the intended dimension or the angle greater than 180 degrees (FALSE). Is the angle is equal to 180 degrees, then the distinction is moot, unneeded, indeterminate, don't-worry-about-it-it'll- probably-never-happen.

Propositions:

- An Angle Tolerance Range (4013) applies to an Angle Dimension (603).
- An Angle Dimension (603) may be a rotational measurement between two intersecting shape elements.
- An Angle Dimension (603) may be an intrinsic measure of a shape element and therefore has a center of symmetry.
- The value of the Angle Dimension is determined from the origin to the target using the right-hand-rule plus a direction (view vector) for explicit measures.

- The origin and the target of an Angle Dimension must:
  1. be a shape element which is planar or linear;
  2. be a Geometric Derivation which resolves to a plane or a line;

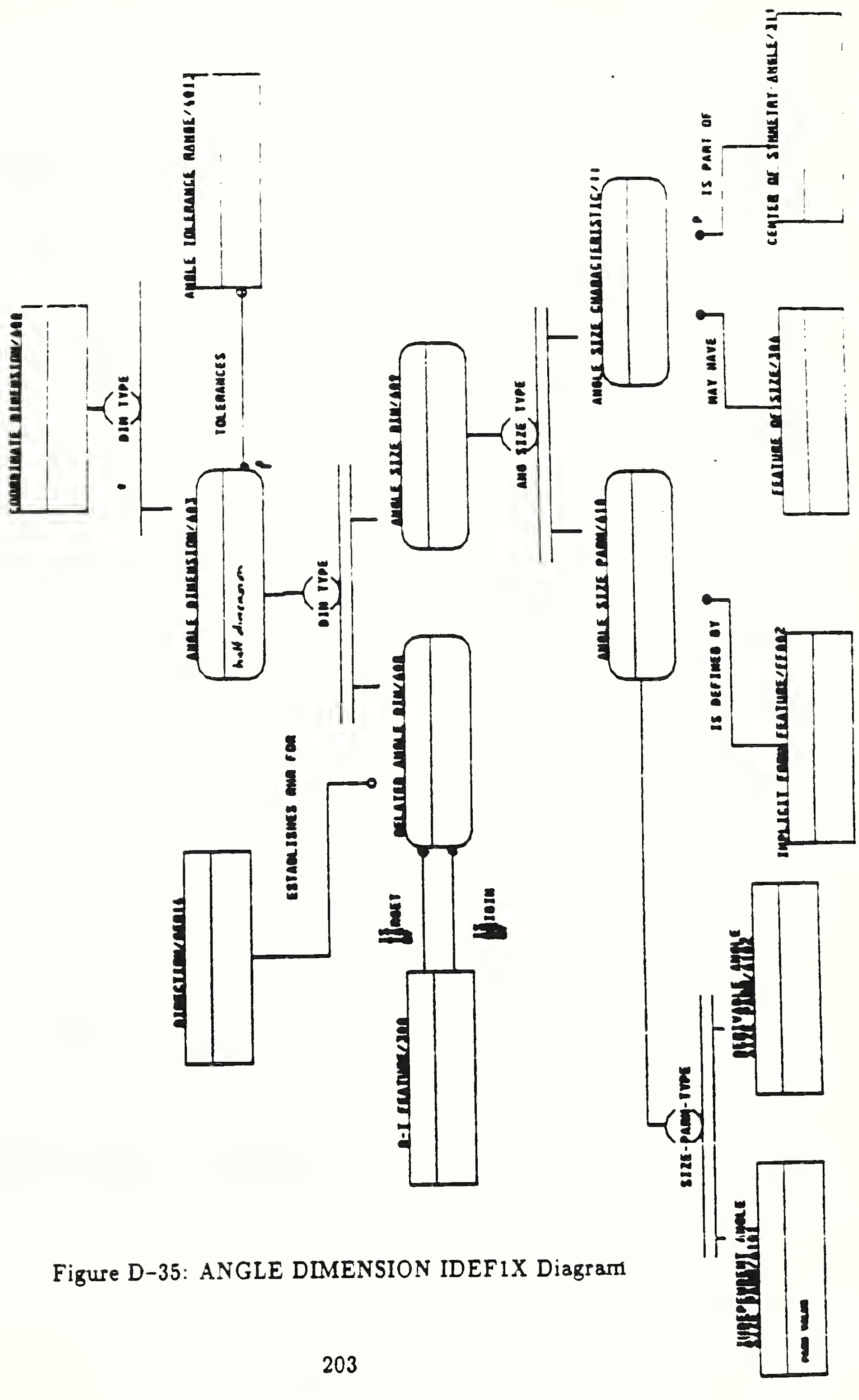


Figure D-35: ANGLE DIMENSION IDEF1X Diagram

SECTION 3: SHAPE VARIATION TOLERANCES

3.6 Issue Log

The purpose of this issues log is to track and report on perceived problems within the Tolerance Model. Each issues consists of the following information:

NUMBER:

A sequentially defined number identifying the issue. The number consists of a prefix indicating the year in which the issue was raised and a suffix which is simply an index.

TITLE:

A name for the issue.

INITIATION DATE:

The date the issue was raised

INITIATOR:

The person/project/meeting that raised the issue.

STATUS:

Indicates the current activity on the issue. The following states have been defined:

Unresolved	No work is being done to resolve the issue.
In work	A resolution to the issue is actively being sought and an individual or group.
Preliminary	A solution has been proposed and is currently under review. Includes proposal date and proposing individual/committee.
Resolved	A proposal has been accepted which adequately solves or satisfies the issue. A Resolved status includes the date of resolution.

RELATED ISSUES:

A list of numbers of the issues which have bearing on this issue.

DESCRIPTION:

The body of text describing the issue. This includes not only an explanation, but also identifies the pertinent entities/ attributes /relationships and any individuals involved.

OPTIONS & EVIDENCE:

This section lists identified solutions and the arguments for and against each one.

Option #	: Description of solution
Pros	: Arguments in favor of solution
Cons	: Arguments against solution

OPTION PROPOSED:

An option selected from the above list which is the recommended resolution to the issue.

EXPLANATION:

Rationale for selecting the proposed solution.

DECISION:

The consensus that the proposed solution should be approved or disaparoved. Also included the identity of the decision making body.

DECISION DATE:

Date of decision.

ACTION:

The decision making body will identify the individual or committee responsible for implementing an approved solution.

ISSUE: TOL-86.1 ANGLE TOLERANCE
INITIATION DATE: January 1986
INITIATOR: Mfg Tech Committee, San Diego Meeting
STATUS: Resolved
RELATED ISSUES: Superceded by 87.2, 88.26
DESCRIPTION: The method used to provide the necessary information to calculate the intended angular measure for an Angle tolerance were points which lie on the intersection of the two entities involved in the tolerance at which tangent vectors to the entities were determined. The angle between these two vectors indicated the angle to which the tolerance applies. There is some question as to whether the information provided is sufficient.

ISSUE OPTIONS & EVIDENCE:

Option 1: Define a set of coordinate triplets (three distinct points) that are associated with the Angle Tolerance, the Toleranced Entity and the Tolerance Origin. One point of each triplet will lie on the intersection of the Toleranced Entity and the Tolerance Origin; one point will lie on lhe Toleranced Entity; the last point will lie on the Tolerance Origin. Each triplet will specify the point at which the tolerance applies and allow the calculation of the value intended dimension (the intersection point is the vertex of the angle).

Pros: This satisfies the perceived information requirements to define an Angle Tolerance.

Cons: The concept and model of the proposed solution is somewhat complicated.

Option 2: Remove all coordinates and simply have the Angle Tolerance reference the Toleranced Entity and the Tolerance Origin, leaving the interpretation up to the individual systems.

Pros: Simple and more direct. Most Angle Tolerances will be simple and unambiguous, making interpretation of the Angle Tolerance a relatively simple matter.

Cons: There is room for error, misinterpretation, and inexactness when tolerancing the angle between two complex surfaces (such as a Ruled Surface and Plane). This approach does not have the completeness required to communicate a complex Angle Tolerance.

OPTION PROPOSED: Option #1. The model implementing this solution has been incorporated into the reference model.

DECISION: The Tolerance Application Committee decided that the proposed solution more completely represents the intention of Angle Tolerances. The coordinate triplets are optional associations that may be included in the definition of an Angle Tolerance for more specificity, but do not have to be included for simple cases.

DECISION DATE: 19th December 1986

ACTION: Tolerance Application Committee has incorporated the approved solution into the Tolerance Reference Model

NOTE: Resolution superceded by subsequent model development.

ISSUE:	TOL-86.2 SIZE TOLERANCED ANGLE
INITIATION DATE:	August 1986
INITIATOR:	Mechanical Products Committee, Peoria Project.
STATUS:	Resolved
RELATED ISSUES:	N/A
DESCRIPTION:	The definition for a Size Tolerance states that the tolerance value applies to a dimension of the toleranced feature which is independent of the feature's location. This definition allows the size of an angle to be toleranced as well. This added interpretation seems to logically make sense, but the model does not explicitly allow for it.

ISSUE OPTIONS & EVIDENCE:

Option 1: Expand the definition of the Size Tolerance to include the tolerancing of the size of the angle between two entities which are symmetrically disposed about a center plane, line, axis or point. This may require the addition of a flag to the Size Tolerance Entity to denote that the tolerance applies to the angle.

Option 2: Create an "Angle Dimension" which is subtyped as a Related Angle Dimension and an Angle Size Dimension. See the definition of Angle Dimension (604)

OPTION PROPOSED:	Option 2
DECISION:	Option 2 has been incorporated as a category of Angle Dimension.
DECISION DATE:	13^{th} July 1988, Denver
ACTION:	Tolerance Committee

ISSUE:	TOL-86.3 APPLICATION OF TOLERANCES TO TOPOLOGY VS GEOMETRY
INITIATION DATE:	Many different times (for the record, 19^{th} Dec 86)
INITIATOR:	Again, many (for the record, Tolerance Appl. Com.
STATUS:	Resolved
RELATED ISSUES:	N/A
DESCRIPTION:	Are tolerances more appropriately applied to topology or geometry entities? Topology all by itself defines logical connectivity, whereas geometry defines the mathematical shape of an object. It would seem that since tolerances control the shape of the produced object and it is the mathematical definition of that shape which is subject to variation, the tolerances would more appropriately be apalied to geometry entities. Geometry alone, however, does not adequately describe the shape of a part because the boundaries of the geometric elements (if, indeed, bounded) do not neessarily correspond to real boundaries of the faces on a physical object, or may correspond to several.

ISSUE OPTIONS & EVIDENCE:

Option 1: Apply Tolerances to geometry entities rather than topology entities.

Pros: This option is intuitively pleasing beause the tolerance is compared to the measured deviation of the mathematical (geometric) definition of a surface (or other feature) on a produed (physical) object from the theoretical, mathematical (geomDtric) definition of the corresponding surface (or other feature) in the (solids) model of the object. It is the geomDtric definitions of phe surfaces which are compared.

Cons: The problem with this option is that geometry funions in many different roles, only one of which is defining the shape of an object. Even the geometry which defines the shape sometimes is not speific enough to be used in conjuction with a tolerance. Several different faces may share the same surface definition and it would be incorrect to imply that both faces must always share the same tolerance as well. Also, a face may define a portion of an unbounded surface, and a tolerance applied to an unbounded surface makes no sense beause unbounded surfaces cannot be measured.

Option 2: Leave approach as-is a enhance the explanation of the intention of the Faces, Edges and Vertices described in the model.

Pros: The concept of Face, Edge and Vertex adequately serve the needs of the Tolerance Model. To impose the constraints implied by hese constructs on geometric elements would be difficult, awkward and confusing. The explanation within the Model Assumptions states that Topologic elements always have underlying geometric definitions. Also stated within the Model Assumpnions is that the constructs Face, Edge and Vertex as defined with a BREP Solid Model are not required, but that their funtional equivalent is required. This allows the Tolerance Model to reference Faces/surfaces which correspond to actual, physical, touchable portions of a produced object.

Cons:	Implies a requirement for BREP Solid Model. Is intuitively unappealing because topology doesn't always have shape (e.g schematics.)
Option 3:	Rename entities in accordance with work of Integration Committee.
Pros:	The concept of "Shape Elements" as defined by the Integration commitnee coresponds exactly with the use of "Face, Edge and Vertex" within phe Tolerance Model. By removing the BREP-ish nature of the models "integration entities", this issue becomes moot.
Cons:	None

OPTION PROPOSED:	Option 3. The Tolerance Models use of topological terms mislead and confused the intent. The concept of Shape Elements embody the correct viewpoint of the model and make this issue moot.
DECISION:	The Tolerance Application Committee has approved the solution.
DECISION DATE:	29th March 1988
ACTION:	Tolerance Committee

ISSUE:	TOL-86.4 TOLERANCES TO/FROM DERIVED GEOMETRY
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee, St. Louis
STATUS:	Resolved
RELATED ISSUES:	Superceded by 88.1
DESCRIPTION:	The point was made that some tolerances apply to geometry entities which do not have a corresponding topology entity; gauge points and breakout tangency planes were cited.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Add an entity called Derived geometry as a candidate Toleranced Entities and Tolerance Origins for coordinane tolerances. The stipulation is that the Derived geometry must be calculable from produt topology (e.g. spatial intersetion curves, centerlines). Each type of Derived geometry must be defined.
Pros:	ıSatisfies perceived need for Tolerance to/from off-part geometry.
Cons:	Open ended and ill-defined. Similar to the dilemma of form feature enumeration.

OPTION PROPOSED:	Option 1.
DECISION:	The Tolerance Application Committee agreed that the need for such a construct exists. However, the time to fully explore this topic is not currently available. Therefore, an entity called Derived Geometry will be added and treated like Faces, Edges, Vertices, Size Features and Features of Size. An explanation of the intent and purpose of this entity will be included, with the assertion that it will be analyzed in the future, but no further definition of it will be made. See example for the purpose and use of this entity.
DECISION DATE:	19th December 1986
ACTION:	Tolerance Application Committee
NOTE:	The proposal made in the resolution to this issue has been expanded upon in the work of the committee dated 25th March 1988. See 88.1 for more details.

ISSUE:	TOL-86.5 TOLERANCE ENTITY DISPLAY
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee, St. Louis
STATUS:	Preliminary
RELATED ISSUES:	N/A
DESCRIPTION:	A practical requirement of all entities is the ability to see and manipulate the entities. How are Tolerances Entities to be displayed? This raises two questions:ı 1) will an answer to this question be of value?; and 2) is this the responsibility of the Tolerance Application Committee? The answer to 1) is obviously yes; in fact it is almost a requirement. The answer to 2) is no, it is not the responsibility of the TAC.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Recommend to some authoritative body that they take action on this subject and await a solution.
Pros:	ı This problem will be faced by many application committees and should be addressed level common to all of them.
Cons:	It may never get done with this approach.
Option 2:	Add three pieces of information to the generic Tolerance Entity (which thereby applies to all tolerance entities): 1) a coordinane (point) location on the toleranced entity; 2) a coordinate (point) location of the tolerance symbol; and 3) an orientation (vector or plane) in which the symbol is visible.
Pros:	ı This provides sufficient information for the display of Tolerance Entities.
Cons:	This solution may not be appropriate for all application committees.

OPTION PROPOSED:	Option 2.
DECISION:	After a long waiting period during which no more appropriate committee addressed this problem, the Tolerance Committee decided to define the information needed to display a tolerance entity. A proposal will be prepared outlining the approach along the line suggested in Option 2.
DECISION DATE:	29th March 1988
ACTION:	The Tolerance Committee.

ISSUE:	TOL-86.6 TOLERANCES TO/FROM PART-IN-PROCESS SHAPE
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee, St. Louis
STATUS:	Resolved
RELATED ISSUES:	N/A
DESCRIPTION:	Can Tolerances span intermediate part shapes? Surfaces are often machined based on dimensions from machined tooling surfaces which will not be present in the final part.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Take no action
Pros:	Doesn't really seem to be a tolerance, but more of a BASIC dimension. In any case, it is outside the scope of this model.
Cons:	N/A

OPTION PROPOSED:	Option 1. At his time there appears to be no need to pursue this issue further.
DECISION:	Adopt Option 1.
DECISION DATE:	19th December 1986
ACTION:	None.

ISSUE:	TOL-86.7 BASIC DIMENSIONS
INITIATION DATE:	Various (f.t.r. 19th December 1986)
INITIATOR:	Various (f.t.r. 19th December 1986)
STATUS:	Resolved
RELATED ISSUES:	87.2
DESCRIPTION:	Should BASIC dimensions as described in the standards be addressed within this model?

ISSUE OPTIONS & EVIDENCE:

Option 1:	Take no action.
Pros:	BASIC dimensions are currently cursorily addressed within the model.
Cons:	BASIC dimensions are part of the standard and should be accommodated within phe refeence model.
Option 2:	Remove any reference To BASIC dimensions from model.
Pros:	Because of the assumption that the geometry in the product model defines the theoretically exact shape, the model is in effect BASIC and, therefore, BASIC dimensions do not need to be explicitly addressed.
Cons:	BASIC dimensions are part of the standard and should be accommodated within phe refeence model.
Option 3:	Enhance the capability of the reference model to handle BASIC dimensions.
Pros:	Will satisfactorily address the issue by coming up with a thought out answer.
Cons:	Will take more time than is available, and the issue is not cruial to the usefulness of the reference model.

OPTION PROPOSED:	Option 2. The Tolerance Application Committee felt that the argument in favor of Option 2 was the strongest. Option 1 would be adequate, but it would open the door to confusion. Option 3 was deemed unsatisfactory in interest of time and importance.
DECISION:	All references to BASIC dimensions in the reference model will be removed. A statement explaining the role of BASIC dimensions within the approach embodied by this model will be added to the assumptions.
DECISION DATE:	19th December 1986
ACTION:	Tolerance Application Committee

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE:	TOL–86.8 DEFAULT TOLERANCES
INITIATION DATE:	Various (f.t.r. 19th December 1986)
INITIATOR:	Various (f.t.r. 19th December 1986)
STATUS:	Resolved
RELATED ISSUES:	N/A
DESCRIPTION:	Default tolerances of some kind are present on virtually all drawings. How is the need for this capability addressed within the model? It was agreed within the Tolerance Application Committee that he appropriate default tolerance for a three dimensional geometric model would be a Profile of a Surface tolerance applied to all otherwise unntoleranced surfaces of the model.

ISSUE OPTIONS & EVIDENCE:

Option 1: Include statement in Assumptions that Profile of a Surface tolerance would apply to all otherwise untoleranced surfaces of the model. The value of the tolerance would be located somewhere else within the product model.

Pros: This is the current approach taken in the reference model and would require no modifications to it.

Cons: The value of phe default tolerance is not readily available. It should not be included in another reference model, but should be located within the Tolerance model. This option does not address the possibility of other kinds of default tolerances.

Option 2: Modify the Profile of a Surface entity to include a flag indicating whether it is default or not. A stipulation would be included in the definition of the entity which states that only one Profile of a Surface entity with the default flag set TRUE may be present within a given product model.

Pros: The default tolerance is explicitly addressed by the reference model and it is clear what he default tolerance is.

Cons: The possibility tht two or more entities may exist which are identified as default is not prohibited other than by the stipulation in the definition. Does not address the possibility of other kinds of default tolerances.

Option 3: Further investigation into default tolerances.

Pros: Will provide a more complete solution.

Cons: Time constraints prohibit a thorough investigation.

OPTION PROPOSED: Option 2. The Tolerance Application committee felt that the argument for Option 2 and against Option 1 were strong enough to select Option 2. Option 3 was not considered at this time due to time constraints. It is recognized that the argument against Option 1 and 2 about other kinds of default tolerances is valid. At some point in the future, when Option 3 becomes feasible, it is likely that the approach described by Option 2 will be carried over to other kinds of tolerances.

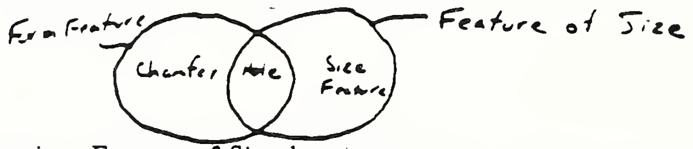
DECISION: The reference model will be changed to reflect the approach described in Option 2.

SECTION 3: SHAPE VARIATION TOLERANCES

DECISION DATE: 19th December 1986
ACTION: Tolerance Application Committee

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE:	TOL-86.9 RELATIONSHIP BETWEEN FORM FEATURE, FEATURE_OF_SIZE, AND SIZE_FEATURE
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee
STATUS:	Preliminary
RELATED ISSUES:	N/A
DESCRIPTION:	A Form Feature is a collection of geometric/topologic elements with a name that connotes a special shape or meaning (e.g. hole, slot, groove). Feature_of_Size is the name of a classification of things which exhibit symmetry about a surface, curve or point and is defined for the Tolerance Application referenced model (i.e. it will not be used in other reference models.) A Size Feature is the name of an entity defined within the Tolerance Application reference model to serve as a surrogate in the absence of defined Form Features. A Size Feature is a Feature_of_Size and the idea of Feature_of_Size is required for the Tolerance Application. The Tolerance Application Committee agrees on the fundamental relationship between these concepts. The relationship is described by the following Venn diagram (examples in each set are included):



A Size Feature is a Feature_of Size but is not a Form Feature. Some Form Features are Features_of_Size. A hole is both a Form Feature and Feature_of_Size. IDEF-1X cannot model this situation, so the issue is "what is the best way to model this relationship?"

ISSUE OPTIONS & EVIDENCE:

Option 1: Redefine terms.
Option 2: Violate IDEF-1X and allow a categorization to have two generic parents.
Option 3: Create an association (intersetion entity) between categories of Form Feature and Feature_of_Size to achieve this dual-parent relationship.
Option 4: Since Feature_of_Size is only used in the Tolerance Application reference model, create an optional relationship between a Form Feature and a category of Feature_of_Size such that whenever a Form Feature is used as a Feature_of_Size, it is identified as such.
The Pros and Cons of the above options consists primarily of pictures and are available from the chairman.

OPTION PROPOSED: The current, working solution is Option 4. Options 1 and 2 were deemed inadequate by the Tolerance Application Committee. Option 3 was awkward. Option 4 satisfied the current needs of the Tolerance Application reference model.

DECISION:	The changes described in Option 4 have been incorporatedd into the reference model. However, the Tolerance Application Committee does not recommend this as a firm solution because it does describe the same situation as in the Venn diagram. A final decision will await comments and review.
DECISION DATE:	N/A
ACTION:	Tolerance Application Committee

ISSUE:	TOL-86.10 APPLICATION OF MATERIAL CONDITION MODIFIER
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee
STATUS:	Resolved
RELATED ISSUES:	N/A
DESCRIPTION:	The Material Condition Modifier (MCM - M/MMC: Maximum Material Condition; L/LMC: Least Material Condition; S/RFS: Regardless of Feature Size) only is applicable when the feature of interest (i.e. the toleranced entity, tolerance origin, or datum) is a Feature of Size. An analysis of ANSI Y14.5M 1982 turned up no counter examples. In fact, section 2.8 specifically states that the MCM applies to feature subjet to variation in size.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Categorize Datum into Conditioned and Unconditioned; the conditioned Danum contain the MCM indicator and is defined by a Feature_of_Size. The MCM indicator with the Tolerance Entities is changed po include an "N" for not applicable and a stipulation is added to lhe definition explaining when it is and is not applicable.
Pros:	Satisfies the problem presented by he issue.
Cons:	None to speak of.

OPTION PROPOSED:	Choice of 1. Other options were not examined beause the Tolerance Application Commitnee felt that this solution satisfactorily addressed the issue.
DECISION:	Change the reference model to reflect the changes described in Option 1.
DECISION DATE:	19th December 1986
ACTION:	Tolerance Application Committee

ISSUE:	TOL-86.11 LOCATION TOLERANCE COORDINATES
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee
STATUS:	Resolved
RELATED ISSUES:	86.1, 87.2, 88.26
DESCRIPTION:	There is an ambiguity in the meaning and intent of the coordinate associated with the Toleranced Entity and the Tolerance Origin of the Location Tolerance. Does a dimension exist in 3-space or is it a strictly planar idea? What is the relationship between the coordinates on either entity? Do lhey exist to be more specific on the intention of the tolerance or merely to facilitate the calculation of the desired dimension? With the idea of "path," the answer to the last question is both. The two coordinates and path are included in the definition of location tolerance to provide information which is implicit in a location toleranced dimension on a drawing but not readily identifiable. The plane of the paper, leaders, witness lines and the view of the product all provide information beyond "this is so far from that plus-or-minus this."

ISSUE OPTIONS & EVIDENCE:

Option 1: To reduce possible ambiguity in meaning and make simple cases more straightforward, the Location Tolerance should be allowed to tolerance only a single entity and the coordinates should be made optional.

Pros: Restricting the Location Tolerance to a single toleranced entity reduces the possibility of misinterpretation of the meaning of the coordinates. Optional vs. required coordinates makes simple cases (e.g. distance between two parallel planes) more straightforward.

Cons: Doesn't fully address the problem.

Option 2: Expand on the idea of a "location dimension" which explicitly contains information that allows a simple determination of phe value to which the tolerance applies. Details of this option are contained in the description of the location dimension in the Tolerance Model Version 3.0.

Pros:

Cons:

OPTION PROPOSED:	Option 2.
DECISION:	The adoption of Option 2 actually makes the issue moot. Formal acceptance of the resolution closes this issue.
DECISION DATE:	13th July 1988
ACTION:	Tolerance Application Committee

ISSUE:	TOL-86.12 CONSTRAINTS BETWEEN TOLERANCES
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Should constraints between tolerances be modelled? Some tolerances imply or take into account other tolerances (a cylindricity tolerance also controls the circularity of the toleranced entity.)

ISSUE OPTIONS & EVIDENCE:

Not applicable.

OPTION PROPOSED:	Not Applicable.
DECISION:	The Tolerance Application Committee has left this issue open. Such situations do exist and are identified in the stannard, but the worth of including them in the reference model was questionable. Addressing them would eliminate the possibility of over-toleranced or conflicting toleranced features, but it was felt that this was a question of good D & T practice and outside the scope of the reference model. A formal deision will be made when comments and reviews have been made.
DECISION DATE:	Not Applicable
ACTION:	Not Applicable

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE:	TOL–86.13 DATUM TARGETS AND TAPER TOLERANCES
INITIATION DATE:	19th December 1986, January 1988
INITIATOR:	Tolerance Application Committee, Bob Parks
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Datum target and Taper Tolerances as specified in the ANSI standard (sections 2.13, 2.14, pgs. 25-27) are not addressed by the reference model.

ISSUE OPTIONS & EVIDENCE:

Not applicable.

OPTION PROPOSED:	Not Applicable
DECISION:	The Tolerance Application Committee recognizes this as a deficiency. A solution will be developed in the future.
DECISION DATE:	Not Applicable
ACTION:	Not Applicable

ISSUE:	TOL-86.14 FORMAT OF DELIVERED REFERENCE MODEL
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee
STATUS:	Preliminary
RELATED ISSUES:	N/A
DESCRIPTION:	IDEF-1X has been chosen as the language for the reference models developed for PDES. Does the Logical Layer Committee require syntactically correct IDEF-1X model or can conventions be adopted within delivered models? The current reference model is not in a fully developed IDEF-1X format and contains syntactic erors. Specifically, the model does not identify Key attributes of entities (rather uses "surrogate" keys: XXXX-id), does not distinguish between identifying and non-identifying relationships, and does not distinguish between independent and dependent entities (among others.)

ISSUE OPTIONS & EVIDENCE:

Option 1:	Revise model in accordance with IDEF-1X rules.
Pros:	?
Cons:	Will pake a considerable amount of time to convert the model.
Option 2:	Leave refeence model as-is and explain the author conventions adopted within the reference model in the assumptions setion.
Pros:	ıThe deviations from IDEF-1X are consistent and not major with respect to the activities of the Logical Layer Committee. The reference model may still be read as an IDEF-1X model.
Cons:	Uses of the reference model which require a complete, syntactically correct reference model will be unable To use the Tolerance Application refeence model.

OPTION PROPOSED:	Option 2. Due to time considerations, the reference model should delivered in as-is condition. There has been no identified reason for delivering a model which completely adheres to IDEF-1X.
DECISION:	The Tolerance Application Committee has decided to adopt the solution proposed in Option 2. Conversion of the model to pure IDEF-1X will be considered for future versions of the model.
DECISION DATE:	19th December 1986
ACTION:	Tolerance Application Committee

ISSUE:	TOL-86.15 SOLICITING REVIEW OF MODEL
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	The size of the Tolerance Application reference model is intimidating (although the content is not overwhelming) and will inhibit quality review. What is the best way to solicit a good review of the model?

ISSUE OPTIONS & EVIDENCE:

Not applicable.

OPTION PROPOSED:	Not Applicable
DECISION:	Not Applicable
DECISION DATE:	Not Applicable
ACTION:	Not Applicable

ISSUE:	TOL-86.16 TYPES OF DATUM ENTITIES
INITIATION DATE:	19th December 1986
INITIATOR:	Tolerance Application Committee
STATUS:	Unresolved
RELATED ISSUES:	88.17
DESCRIPTION:	The types or nature of entities (e.g. "planar" face) which may be toleranced by a given tolerance entity are constrained. Should the type of entities which serve as datums for given tolerances be similarly constrained?

ISSUE OPTIONS & EVIDENCE:

Not applicable.

OPTION PROPOSED:	Not Applicable
DECISION:	Not Applicable
DECISION DATE:	Not Applicable
ACTION:	Not Applicable

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE:	TOL–87.1 UTILITY OF TOLERANCING EDGES AND VERTICES
INITIATION DATE:	21st August 1987
INITIATOR:	Bob Johnson
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Since "faces" of a part are the features which are actually produed and inspected, is there utility in applying tolerances to edges and vertices? What do tolerances applied to edges of vertices really mean; doesn't such a tolerance imply a tolerance to or control of the adjacent faces? Isn't he ideal situation for CIM to work only to the surfaces of the part?

ISSUE OPTIONS & EVIDENCE:

Not applicable.

OPTION PROPOSED:	Not Applicable
DECISION:	Not Applicable
DECISION DATE:	Not Applicable
ACTION:	Not Applicable

ISSUE:	TOL-87.2 DIMENSIONS
INITIATION DATE:	21st August 1987
INITIATOR:	Bob Johnson
STATUS:	Resolved
RELATED ISSUES:	86.1, 88.26, 88.5
DESCRIPTION:	The tolerances defined in this reference model imply underlying dimensions of the geometric model, particularly he Coordinate Tolerances. While dimensionality is inherent in the model geometry and dimensions can be derived, the fact that a dimension has been called out by a designer implies more meaning than simply the dimensional value. It implies a critical relationship between features on the part which must then be checked by QA. The implicitness of the dimension in the tolerances burys the significance of specifying a dimension. Therefore, the aspect of "dimensions" as incorporated in the Tolerance reference model should be explained in greater detail.

ISSUE OPTIONS & EVIDENCE:

Option 1: Expand on lhe idea of Location, Angle and Size dimensions. Version 3.0 of the Tolerance Model contains a proposed expansion on the idea of dimension.

OPTION PROPOSED:	Option 1.
DECISION:	The proposal appears to satisfy the concerns expressed in this issue, although it is recognized that deeper implications of this issue may be missed. Any omissions will be documented as new issues.
DECISION DATE:	13th July 1988
ACTION:	Tolerance Committee

ISSUE:	TOL-87.3 ALGORITHMIC DEFINITION OF FEATURES
INITIATION DATE:	21st August 1987
INITIATOR:	Bob Johnson
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	The features of a part to which tolerances apply and which are used for datums need to be algorithmically defined in order to rigorously define the meaning of a tolerance. A simple statement that a tolerance applies to a cylindrical feature does not convey enough information; a procedure should be defined to evaluate just what is a cylindrical feature. Datum reference frames also need to be constructed according to a pre-defined procedure. A procedural approach would ensure tht the feature, datum or tolerance is interpreted exactly as intended.

ISSUE OPTIONS & EVIDENCE:

Not applicable.

OPTION PROPOSED:	Not Applicable
DECISION:	Not Applicable
DECISION DATE:	Not Applicable
ACTION:	Not Applicable

ISSUE:	TOL-88.1 DERIVED GEOMETRY
INITIATION DATE:	13th January 1988
INITIATOR:	Mark Dunn, James Blaha
STATUS:	Preliminary
RELATED ISSUES:	86.4
DESCRIPTION:	Issue 86.4 talked about he use of off-part geometry which was derivable from part geometry as the target or the origin of a tolerance. At the time a "stub" was included to introduce the idea into the Tolerance Model. The problem has arisen again and must be resolved: how to include derived geometry in the model.

ISSUE OPTIONS & EVIDENCE:

Option 1: Develop a construct which algorithmically defines non-part geometry based upon part geometry.

Pros:

Cons:

Option 2: Develop a construct that associates the components of the shape model with a derivation type designation and (optionally) the derived result. The derivation type designation would reference an externally defined algorithm which will produce the result from the input components.

OPTION PROPOSED: Option 2.

DECISION: Not Applicable

DECISION DATE:

ACTION:

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE:	TOL–88.2 TOLERANCING SUBFACES
INITIATION DATE:	22nd Oct 86, Jan 88
INITIATOR:	James Blaha, Bob Parks
STATUS:	Unresolved
RELATED ISSUES:	86.13, 88.6
DESCRIPTION:	Tolerances may apply only to a given subregion of a face rather than the whole face. Also, these subregions may be used as datums. Datum Targets (86.13) pose a similar problem. (Reference ANSI Y14.5M - 1982, pg. 45, section 4.4.8 for datums). Drafting must be able to provide for the representation of such datum specifications, it must be able to obtain the extent of the surface being specified as a datum. (Figure 104, pg. 45).

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:

OPTION PROPOSED:
DECISION: Not Applicable
DECISION DATE:
ACTION:

ISSUE:	TOL-88.3 DATUM LABELS
INITIATION DATE:	15th December 1986
INITIATOR:	?
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Is the label attribute in datums simply a man-readable piece of text? If so, does it properly belong in this model? If label is a meaningless attribute, then does datum really have any meaning? That is not as strange as it sounds, because "datum" is not a thing itself, but rather a role played by a thing.

ISSUE OPTIONS & EVIDENCE:

Option 1: Delete the attribute Label from the Datum Entity.
Pros:
Cons:
Option 2: Delete both the attribute label and the entity Datum.
Pros:
Cons:
Option 3: Leave as-is

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.4 UNCONDITIONED DATUM AND NOT APPLICABLE MLSN
INITIATION DATE:	January 1988
INITIATOR:	W.C. Burkett
STATUS:	unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	The use of a material condition modifier (MLS) in conditioned datums is applicable only when the underlying shape element is a feature of size. Otherwise, it is not applicable (N). This also includes the question of the default RFS for an unspecified material condition call-out.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL-88.5 AMBIGUOUS SIZE TOLERANCES
INITIATION DATE:	13th January 1988
INITIATOR:	Mark Dunn
STATUS:	Resolved
RELATED ISSUES:	87.2, 88.26, 88.13
DESCRIPTION:	If a toleranced feature has more than one dimension subject to variation is size, how can multiple size tolerances be applied and interpreted unambiguously? This problem is particularly apparent in an implicit feature like a pocket, which has both a width and a length dimension. The size tolerance for each would be applied to the whole pocket, thereby causing the ambiguity.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Expand on the idea of a Size dimension that will distinguish between different size dimensions on a single feature and allow each to be toleranced separately. Size Dimension will be categorized as either a Size Parameter, which is referenced by Implicit Form Feature, and Size Characteristics (from which the value is calculated). See details in Tolerance Model Version 3.0.
Pros:	
Cons:	
Option 2:	

OPTION PROPOSED:	Option 1
EXPLANATION:	
DECISION:	The proposal for handling Size Dimensions as outlined in version 3.0 of the Tolerance Model solves the problem as outlined inthe issue and mets with the approval of the Form Feature Committee.
DECISION DATE:	13th July 1988
ACTION:	Tolerance Committee

ISSUE:	TOL-88.6 GAGE GEOMETRY (POINTS, LINES, CIRCLES)
INITIATION DATE:	15th December 1986
INITIATOR:	?
STATUS:	Unresolved
RELATED ISSUES:	86.4, 86.13, 88.1, 88.2
DESCRIPTION:	Gage points are often used to dimension/tolerance slanted planes on prismatic parts, conical surfaces on turned parts, etc. The essence of a gage point is the use of a basic dimension to specify the "to" (occasionally the "from") location, which is then constrained by the tolerance.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.7 NUMBER OF ANGULARITY AND PERPENDICULARITY DATUMS
INITIATION DATE:	22nd December 1986, 22nd July 1987
INITIATOR:	Mark Dunn, Ed Klages
STATUS:	Unresolved
RELATED ISSUES:	88.9, 88.24, 88.25, 88.30, 88.46
DESCRIPTION:	Angularity Tolerance and Perpendicularity Tolerance currently allow for up to two datums to be specified. The Y14.5 standards state that each of the tolerances are with respect to "a" datum.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.8 CONCENTRICITY CYLINDRICAL ZONE
INITIATION DATE:	9^{th} January 1987
INITIATOR:	Mark Dunn
STATUS:	Unresolved
RELATED ISSUES:	88.10, 88.12
DESCRIPTION:	The cylindrical_zone attribute is superfluous. According to Y14.5 and Foster, the tolerance zone is necessarily cylindrical.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE: TOL-88.9 CIRCULAR RUNOUT. TOTAL RUNOUT DATUMS

INITIATION DATE: 9th January 1987, 22nd July 1987
INITIATOR: Mark Dunn, Ed Klages
STATUS: Unresolved
RELATED ISSUES: 88.7, 88.24, 88.25
DESCRIPTION: Per Y14.5 and Foster, these tolerances may have a secondary datum. The model only provides for one datum.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL–88.10 CONCENTRICITY PROJECTED TOLERANCE ZONE
INITIATION DATE:	9th January 1988
INITIATOR:	Mark Dunn
STATUS:	Unresolved
RELATED ISSUES:	88.16, 88.25, 88.42
DESCRIPTION:	Y14.5 says that projected tolerances zones may be used with location and orientation tolerances. The model is consistent with this one exception – there is no Projected attribute for the Concentricity tolerance. Should there be? Note that 14.5 does not explicitly say that any location or orientation tolerance type is susceptible to projected zones, nor did a brief search uncover an example of a concentricity tolerance with a projected zone.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.11 PROFILE OF A LINE, SURFACE TOLERANCED ENTITY
INITIATION DATE:	9th January 1988
INITIATOR:	Mark Dunn
STATUS:	Unresolved
RELATED ISSUES:	88.8, 88.10
DESCRIPTION:	One application of these tolerances may apply to multiple faces or edges as a set. Hence the Toleranced_Entity attribute needs to be a list of lists, rather than a simple list. More precisely, the Profile of a Line Toleranced Entity needs to be a list of coplanar edges or a list of faces and the Profile of a Surface Toleranced Entity needs to be a list of faces.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE: TOL-88.12 TOLERANCE ZONE TYPES
INITIATION DATE: 9^{th} Janaury 1987
INITIATOR: Mark Dunn
STATUS: Unresolved
RELATED ISSUES: N/A
DESCRIPTION: The model makes no provision for spherical Tolerance zones. The Cylindrical_zone attribute needs to be replaced by an attribute having one of three values: parallelipipedic, cylindrical, or spherical.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.13 TOLERANCES ON IMPLICIT FORM FEATURES
INITIATION DATE:	13th January 1988, 9th January 1987
INITIATOR:	Mark Dunn
STATUS:	Resolved
RELATED ISSUES:	88.5
DESCRIPTION:	While implicit form features are shape defining components of shape model, they do not contain explicit pieces of geometry or other components to which a tolerance may be applied. If an implicit feature contains a single size parameter (such as the diameter of a hole), then the tolerance may be applied to the whole feature, with the implication that the size tolerance refers to the single size dimension. If the implicit feature contains more than one size dimension, an ambgiuity arises.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Separate the notion of a size dimension from the definition of implicit features and allow size tolerances to be applied to these explicit size dimensions or to explicit features of size. See details of Tolerance Model Version 3.0.
Pros:	
Cons:	
Option 2:	

OPTION PROPOSED:	Option 1
EXPLANATION:	This issue is essentially equivalent to 88.5. See the explanation in that issue for a full description of Size Dimension and Size Parameters.
DECISION:	The categorization of Size Dimension into Size Parameter and Size Characteristic satisfies the requirements of this issue.
DECISION DATE:	13th July 1988
ACTION:	Tolerance Committee

ISSUE: TOL-88.14 TOLERANCE QUALIFIERS
INITIATION DATE: 9th January 1987, January 1988
INITIATOR: Mark Dunn, Bob Parks
STATUS: Unresolved
RELATED ISSUES: 88.5
DESCRIPTION: There are a number of "qualifiers" that may be associated with tolerance data and which the tolerances model does not support. Examples are: ALL OVER, ALL AROUND, EACH ELEMENT, EACH RADIAL ELEMENT, FREE STATE, AVERAGE DIAMETER, FIM (FULL INDICATOR MOVEMENT). These are all apparently substantive data. In many cases, their message may be deducible from context, but this is not always possible or easy.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.14A CONSTRAINTS AND MODEL COMPLEXITY
INITIATION DATE:	9th January 1987
INITIATOR:	Mark Dunn
STATUS:	Preliminary
RELATED ISSUES:	N/A
DESCRIPTION:	If representation were the only motivating consideration, the tolerance information model could be very terse. (About 10 or 15 entities would suffice.) The much larger number of entities in the model is a consequence of uisng the information model to constrain the data. With this in mind, and considering that only a fraction of "good practice" can be enforced in the information model, the following issue arises: should extensive constraining via the information model be attempted? Or would it be better to develop a simple, terse unconstrained model that focuses on representation, awaiting (and agitating for) appropriate constraining tools?

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:

EXPLANATION:	a This issue has been resolved to a certain degree already. Extensions to the Express language enabled the model to be simplified by moving the constraints from the model (hence, deleting entities) to Express staements. This change is reflected between versions 2.0 and 2.1 of the model. (2nd October 1987)
DECISION:	N/A
DECISION DATE:	

ACTION:

ISSUE:	TOL-88.15 TOLERANCES AND POLYHEDRIC MODELS
INITIATION DATE:	1th April 1987
INITIATOR:	Ulrich Gengenbach
STATUS:	Resolved
RELATED ISSUES:	N/A
DESCRIPTION:	The Tolerance Model has a very Boundary Representation feeling to it. How (or should) Tolerances be applied to Polyhedric representation models?

ISSUE OPTIONS & EVIDENCE:

Option 1: The application of tolerances to polyhedric models depends upon the intended use of the model. If the model is used primarily for efficient display of an object model and is not used for manufacturing applications such as NC and QA, then there is no need to apply tolerances to the model. If this is the case, then the model should be considered application specific, like an FEM mesh.

Pros:

Cons:

Option 2: If there is still a need to apply tolerances to this type of model, then there are two probelms which must be resolved. The first concerns the multitude of facets used to approximate a non-planar surface. Although a polyhedric model is basically amenable to the requirements of the Tolerance Model, tolerances are applied to single surfaces, and the many independent faces used in a polyhedric approximation prevent this. If the facets could be grouped to form a single thing, then a tolerance may be applied to it. The second problem is somewhat philosophical. When a tolerance is applied to a non-planar surface, it is an approximation of the desired surface which is toleranced. This poses a contradiction because a tolerance is usually applied to the theoretically exact surface definition. The toleranced surface on an actual produced part cannot be inspected from the polyhedric model because it does not contain the exact surface definition.

Pros:

Cons:

OPTION PROPOSED:	Option 1
EXPLANATION:	Option 1 allows both models to remain unaffected by this issue, while placing the role of the Tolerance Model and Polyhedric Model into perspective. Chosing Option 2 would require some extensions to the polyhedric model.
DECISION:	Option 1
DECISION DATE:	18th May 1987

ACTION:

ISSUE:	TOL-88.16 PROFILE TOLERANCE APPLICATION
INITIATION DATE:	22nd July 1987, January 1988
INITIATOR:	Ed Klages, Bob Parks
STATUS:	Unresolved
RELATED ISSUES:	88.11
DESCRIPTION:	In addition to specifying whether the tolerance appliation is to be inside, outside or bilateral, some provision must be made for an unequally disposed bilateral tolerance. See ANSI Y14.5 - 1982 6.5.1 (b).

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL–88.17 DATUM CONSTRAINTS
INITIATION DATE:	14th October 1987
INITIATOR:	Bob Parks
STATUS:	Unresolved
RELATED ISSUES:	86.16
DESCRIPTION:	Primary, Secondary and Tertiary datums must be exclusive of each other (primary and secondary cannot be the same, primary and tertiary must be different, etc.). Also, where multiple datums are specified for a particular geometric tolerance they should be sufficient to establish a datum reference frame of three mutually perpendicular planes.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.18 TOLERANCE EXISTANCE FOR DRAFTING
INITIATION DATE:	14th October 1987
INITIATOR:	Bob Parks
STATUS:	Preliminary
RELATED ISSUES:	N/A
DESCRIPTION:	If a product model is not complete (i.e. lacking a particular tolerance with a datum specification), how will drafting be allowed to deal with the product data (augmentation)?

ISSUE OPTIONS & EVIDENCE:

Option 1:	The expansion of the "dimension" concept in the Tolerance Model Version 3.0 may resolve this concern.
Pros:	
Cons:	
Option 2:	

OPTION PROPOSED:	Option 1
EXPLANATION:	
DECISION:	N/A
DECISION DATE:	

ACTION:

ISSUE:	TOL-88.19 TOLERANCE NAMES
INITIATION DATE:	23rd December 1987
INITIATOR:	Mark Dunn
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	The names of the tolerance entities are not sufficiently descriptive in that the word "tolerance" is absent. This is particularly worrisome for entities LOCATION, ANGLE, SIZE , and POSITION, whose names suggest nominal shape concepts.

ISSUE OPTIONS & EVIDENCE:

Option 1: Add the word "tolerance" to the names of the tolerance entities so that, for example, entity 404 would be ANGLE TOLERANCE.

Pros:

Cons:

Option 2:

OPTION PROPOSED:

EXPLANATION:

DECISION: N/A

DECISION DATE:

ACTION:

ISSUE:	TOL-88.20 LOCATION TOLERANCE DIMENSION
INITIATION DATE:	23rd December 1987
INITIATOR:	Mark Dunn
STATUS:	Preliminary
RELATED ISSUES:	86.11, 87.2, 88.26
DESCRIPTION:	The information in and associated with the LOCATION/403 entity is not adequate to describe the dimension being toleranced. (The SIZE/405 and probably ANGLE/404 suffer from the same problem.) The original and basic idea of the model is that location tolerances apply to the dimensions (nominal distances) between pairs of "physical" topological/geometric entities. However, this is sufficient only for the simple cases where there is a constant distance between the origin and target (toleranced entity), e.g. parallel planes, concentric cylinders. There are many cases that are not so simple either because the the origin or the target is non-physical or because the Brep-ish model contains no pair of parallel topological/geometric entities to serve as the origin and target. The following data were included in the LOCATION/403 entity to provide the specificity needed for non-simple cases: Origin_Loc, a point nominally on the origin of the toleranced dimension; Tol Ent loc, a point nominally on the target of the toleranced dimension; Path, the nominal direction of measurement of the toleranced dimension. It is felt that even with this information, the model is unsatisfactory. On any particular piece, the points will be inside the material or in the air and the path (direction) will deviate from the nominal. The origin and target of the dimension of interest, as well as the direction of measurement, can only be determined from physical measurement and a knowledge of the intended dimension. Thus, the specification of the intended measurement must be explicit in or deriveable from the modeled information. **NOTE:** This problem description has been superceded and rendered obsolete by the work of the Tolerance Committee as reported in the report dated 25th March 1988 and Version 3.0 of the Tolerance Model. The concept of dimension has been expanded upon, hopefully rectifying the problem spelled out above. The details of the Technical Report have been incorporated into a new version of the Tolerance Model, version 3.0.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Expand on the "dimension" concept for Location, Size and Angle tolerances. See details in the Tolerance Model Version 3.0.
Pros:	
Cons:	
Option 2:	

SECTION 3: SHAPE VARIATION TOLERANCES

OPTION PROPOSED:	Option 1
EXPLANATION:	This issue is no longer valid because the new approach for determining the dimensional value for a coordinate dimension requires that the tolerance origin and tolerance target be parallel to one another.
DECISION:	This issue is considered resolved by the committee.
DECISION DATE:	13th July 1988
ACTION:	Tolerance Committee

ISSUE:	TOL-88.21 TABULATED TOLERANCES
INITIATION DATE:	Janaury 1988
INITIATOR:	Bob Parks
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Tabulated Tolerances for a family of parts cannot be accommodated in the model.

ISSUE OPTIONS & EVIDENCE:

Option 1: Make the tolerance attribute of the Geometric Tolerance entity a selection of type number or tolerance-id, where the tolerance-id corresponds to a table of values.

Pros:

Cons:

Option 2:

OPTION PROPOSED:

EXPLANATION:

DECISION: N/A

DECISION DATE:

ACTION:

ISSUE:	TOL-88.22 TEMPORARY AND PERMANENT DATUMS
INITIATION DATE:	Janaury 1988
INITIATOR:	Bob Parks
STATUS:	Unresolved
RELATED ISSUES:	86.6
DESCRIPTION:	Since temporary datums may be established for machining operations that create permanent datums, should this distinction be accomodated in the model? (reference ANSI Y14.5M 1982, section 4.2.1, page36.)

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.23 UNIDIRECTIONAL AND BI-DIRECTIONAL DIMENSIONS
INITIATION DATE:	15th February 1988
INITIATOR:	Mark Dunn
STATUS:	Preliminary
RELATED ISSUES:	88.29
DESCRIPTION:	It is necessary to distinguish between bi-directional (undirected, "between") location dimensions and unidirectional (directed, "from/to").

ISSUE OPTIONS & EVIDENCE:

Option 1:	Add a flag to the Location Dimension to distinguish between directed and bi-directional dimensions. See Coordinate Dimensions in Version 3.0 of the Tolerance Model.
Pros:	
Cons:	
Option 2:	

OPTION PROPOSED:	Option 1
EXPLANATION:	The addition of a simple flag, as reflected in version 3.0 of the Tolerance Model resolves this problem. The same issue, however, applies to the Related Angle Dimension (but is recorded as a separate issue.
DECISION:	This issue is resolved with the noted change.
DECISION DATE:	13th July 1988
ACTION:	Tolerance Committee

ISSUE:	TOL–88.24 CO-DATUMS
INITIATION DATE:	15th February 1988
INITIATOR:	Mark Dunn
STATUS:	Unresolved
RELATED ISSUES:	88.7, 88.9, 88.25, 88.46
DESCRIPTION:	The model only provides for co-datums for circular runout, concentricity, and total runout. It is possible that co-datums may be specified elsewhere.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.25 PRFOILE OF A LINE - NUMBER OF DATUMS
INITIATION DATE:	15th February 1988
INITIATOR:	Mark Dunn
STATUS:	Unresolved
RELATED ISSUES:	88.7, 88.9, 88.24, 88.11, 88.16
DESCRIPTION:	Is a tertiary datum possible for a profile of a line tolerance? It seems that a third datum may be illogical in a 2-D tolerance.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.26 DEFINITION OF "DIMENSION"
INITIATION DATE:	15th February 1988
INITIATOR:	Mark Dunn
STATUS:	Preliminary
RELATED ISSUES:	86.1, 87.2, 86.11, 88.20
DESCRIPTION:	There are two concepts in the term "dimension": a measurement on a product and the value of that measurement. The latter can be determined (nominally) from a model if the measurement is known. The tolerance model must provide for describing the measurement.

ISSUE OPTIONS & EVIDENCE:

Option 1: The components which make up a dimension should be separated and a clear explanation of what a "dimension" is should become part of the model. A possible approach for doing this was reported in a technical report dated 25th March 1988 and in version 3.0 of the Tolerance Model (8th July 1988).

Pros:

Cons:

Option 2:

OPTION PROPOSED:	Option 1
EXPLANATION:	The expansion of the idea of "dimension" within the Tolerance Model will eliminate much of the ambiguity in the relationship of "dimensions" to the tolerances.
DECISION:	The definition of dimension within version 3.0 of the Tolerance Model resolves this issue.
DECISION DATE:	13th July 1988
ACTION:	Tolerance Committee

ISSUE: TOL-88.27 MINIMUM AND MAXIMUM DIMENSION VALUE

INITIATION DATE: 15th February 1988
INITIATOR: Kim Perlotto
STATUS: Unresolved
RELATED ISSUES: 88.36
DESCRIPTION: Sometimes a minimum value is given, with no maximum and vice-versa. The model can stretched to cover maximum, but not minimums.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION: N/A
DECISION DATE:
ACTION:

ISSUE:	TOL-88.28 DIAMETER VS. RADIUS SIZE TOLERANCE
INITIATION DATE:	13th July 1988
INITIATOR:	Mark Dunn
STATUS:	Preliminary
RELATED ISSUES:	88.5
DESCRIPTION:	A Size Tolerance may be applied to a diametrical or a radial dimension, but there is no way to indicate this distinction. It is important to make this distinction because the tolerance zone for a radial tolerance is twice the size of a tolerance zone for a diameter tolerance of equal value.

ISSUE OPTIONS & EVIDENCE:

Option 1: The addition of a simple flag within the Size Dimension will indicate whether the tolerance applies to the radial value or diameter value.

Pros:

Cons:

Option 2:

OPTION PROPOSED:

EXPLANATION:

DECISION: N/A

DECISION DATE:

ACTION:

ISSUE:	TOL–88.29 UNI-DIRECTIONAL vs. BI-DIRECTIONAL ANGLE DIMENSION
INITIATION DATE:	13th July 1988
INITIATOR:	Mark Dunn
STATUS:	Preliminary
RELATED ISSUES:	88.23
DESCRIPTION:	As described in 88.23, a coordinate dimension may uni-directional (i.e. measured in a specified direction) or may be bi-directional (i.e. direction of measurement unimportant.) The issue described in 88.23 as applied to Location dimensions also applies to Related Angle Dimensions and may be similarly resolved.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Include a binary flag within the Related Angle Dimension that indicated whether the measurement is directed or undirected.
Pros:	Consistent with Location Dimension.
Cons:	
Option 2:	

OPTION PROPOSED:	Option 1
EXPLANATION:	
DECISION:	
DECISION DATE:	

ACTION:

ISSUE:	TOL-88.30 NUMBER OF DATUMS FOR ANGULARITY, PARALLELISM, PERPENDICULARY
INITIATION DATE:	13th July 1988
INITIATOR:	John Yanney (GD-FW), JNC-Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	88.7, 88.46
DESCRIPTION:	Angularity, Parallelism, and Perpendicularity tolerances do not allow for the specification of three datums. Three datums may be specified to form a Datum Reference Frame for each tolerance.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL-88.31 RELATIONSHIP BETWEEN COORDINATE DIMENSION AND COORDINATE TOLERANCE
INITIATION DATE:	13th July 1988
INITIATOR:	Mark Dunn
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	The relationship between the coordinate tolerance entities and the dimension entities are backwards. The dimensional entity should be the parent, the tolerance entity the dependent child (via a "Z" relationship). The dimension is the information of first instance without which the tolerance is meaningless; the tolerance is subordinate.

ISSUE OPTIONS & EVIDENCE:

Option 1: Flip the relationship causing the Dimension to be the Parent and Tolerance the child in the relationship.

Pros:

Cons:

Option 2: Leave as is, with Tolerance the Parent and Dimension the Child.

OPTION PROPOSED:

EXPLANATION:

DECISION:

DECISION DATE:

ACTION:

ISSUE:	TOL-88.32 D & T SHAPE ELEMENT AND FORM FEATURE CATEGORIZATION
INITIATION DATE:	13th July 1988
INITIATOR:	Mark Dunn
STATUS:	Preliminary
RELATED ISSUES:	N/A
DESCRIPTION:	The work of the Integration Committee has resulted in some specified relationships between shape elements, their representations and Form Features. The Tolerance Model, however, takes some liberties in the inclusion of these concepts. In order to keep the work in sync, the model should be changed to correspond to the Integration Work. This is basically an IDEF1X modelling problem.

ISSUE OPTIONS & EVIDENCE:

Option 1: Change "Shape Element" within the Tolerance Model to "DT Shape Element", categorize it according the needs of the Tolerance Model and establish relationships between the categories and the corresponding Shape Element from the Integration Model. Also change Form Feature to DT Form Feature and relate it to Form

Pros:

Cons:

Option 2:

OPTION PROPOSED: Option 1. See Version 3.1 of the Tolerance Model for details (Entity 300, DT_Feature).

EXPLANATION:

DECISION:

DECISION DATE:

ACTION:

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE:	TOL-88.33 SYMMETRY TOLERANCE
INITIATION DATE:	13th July, 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Both the ISO and ANSI standards specify a geometric tolerance called Symmetry. This tolerance is not included in the Tolerance Model, but should be.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Include a geometric Symmetry Tolerance
Pros:	Will correspond with the current specification.
Cons:	Was under consideration for deletion from Standard (at least the ANSI version of the standard). The current status of this question is unknown.
Option 2:	

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL-88.34 ARRANGEMENT OF ENTITY DEFINITIONS
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	The Tolerance Entities are currently arranged alphabetically within the model. They should be rearranged categorically according to the standards (Tolerances of Form, Orientation, Runout, Profile.)

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL-88.35 START POINT FOR PROJECTED TOLERANCE ZONE
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Projected Tolerance Zone is currently defined in terms of direction and extent (length). A start point for the zone should also be included as part of the definition.

ISSUE OPTIONS & EVIDENCE:

Option 1:	Include a start point with the PTZ definition
Pros:	Would more clearly define the projected zone.
Cons:	Because a tolerance can be applied to more than one target at a time (e.g. a Position Tolerance can be applied to a set of Holes.) the start point for a Projected Tolerance Zone for a single tolerance may not be unique (i.e. there may be many start points, one for each target (e.g. hole), each with the same direction and extent.)
Option 2:	Include a set of start points within the PTZ definition.

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL-88.36 COORDINATE TOLERANCE RANGE APPLICATIONS
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	88.27
DESCRIPTION:	The Coordinate Tolerance Range (plus/minus) for the value of a measurement currently restricted to a positive or zero value for the Plus_Tolerance, a positive or zero value for the Minus_Tolerance, and Plus_Tol + Minus_Tol not equal to zero. There are a number of additional cases, examples of which are in the ISO and ANSI Standards, that are not accommodated by this approach. These include: 1) both the upper bound and lower bound of the range have the same sign (e.g. +0.010, +0.005; -0.02, -0.06); 2) limit dimensioning (i.e. specification of maximum/minimum values or a single maximum or minimum value for the dimension); 3) the use of ISO symbols for tolerances (e.g. 0 12H7/h6).

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE:	TOL-88.37 MATERIAL CONDITION MODIFIER FOR PROFILE OF LINE/SURFACE
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	The Profile of a Line and Profile of a Surface Tolerance use Conditioned Datums, yet do not also have a Material Condition Modifier (MCM) attribute. Both tolerances should have a MCM as an attribute.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL-88.38 LOCATION DIMENSION VALUE
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	A nominal dimension value is necessary to define the Location Dimension. A value is included for both the Size and Angle Dimensions, and should be included in Location.

ISSUE OPTIONS & EVIDENCE:

Option 1: Add an attribute for the Nominal Location Dimension Value
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL-88.39 TARGET OF POSITION, CONCENTRICITY, CIRCULAR RUNOUT
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Position, Concentricity and Circular Runout tolerances can apply equally to Features of Size, Area and Seams. Currently, each tolerance can apply to only a subset of these things.

ISSUE OPTIONS & EVIDENCE:

Option 1: Change the definition of each entity to allow it reference each type of target: Feature of Size, Area and Seam.

Pros:

Cons:

Option 2:

OPTION PROPOSED:

EXPLANATION:

DECISION:

DECISION DATE:

ACTION:

ISSUE:	TOL-88.40 PER UNIT LENGTH FOR PARALLELISM, PERPENDICULARY, ANGULARITY
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	A Per Unit Length specification is valid not only with the context of a Straightness Tolerance, but also within Parallelism, Perpendicularity and Angularity Tolerances. An attribute should be added to each entity to account for this.

ISSUE OPTIONS & EVIDENCE:

Option 1: Add an attribute "Per Unit Length" to the Parallelism, Perpendicularity, and Angularity tolerances.

Pros:

Cons:

Option 2:

OPTION PROPOSED:

EXPLANATION:

DECISION:

DECISION DATE:

ACTION:

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE:	TOL-88.41 MATERIAL CONDITION MODIFIER FOR CONCENTRICITY, CIRCULARITY, CYLINDRICITY, CIRCULAR AND TOTAL RUNOUT TOLERANCES.
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	The Material Condition Modifier can be specified for Concentricitym, Circularity, Cylindricity, Circular and Total Runout Tolerances. These entities should be modified to reflect this fact.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL-88.42 PROJECT TOLERANCE ZONE FOR CONCENTRICITY
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	88.10
DESCRIPTION:	The purpose of the Projected Tolerance Zone is to increase the size the tolerance zone defined by a tolerance beyond the limits of the feature being toleranced. Given it's applicablility to Position, Angularity, Parallelism, and Perpendicularity, it would also seem applicable to Concentricity.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL–88.43 APPLICATION DIRECTION FOR PARALLELISM, PERPENDICULARITY , POSITION, CIRCULAR RUNOUT, AND TOTAL RUNOUT.
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Straightness Tolerance can be applied to a surface in a specified direction (e.g. on a cylinder, surface elements parallel to the axis can be toleranced with a straightness tolerance.) In a similar fashion, a direction may be used to specify the application of Parallelism, Perpendicularity, Position, Circular Runout and Total Runout.

ISSUE OPTIONS & EVIDENCE:

Option 1: Include a direction specification in the identified entities.

Pros:

Cons:

Option 2:

OPTION PROPOSED:

EXPLANATION:

DECISION:

DECISION DATE:

ACTION:

ISSUE:	TOL-88.44 DEFAULT TOLERANCES FOR OTHER TOLERANCES.
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	86.8
DESCRIPTION:	A default tolerance is currently only allowed for Profile of a Surface Tolerance. All tolerance entities should be allowed to be specified as a default.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

SECTION 3: SHAPE VARIATION TOLERANCES

ISSUE:	TOL-88.45 APPLICATION OF TOTAL AND CIRCULAR RUNOUT TOLERANCE
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	N/A
DESCRIPTION:	Application of the tolerance is currently specified in Profile Line Tolerance and Profile Surface Tolerance. Isn't it necessary that Application should also be specified in Circular Runout and Total Runout Tolerance?

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

ISSUE:	TOL-88.46 SPECIFICATION OF DATUMS FOR PERPENDICULARITY, PARALLELISM AND ANGULAR TOLERANCE.
INITIATION DATE:	13th July 1988
INITIATOR:	JNC - Dr. Hashimoto
STATUS:	Unresolved
RELATED ISSUES:	88.7, 88.24, 88.30
DESCRIPTION:	With respect to Datums, the Angularity, Parallelism and Perpendicularity tolerances should be modified as follows:

Descriptions in Version 3.0

- In Parallelism tolerance (412), Primary Datum can be specified.
- In Perepndicularity Tolerance (413), Primary and Secondary Datums can be specified.
- In Angularity (406), Primary, Secondary and Tertiary Datums can be specified.

Amended version:

- In Parallelism Tolerance and in Perpendicularity Tolerance, Primary Datum, Co-primary Datum, Secondary Datum, and Co-secondary datum can be specifed.
- In Angularity Tolerance, Primary Datum and Co-primary datum can be specified.

ISSUE OPTIONS & EVIDENCE:

Option 1:
Pros:
Cons:
Option 2:

OPTION PROPOSED:
EXPLANATION:
DECISION:
DECISION DATE:
ACTION:

3.7 Change History

Model changes reflected in this section outline the differences between the PDES Tolerance Model Version (unnumbered) dated 26th September 1986 and Version 1.0 dated 9th January 1987.

1. Tolerances are often to/from off-part geometry which is derived from product geometry (e.g. centerlines). An Entity called DERIVED GEOMETRY was added to the model.
2. The Angle Tolerance was considered confusing and imprecise. Changes were made remedy this problem.
3. References to BASIC dimensions have been removed from the model. The geometric, product model itself is considered BASIC.
4. Default tolerances will be handled by adding a flag to the Profile of a Surface tolerance to indicate a default condition.
5. The relationship between Size Feature, Feature_of_Size, and Form Feature has been clarified.
6. Material Condition Modifiers (MMC, LMC, RFS) apply only to "features" subject to variation in size (i.e. features_of_size). Changes to reflect this have been made.
7. There was some confusion over the intent and meaning of the coordinates associated with the Location Tolerance. Some minor changes have been made to reduce the probability of problems, but further work in necessary.

Model changes reflected in the following section outline the differences between the PDES Tolerance Model Version 1.0 dated 9th January 1987 and Version 2.0 dated 27th March 1987. These changes were prompted by the release of the PDES Initial Testing Draft and bring this model into correspondence with the Testing Draft. There have been no changes in technical content, but rather a conversion to bring this model in line with the released Testing Draft. All entities and definitions within the model are entities which appear in the Testing Draft.

1. The explanation on Model Content in the Assumptions section has been modified to reflect the release of the Testing Draft.
2. The Entity Pool section has been modified so that the alphabetic and numeric listing of the entities each fall entirely on a single page.
3. Geometry(100) was renamed Wire_Frame_Geometry(100) and the diagram changed to reflect the Testing Draft.
4. Unit_Vector(101) was renamed Direction(101) to bring it in line with the Testing Draft.
5. Point_Vector(102) was renamed Projected_Tolerance_Zone and changed to reflect the contents of the Geometry model. The concept of Vector and Point Vector did not exist in the Geometry Model, so rather than create them, an entity was defined (Projected_Tolerance_Zone) that contained the same functionality and had a clearly defined usage and intent.

6. Vector(103) was deleted as unnecessary (see item 5).
7. Subtypes of Curve(106) were deleted as superfluous.
8. Coordinate(107) was renamed Cartesian_Point.
9. Topology(200) was renamed Shape_Brep(200).
10. Entities 204-214 were named Face or Edge with a geometric adjective modifying the meaning were deleted. The purpose of these entities were to constraint the types of entities to which a certain tolerance may apply. These constraints have been incorporated into an Express WHERE clause in the entity's definition. This made these entities unnnecessary.
11. References to Form Features have been removed since they are not pertinent to the definition of the Tolerance Model.
12. Tolerance(400) was renamed Shape_Tolerance(400).

The changes to the model outlined in the following section represent the differences between Version 2.0, 27th March 1987, and Version 2.1, 2nd October 1987. These changes were prompted by an extension to the EXPRESS language (in particular the SELECT construct) which allowed the model to be simplified. The extensions to EXPRESS allowed contraints previously represented as unique entities to be included in the EXPRESS definition of other, more relevent entities. The overall result is that all but one of the 500-series entities have been removed from the model. The technical content of the two versions should be equivalent.

1. The notation "< –" and "– >" used in the propositions for each entity has been removed. The intent had been to indicate the direction of the migration of key attributes according to IDEF-1X. The differences between the EXPRESS definition on an entity and the the IDEF-1X model have blurred this distinction to the point where it is meaningless. The SELECT capability of EXPRESS and the categorized associative entity required by IDEF-1X (the 500-series entities) appear to behave different with regard to key migration.
2. All 500-series entities have been removed from the model except for entity 521. The constraints represented by those entities are now captured using the EXPRESS SELECT option. The entities still exist, but are now included as support entities on the subject entity diagram rather than uniquely identified.
3. Entity 521 Angle_Intersection has been renamed and reconstructed as Point_Triplet. Instead of the complicated structure which existed previously, the precise angle definitions are now defined by the Point_Triplets with constraints that restrict the relationship between the points, the toleranced entity and the tolerance origin. The Angle Tolerance now references a list of Point_Triplets and a single toleranced entity and tolerance origin.
4. The introduction of the SELECT construct and elimination of the 500 series associative entities has simplified the subtyping of the tolerance entities. Rather than being a subtype of XXX_Tol_Ent, Face is now just a subtype of Shape_BREP.

SECTION 3: SHAPE VARIATION TOLERANCES

The changes outlined in the following section reflect the differences between version 2.1 of the Tolerance Model dated 2nd October 1987 and version 3.0 dated 8th July 1988. These changes were prompted by a meeting with the ad hoc Form Features committee in January 1988 and were developed during an interim meeting of the Tolerance Committee 15th – 18th February 1988. The results of this interim meeting are detailed in a technical report dated 25th March 1988.

1. The idea of "dimensions" was developed within the model. The information necessary to determine the dimension was unsatisfactorily buried with the Coordinate Tolerance entities. In the version of the model, the emphasis is flip-flopped. The Tolerance range takes on a lesser role and Coordinate Dimensions are defined. The Coordinate Tolerances Location, Size and Angle have been replaced with Location Dimension, Size Dimension and Angle Dimension. The entity Coordinate Tolerance has been replaced with Coordinate Tolerance Range. The information necessary to define the dimension is made explicitly, so implicit mechanisms such as Point Triplet and Location-Tolerance-Location point are no longer needed.

2. The role of Geometric Derivation has been expanded upon. Originally just a "stub" in this model, the work on Form Features has prompted an expansion of this idea. It is really an extension to the model, rather than a change to existing work.

3. The notion of Dimension/Tolerance Feature has been introduced to sort out the entities to which tolerances are applied "to" and "from". This is very similar to a structure that was part of an earlier version of the Tolerance Model. It organizes Shape Elements, Features of Size, Size Features, and F· ·m Features.

4. Projected Tolerance Zone was modified by eliminating the position for the zone. If the same tolerance applies to several entities (such as a set of holes), then a single position for the tolerance zone would be meaningless.

5. The Tolerance Value for the Geometric Tolerances was moved from the Geometric Tolerance entity into each of the subtypes because of the constraint on that value in the Profile of a Surface tolerance entity.

6. The entities Shape_BREP, Face, Edge and Vertex were renamed Shape_Element, Area, Seam and Corner in accordance with the work of the Integration Committee.

The following changes reflect the differences between version 3.0, dated 8th July 1988 and version 3.1, dated 8th August 1988. These changes were prompted by the meetings of the PDES Integration Committee and consist primarily of editorially changes

1. The IDEF model contained in this document was "formalized" from its earlier, free-form version. This means that there are a whole bunch of new entity numbers (although there are the same number of boxes). The EXPRESS definitions did not change, nor did 99changed to reflect the fact that they were defined in other models.

2. There were only two minor technical changes introduced with this version. In order to be more "integrated" with the form features model, the attribute Parameter_Value within Size_Parameter and Angle Size_Parameter were made optional. This was to allow derivable

attributes of Implicit Form Features (like the diagonal of a rectangular pocket) to be toleranced without explicitly calling out a value.

3. The other technical change were to allow Concentricity and Circular Runout Tolerances to be applied to Seams.

4. There was also one semi-significant technical change. This involved the categorization of DT Feature into Form Feature and Shape Elements. Since the work of the Integration Committee explicitly defined how these concepts were related, the liberties taken including them into the Tolerance Model resulted in a model which did not correspond to the Integration Model. For instance, in version 3.0 of the Tolerance Model Shape Element was categorized into Area, Seam and Corner, whereas in the Integration Model the same entity was more extensively categorized; this apparent discrepancy was seen as unacceptable. So within the Tolerance Model, Shape Element became DT Shape Element, and Form Feature became DT Form Feature, essentially introducing an addition level between the entities in the Tolerance Model and the entities in the Integration Model.

The following changes detail the differences between Version 3.1 of the Tolerance Model, dated 8th August 1988, and Version 3.2, dated 26th August 1988. These changes were prompted, once again, by the work of the Integration Committee and were made to accomodate the publication of Volume 3.0 of the PDES document. With a single technical exeception, there is absolutely N difference between Version 3.1 of the model and Version 3.2. With the single caveat explained here, 3.1 may be considered the latest version of the model.

1. A single technical change was made to accomodate the needs of the Form Features committee. A discussion at the Denver meeting questioned whether a tolerance applied to a radius was the same as that applied to a diameter. There was an obvious difference of a factor of 2. To take with distinction into account, a boolean valued attribute called Half dimension was added to Size_Dimension and to Angle_Dimension. TRUE would mean that tolerance applies to the radius, FALSE that it applies to the full diameter.

2. The PDES/STEP document section number was changed from 3.1.1.6 to 3.1.1.2. This is reflected on every page of this document.