Parasolid XT Format Reference

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Introduction to the Parasolid XT Format

This Parasolid® Transmit File Format manual describes the formats in which Parasolid represents model information in external files. Parasolid is a geometric modeling kernel that can represent wireframe, surface, solid, cellular and general non-manifold models.

Parasolid stores topological and geometric information defining the shape of models in transmit files. These files have a published format so that applications can have access to Parasolid models without necessarily using the Parasolid kernel. The main audience for this manual is people who intend to write translators from or to the Parasolid transmit format.

Reading and writing transmit files are significantly different problems. Reading is simply a question of traversing the transmit file and interpreting the records stored within it. Writing is a significantly harder process; as well as getting the data format of the transmit file correct applications must also ensure that the many complex and subtle inter-relationships between the geometric nodes in the file are satisfied.

The presentation of material in this manual is structured to help the construction of applications that perform read operations. It is strongly advised that the construction of applications that write files is only attempted when a copy of Parasolid is available during the development process to check the consistency and validity of files being produced.

This manual documents the Parasolid transmit file format. This format will change in subsequent Parasolid releases at which time this manual will be updated. As new versions of Parasolid can read and write older transmit file formats these changes will not invalidate applications written based on the information herein.

Types of File Documented

There are a number of different interface routines in Parasolid for writing transmit files. Each of these routines can write slightly different combinations of Parasolid data, the ones that are documented herein are:

- Individual components (or assemblies) written using SAVMOD
- Individual components written using PK_PART_transmit
- Lists of components written using PK_PART_transmit

- Partitions written using PK_PARTITION_transmit

The basic format used to write data in all the above cases is identical; there are a small number of node types that are specific to each of the above file types.

Text and Binary Formats

Parasolid can encode the data it writes out in four different formats:

1. Text (usually ASCII)
2. Neutral binary
3. Bare binary (this is not recommended)
4. Typed binary

In text format all the data is written out as human readable text, they have the advantage that they are readable but they also have a number of disadvantages. They are relatively slow to read and write, converting to and from text forms of real numbers introduces rounding errors that can (in extreme cases) cause problems and finally there are limitations when dealing with multi-byte character sets. Carriage return or line feed characters can appear anywhere in a text transmit file but other unexpected non-printing characters will cause Parasolid to reject the file as corrupt.

Neutral binary is a machine independent binary format.

Bare binary is a machine dependent binary format. It is not a recommended format since the machine type which wrote it must be known before it can be interpreted.

Typed binary is a machine dependent binary format, but it has a machine independent prefix describing the machine type that wrote it and so can be read on all machine types.

Standard File Names and Extensions

Due to changing operation system restrictions on file names over the years Parasolid has used several different file extensions to denote file contents. The recommended set of file extensions is:

- .X_T and .X_B for part files, .P_T and .P_B for partition files.

Extensions that have been used in the past are:

- xmt_txt, xmp_txt - text format files on VMS or Unix platforms
- xmt_bin, xmp_bin - binary format files on VMS or Unix platforms

The Alternative Solution

An alternative solution for reading and writing XT data is to license the Parasolid software, which is available in Designer, Editor, Communicator and Educator packages. For further details on these packages, and contact information, visit the Parasolid website at http://www.parasolid.com/.

Logical Layout

The logical layout of a Parasolid transmit file is:

- A human-oriented text header.

  The initial text header is read and written by applications' Frustrums and is not accessible to Parasolid. Its detailed format is described in the section `Physical layout'.

- A short flag sequence describing the file format, followed by modeller identification information and user field size.

  The various flag sequences (mixtures of text and numbers) are documented under `Physical layout'; the content of the modeller identification information is:

  - the modeller version used to write the file, as a text string of the form:

    : TRANSMIT FILE created by modeller version 1200123

    This information is used by routines such as PK_PART_ask_kernel_version.

  - the schema version describing the field sequences of the part nodes as a text string of the form:

    SCH_1200123_12006

    This example denotes a file written by Parasolid V12.0.123 using schema number 12006: there will be a corresponding file sch_12006 in the Parasolid schema distribution.

    Note that applications writing XT files should use version 1200000 and schema number 12006.

  The user field size is a simple integer.

- The objects (known as ‘nodes’) in the file in an unordered sequence, followed by a terminator.

  Every node in the file is assigned an integer index from 1 upwards (some indices may not be used). Pointer fields are output as these indices, or as zero for a null pointer.

  Each node entry begins with the node type. If the node is of variable length (see below), this is followed by the length of the variable field. The index of the node is then output, followed by the fields of the node. If the file contains user fields, and the node is visible at the PK interface, then the fields are followed by the user field, in integers.

The terminator which follows the sequence of nodes is a two-byte integer with value 1, followed by an index with value 0. The index is output as '0' in a text file, and as a 2-byte integer with value 1 in a binary file.

The node with index 1 is the root node of the transmit file as follows:

Contents of file	**Type of root node**
Body	BODY
Assembly	ASSEMBLY
Array of parts	POINTER_LIS_BLOCK
Partition	WORLD

Schema

Parasolid permanent structures are defined in a special language akin to C which generates the appropriate files for a C compiler, the runtime information used by Parasolid, along with a schema file used during transmit and receive. The schema file for version 12.0 is named sch_12006 and is distributed with Parasolid. It is not necessary to have a copy of this file to understand the XT format.

For each node type, the schema file has a node specifier of the form

<nodetype> <nodename>; <description>; <transmit 1/0> <no. of fields> <variable 1/0>

e.g.

29 POINT; Point; 1 6 0

This is followed by a list of field specifiers which say what fields, and in what order, occur in the transmit file.

Field specifiers have the format:

<fieldname>; <type>; <transmit 1/0> <node class> <n_elements>

e.g.

owner; p; 1 1011 1

Nodes and fields with a transmit flag of zero are ephemeral information not written to a transmit file. Only pointer fields have non-zero node class, in which case it specifies the set of node types to which this field is allowed to point. The element count is interpreted as follows:

0	a scalar, a single value
1	a variable length field (see below)
n > 1	an array of n values

Note that in the schema file, fins are referred to as ‘halfedges’, and groups are referred to as ‘features’. These are internal names not used elsewhere in this document.

Embedded schemas

When reading a part, partition, or delta, Parasolid converts any data that it encounters from older versions of Parasolid to the current format using a mixture of automatic table conversion (driven by the appropriate schemas), and explicit code for more complex algorithms.

However, backwards compatibility of file information – that is, reading data created by a newer version of Parasolid into an application (such as data created by a subcontractor) – can never be guaranteed to work using this method, because the older version does not contain any special-case conversion code.

From Parasolid V14 onwards, parts, partitions and deltas can be transmitted with extra information that is intended to replace the schema normally loaded to describe the data layout. This information contains the **differences** between its schema and a defined base schema (currently V13's SCH_13006).

This enables parts, partitions, and deltas to be successfully read into older versions of Parasolid without loss of information.

The only fields that are included in this information are those which can be referenced in a cut-down version of the schema pertaining only to the XT part data that is transmitted. Specifically, a full schema definition can contain fields that are not relevant in the context of the transmitted data (fields relating to snapshots, for example), and these fields are excluded.

Fields that are included are referred to as **effective fields**, and are either transmittable (`xmt_code` == 1) or have variable-length (`n_elts` == 1)

Physical layout

Most of the data are composed of integers, logical flags, and strings, but are of restricted ranges and so transmitted specially in binary format. The binary representation is given in **bold** type, such as “integer (**byte**)”. This is only relevant to applications that attempt to read or write Parasolid data directly rather than via a Parasolid image. Two important elements are

- **short string**s

  These are transmitted as an integer length (**byte**) followed by the characters (without trailing zero).

- **positive integer**s

  These are transmitted similarly to the pointer indices which link individual objects together, i.e., small values 0..32766 are transmitted as a single **short** integer, larger ones encoded into two.

XT format

Presence of the new format is indicated by a change to the standard header: the archive name is extended by the number of the base schema, e.g., `SCH_1400068_14000_13006`, and then the maximum number of node types is inserted (**short**).

Transmission then continues as normal, except that when transmitting the first node of any particular type, extra information is inserted between the nodetype and the variable-length, index data as follows:

- The arrays of effective fields in the base schema node and the current schema node are assembled.
- If the nodetype does not exist in the base schema then it is output as follows:
  - number of fields (**byte**)
  - name and description (**short string**s)
  - fields one by one as

`name`	short string	
`ptr_class`	Short	
`n_elts`	Positive integer	
`type`	short string	The field type. Allowed values are described in “Field types”, below. Omitted if `ptr_class` non-zero
`xmt_code`	logical (byte)	Omitted for fixed-length (`n_elts` != 1)

- If the two arrays match (equal length and all fields match in `name`, `xmt_code`, `ptr_class`, `n_elts` and `type`) then output the flag value 255 (**byte** 0xff).
- If the two arrays do not match, output the number of effective fields in the current schema (**byte**), and an edit sequence as follows.
    - Initialize pointers to the first base field and first current field, then while there are still unprocessed base and current fields, output a sequence of Copy, Delete and Insert instructions
        - If the base field matches the current field, output 'C' (**char**) to indicate an unchanged (Copied) field and advance to the next base and current fields;
        - If the base field does not match any unprocessed current field, output 'D' (**char**) to indicate a Deleted field and advance to the next base field;
        - Otherwise, output 'I' (**char**) to indicate an Inserted field, followed by the current field in the above format, and advance to the next current field.
    - If there are any unprocessed current fields, then output an Append sequence, each instruction being 'A' (**char**) followed by the field.
- Finally, output 'Z' (**char**) to signal the end.

Space compression

For text data in transmit formats PK_transmit_format_text_c and PK_transmit_format_xml_c, a new escape sequence is defined: the 2-character sequence **\9** denotes a sequence of nine spaces. At V14, this applies to attribute definition names, field names, and attribute strings.

Field types

The XT format is not itself a binary protocol, and so does not define data sizes; the only requirement is that a runtime implementation has sufficient room for the information. The available implementations run with 8bit ASCII characters, 8bit unsigned bytes (0..255), 16bit short integers (0..65535 or -32768..32767), 32bit integers (0..4G-1, -2G..2G-1) and IEEE reals. The implementation used in a given binary file is specified by the "PS<code>" at the start of the file. See the chapter on “Physical Layout” for more information.

The full list of field types used in transmit files is as follows:

u unsigned byte 0-255

c char

l unsigned byte 0-1 (i.e. logical)

```
typedef char logical;
```

n short int

w unicode character, output as a short int

d int

p pointer-index

Small indices (less than 32767) are treated specially in binary files to save space. See the section below on binary format.

f double

i These correspond to a region of the real line:

```
typedef struct { double low, high; }interval;
```

v array [3] of doubles

These correspond to a 3-space position or direction:

```
typedef struct { double x,y,z; } vector;
```

b array [6] of doubles

These correspond to a 3-spce region:

```
typedef struct { interval x,y,z; } box;
```

Note that the ordering is not the same as presented at Parasolid's external PK or KI interfaces.

h array [3] of doubles

These represent points of intersection between two surfaces; only the position vector is written to a transmit file, as Parasolid will recalculate other data as required. The structure is documented further in the section on intersection curves.

Point

As an example, consider a POINT; its formal description is

```
struct POINT_s          // Point
```

```
        {
        int                             node_id;                // $d
        union  ATTRIB_GROUP_u           attributes_groups;      // $p
        union  POINT_OWNER_u            owner;                  // $p
        struct POINT_s                  *next;                  // $p
        struct POINT_s                  *previous;              // $p
        vector                          pvec;                   // $v
        };
typedef struct POINT_s          *POINT;
```

Its corresponding schema file entry is

29 POINT; Point; 1 6 0

node_id; d; 1 0 0

attributes_groups; p; 1 1019 0

owner; p; 1 1011 0

next; p; 1 29 0

previous; p; 1 29 0

pvec; v; 1 0 0

Pointer classes

In the above example, the attributes_groups field must be of class ATTRIB_GROUP_cl, the owner must be of class POINT_OWNER_cl, and the next and previous fields must refer to POINTs. A full list of node types and node classes is given at the end of the document.

Each node class corresponds to a union of pointers given in the Schema Definition section.

Variable-length nodes

Variable-length nodes differ from fixed-length nodes in that their last field is of variable length, i.e. different nodes of the same type may have different lengths. In the schema the length is notionally given as 1, e.g.

```
struct REAL_VALUES_s          // Real values
    {
    Double                          values[1];                      // $f[]
    };
```

Its schema file entry would be

83 REAL_VALUES; Real values; 1 1 1

values; f; 1 0 1

The number of entries in each such node is indicated by an integer in the transmit file between its nodetype and index, so an example might be

83 3 15 1 2 3

Unresolved indices

In some cases a node will contain an index field which does not correspond to a node in the transmit file, in this case the index is to be interpreted as zero.

Simple example

Here is a reformatted text example of a sheet circle with a color attribute on its single edge:

```
**ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz**********
*
**PARASOLID !"#$%&'()*+,-./:;<=>?@[\]^_`{|}~0123456789**********
**PART1;MC=osf65;MC_MODEL=alpha;MC_ID=sdlosf6;OS=OSF1;OS_RELEASE=
V4.0;FRU=sdl_parasolid_test_osf64;APPL=unknown;SITE=sdl-cambridge-
u.k.;USER=davidj;FORMAT=text;GUISE=transmit;DATE=29-mar-2000;
**PART2;SCH=SCH_1200000_12006;USFLD_SIZE=0;
**PART3;
**END_OF_HEADER**************************************************
```

T51 : TRANSMIT FILE created by modeller version 120000017 SCH_1200000_120060	
12 1 12 0 2 0 0 0 0 1e3 1e-8 0 0 0 1 0 3 1 3 4 5 0 6 7 0	body
70 2 0 1 0 0 4 1 20 8 8 8 1 T	list
13 3 3 0 1 0 9 0 0 6 9	shell
50 4 11 0 9 0 0 0 +0 0 0 0 0 0 1 1 0 0	plane
31 5 10 0 7 0 0 0 +0 0 0 0 0 0 1 1 0 0 1	circle
19 6 5 0 1 0 0 3 V	region
16 7 6 0 ?10 0 0 5 0 0 1	edge
17 10 0 11 10 10 0 12 7 0 0 +	fin
15 11 7 0 10 9 0	loop
17 12 0 0 0 0 0 10 7 0 0 -	fin (dummy)
14 9 2 13 ?0 0 11 3 4 +0 0 0 0 3	face
81 1 13 12 14 9 0 0 0 0 15	attribute (variable 1)
80 1 14 0 16 8001 0 0 0 0 3 5 0 0 FFFFTFTFFFFFF2	attrib_def (variable 1)
83 3 15 1 2 3	real_values (variable 3)
79 15 16 SDL/TYSA_COLOUR	att_def_id (variable 15)
74 20 8 1 0 13 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	pointer_lis_block
1 0	terminator

Note that the tolerance fields of the face and edge are unset, and represented as ‘?’ in the text transmit file and that the annotations in the column ‘body’ to ‘terminator’ give the node type of each line and are not part of the actual file. If the above file had no trailing spaces, it would be a valid XT file (the leading spaces on some of the lines are necessary).

Physical Layout

Parasolid transmit files have two headers:

- a textual introduction containing human-directed information about the part, written by the Frustrum and not accessible to Parasolid, and
- an internal prefix to the part data, describing to Parasolid the format of the part data and thus not seen explicitly by an application's Frustrum.

Common header

The Parasolid common header recommended to Frustrum writers consists of:

- A preamble containing all characters in the ASCII printing set. This is used by the KID Frustrum to detect obvious network corruption, but could be used to attempt to translate a text file from one character set to another.
- Part 1 data: a sequence of keyword-value pairs, separated by semicolons, of possibly interesting information. All are optional.

```
MC              =       vax, hppa, sparc, ...
                                // make of computer
        MC_MODEL    =       4090, 9000/780, sun4m, ...
                                //  model of computer
        MC_ID       =       ...
                                //  unique machine identifier
        OS          =       vms, HP-UX, SunOS, ...
                                //  name of operating system
OS_RELEASE =    V6.2, B.10.20, 5.5.1, ...
                                //  version of operating system
FRU     =   sdl_parasolid_test_vax,
              mdc_ugii_v7.0_djl_can_vrh, ...
//  frustrum supplier and implementation name
```

```
        APPL        =    kid, unigraphics, ...
// application which is using Parasolid
        SITE        =    ...
// site at which application is running
        USER        =    ...
                         // login name of user
        FORMAT      =    binary, text, applio
                         // format of file
        GUISE       =    transmit, transmit_partition
                         // guise of file
    KEY             =    ...
                         // name of key
        FILE        =    ...
                         // name of file
        DATE        =    dd-mmm-yyyy
// e.g. 5-apr-1998
```

The ‘part 1’ data is ‘standard’ information which should be accessible to the Frustrum (e.g. by operating system calls). It is the responsibility of the Frustrum to gather the relevant information and to format it as described in this specification.

- part 2 data: a sequence of keyword-value pairs, separated by semicolons.

```
        SCH         =    SCH_m_n
// name of schema key e.g.SCH_1200000_12006
USFLD_SIZE  =    m
// length of user field (0 - 16 integer words)
```

Applications writing XT files must use a schema name of `SCH_1200000_12006`

- part 3 data: non-standard information, which is only comprehensible to the Frustrum which wrote it.

The ‘part 3’ data is non-standard information, which is only comprehensible to the Frustrum which wrote it. However, other Frustrum implementations must be able to

parse it (in order to reach the end of the header), and it should therefore conform to the same keyword/value syntax as for ‘part 1’ and ‘part 2’ data. However, the choice and interpretation of keywords for the ‘part 3’ data is entirely at the discretion of the Frustrum which is writing the header.

- a trailer record.

An example is:

ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz********
*

PARASOLID !"#$%&'()*+,-./:;<=>?@[\]^_`{|}~0123456789********

**PART1;MC=vax;MC_MODEL=4090;MC_ID=VAX14;OS=vms;OS_RELEASE=V6.2;FRU=sdl_parasolid_test_vax;APPL=unknown;SITE=sdl-cambridge u.k.;USER=ALANS;FORMAT=text;GUISE=transmit;KEY=temp;FILE=TEMP.XMT_TXT;DATE=8-sep-1997;

**PART2;SCH=SCH_701169_7007;USFLD_SIZE=0;

**PART3;

END_OF_HEADER********

Keyword Syntax

All keyword definitions which appear in the three parts of data are written in the form

```
<name>=<value> e.g. MC=hppa;MC_MODEL=9000/710;
```

where

<name> consists of 1 to 80 uppercase, digit, or underscore characters

<value> consists of 1 or more ASCII printing characters (except space)

Escape sequences provide a way of being able to use the full (7 bit) set of ASCII printing characters and the new line character within keyword values. Certain characters must be escaped if they are to appear in a keyword value:

Character	Escape sequence
newline	^n
space	^_
semicolon	^;
uparrow	^^

The two character escape sequences may be split by a new line character as they are written to file. They must not cause any output lines to be longer than 80 characters.

Only those characters which belong to the ASCII (7 bit) printing sequence, plus the new line character, can be included as part of a keyword value.

Text

Parasolid has no knowledge of how files are stored. On writing, Parasolid produces an internal bytestream which is then split into roughly 80-character records separated by newline characters ('\n'). The newlines are not significant.

As operating systems vary in their treatment of text data, on reading all newline and carriage return characters ('\r') are ignored, along with any trailing spaces added to the records. However, leading spaces are not ignored, and the file must not contain adjacent space characters not at the end of a record.

Text XT files written by version 12.1 and later versions use escape sequences to output the following characters, except for '\n' at the end of each line:

null "\0"

carriage return "\n"

line feed "\r"

backslash "\\"

These characters are not escaped by versions 12.0 and earlier.

The flag sequence is the character ‘T’. This is followed by the length of the modeler version, separated by a space from the characters of the modeler version, similarly the schema version, finally the userfield size. For example:

T

51 : TRANSMIT FILE created by modeller version 1200000

17 SCH_1200000_12006

0

NB: because of ignored layout, what Parasolid would read is

T51 : TRANSMIT FILE created by modeller version 120000017 SCH_1200000_120060

For partition files, the modeller version string would be given as

63 : TRANSMIT FILE (partition) created by modeller version 1200000

All numbers are followed by a single space to separate them from the next entry. Fields of type c and l are not followed by a space.

Logical values (0,1) are represented as characters F,T.

There are two special numeric values (-32764 for integral values, -3.14158e13 for floating point) which are used inside Parasolid to mark an ‘unset’ or ‘null’ value, and they are represented in a text transmit file as the question mark ‘?’. If a vector has one component null, then all three components must be null, and it will be output in a text file as a single ‘?’.

Binary

There are three types of binary file: `bare' binary, typed binary, and neutral binary. They are distinguished by a short flag sequence at the beginning of the file. In all cases, the flag sequence is followed by the length of the modeller version as a 2-byte integer, the characters of the modeller version, the length of the schema version as a 4-byte integer, the characters of the schema version, and finally the userfield size as a 4-byte integer.

As with text files, there are two special numeric values (-32764 for integral values, -3.14158e13 for floating point) which are used inside Parasolid to mark an ‘unset’ or ‘null’ value, and they are represented in a text transmit file as the question mark ‘?’.

bare binary

In bare binary, data is represented in the natural format of the machine which wrote the data. The flag sequence is the single character 'B' (for ASCII machines, '\102'). The data must be read on a machine with the same natural format with respect to character set, endianness and floating point format.

typed binary

In typed binary, data is represented in the natural format of the machine that wrote the data. The flag sequence is the 4-byte sequence “PS” followed by a zero byte and a one byte, i.e., ‘P’ ‘S’ ‘\0’ ‘\1’, followed by a 3-byte sequence of machine description.

	Byte order	**Double representation**	**Character representation**
0	Big-endian	IEEE	ASCII
1	Little-endian	VAX D-float	EBCDIC

neutral binary

In neutral binary, data is represented in big-endian format, with IEEE floating point numbers and ASCII characters. The flag sequence is the 4-byte sequence "PS" followed by two zero bytes, i.e., 'P' 'S' '\0' '\0'. At Parasolid V9, the initial letters are ASCII, thus '\120' '\123'.

The nodetype at the start of a node is a 2-byte integer, the variable length which may follow it is a 4-byte integer.

Logical values (0,1) are represented as themselves in 1 byte.

Small pointer indices (in the range 0-32766) are implemented as a 2-byte integer, larger indices are represented as a pair, thus:

```
if (index < 32767)
        {                               // case: small index
        op_short( index + 1 );          // offset so is > 0
        }
else
        {                               // case: big index
        op_short( -(index % 32767 + 1) );   // remainder: add 1 so > 0
        op_short( index / 32767 );          // nonzero quotient
        }
```

where op_short outputs a 2-byte integer.

The inverse is performed on reading:

```
short q = 0, r;
ip_short( &r );
if (r < 0)
        {
        ip_short( &q );
        r = -r;
        }
index = q * 32767 + r - 1;
```

where ip_short reads a 2-byte integer.

Model Structure

Topology

This section describes the Parasolid Topology model, it gives an overview of how the nodes in an XT file are joined together. In this section the word ‘entity’ means a node which is visible to a PK application – a table of which nodes are visible at the PK interface appears in the section `Node Types'.

The topological representation allows for:

- Non-manifold solids
- Solids with internal partitions
- Bodies of mixed dimension (i.e. with wire, sheet, and solid `bits')
- Pure wire-frame bodies
- Disconnected bodies

Each entity is described, and its properties and links to other entities given.

General points

In this section a set is called **finite** if it can be enclosed in a ball of finite radius - not that it has a finite number of members.

A set of points in 3-dimensional space is called **open** if it does not contain its boundary.

Back-pointers, next and previous pointers in a chain, and derived pointers are not described explicitly here. For information on this see the following description of the schema-level model.

Entity definitions

Assembly

An assembly is a collection of instances of bodies or assemblies. It may also contain construction geometry. An assembly has the following fields:

- A set of instances.
- A set of geometry (surfaces, curves and points).

Instance

An instance is a reference to a body or an assembly, with an optional transform:

- Body or assembly.
- Transform. If null, the identity transform is assumed.

Body

A body is a collection of faces, edges and vertices, together with the 3-dimensional connected regions into which space is divided by these entities. Each region is either **solid** or **void** (indicating whether it represents material or not).

The point-set represented by the body is the disjoint union of the point-sets represented by its solid regions, faces, edges, and vertices. This point-set need not be connected, but it must be finite.

A body has the following fields:

- A set of regions.

  A body has one or more regions. These, together with their boundaries, make up the whole of 3-space, and do not overlap, except at their boundaries. One region in the body is distinguished as the exterior region, which must be infinite; all other regions in the body must be finite.

- A set of geometry (surfaces, curve and/or points).
- A body-type. This may be wire, sheet, solid or general.

Region

A region is an open connected subset of 3-dimensional space whose boundary is a collection of vertices, edges, and oriented faces.

Regions are either solid or void, and they may be non-manifold. A solid region contributes to the point-set of its owning body; a void region does not (although its boundary will).

Two regions may share a face, one on each side.

A region may be infinite, but a body must have exactly one infinite region. The infinite region of a body must be void.

A region has the following fields:

- A logical indicating whether the region is solid.

- A set of shells. The positive shell of a region, if it has one, is not distinguished.

The shells of a region do not overlap or share faces, edges or vertices.

A region may have no shells, in which case it represents all space (and will be the only region in its body, which will have no faces, edges or vertices).

Shell

A shell is a connected component of the boundary of a region. As such it will be defined by a collection of faces, each used by the shell on one `side', or on both sides; and some edges and vertices.

A shell has the following fields:

- A set of (face, logical) pairs.

  Each pair represents one side of a face (where true indicates the front of the face, i.e. the side towards which the face normal points), and means that the region to which the shell belongs lies on that side of the face. The same face may appear twice in the shell (once with each orientation), in which case the face is a 2-dimensional cut subtracted from the region which owns the shell.

- A set of wireframe edges.

  Edges are called **wireframe** if they do not bound any faces, and so represent 1-dimensional cuts in the shell's region. These edges are not shared by other shells.

- A vertex.

  This is only non-null if the shell is an **acorn** shell, i.e. it represents a 0-dimensional hole in its region, and has one vertex, no edges and no faces.

A shell must contain at least one vertex, edge, or face.

Face

A face is an open finite connected subset of a surface, whose boundary is a collection of edges and vertices. It is the 2-dimensional analogy of a region.

A face has the following fields:

- A set of loops. A face may have zero loops (e.g. a full spherical face), or any number.
- Surface. This may be null, and may be used by other faces.
- Sense. This logical indicates whether the normal to the face is aligned with or opposed to that of the surface.

Loop

A loop is a connected component of the boundary of a face. It is the 2-dimensional analogy of a shell. As such it will be defined by a collection of fins and a collection of vertices.

A loop has the following fields:

- An ordered ring of fins.

  Each fin represents the oriented use of an edge by a loop. The sense of the fin indicates whether the loop direction and the edge direction agree or disagree. A loop may not contain the same edge more than once in each direction.

  The ordering of the fins represents the way in which their owning edges are connected to each other via common vertices in the loop (i.e. nose to tail, taking the sense of each fin into account).

  The loop direction is such that the face is locally on the left of the loop, as seen from above the face and looking in the direction of the loop.

- A vertex.

  This is only non-null if the loop is an **isolated** loop, i.e. has no fins and represents a 0-dimensional hole in the face.

Consequently, a loop must consist either of:

- A single fin whose owning **ring** edge has no vertices, or
- At least one fin and at least one vertex, or
- A single vertex.

Fin

A fin represents the oriented use of an edge by a loop.

A fin has the following fields:

- A logical **sense** indicating whether the fin's orientation (and thus the orientation of its owning loop) is the same as that of its owning edge, or different.
- A curve. This is only non-null if the fin’s edge is tolerant, in which case every fin of that edge will reference a trimmed SP-curve. The underlying surface of the SP-curve must be the same as that of the corresponding face. The curve must not deviate by more than the edge tolerance from curves on other fins of the edge, and its ends must be within vertex tolerance of the corresponding vertices.

Note that fins are referred to as ‘halfedges’ in the Schema file.

Edge

An edge is an open finite connected subset of a curve; its boundary is a collection of zero, one or two vertices. It is the 1-dimensional analogy of a region.

An edge has the following fields:

- Start vertex.
- End vertex. If one vertex is null, then so is the other; the edge will then be called a **ring** edge.
- An ordered ring of distinct fins.

  The ordering of the fins represents the spatial ordering of their owning faces about the edge (with a right-hand screw rule, i.e. looking in the direction of the edge the fin ordering is clockwise). The edge may have zero or any number of fins; if it has none, it is called a **wireframe** edge.
- A curve. This will be null if the edge has a tolerance. Otherwise, the vertices must lie within vertex tolerance of this curve, and if it is a Trimmed Curve, they must lie within vertex tolerance of the corresponding ends of the curve. The curve must also lie in the surfaces of the faces of the edge, to within modeller resolution.
- Sense. This logical indicates whether the direction of the edge (start to end) is the same as that of the curve.
- A tolerance. If this is null-double, the edge is **accurate** and is regarded as having a tolerance of half the modeller linear resolution, otherwise the edge is called **tolerant**.

Vertex

A vertex represents a point in space. It is the 0-dimensional analogy of a region.

A vertex has the following fields:

- A geometric point.
- A tolerance. If this is null-double, the vertex is **accurate** and is regarded as having a tolerance of half the modeller linear resolution.

Attributes

An attribute is an entity which contains data, and which can be attached to any other entity except attributes, fins, lists, transforms or attribute definitions. An attribute has the following fields:

- Definition. An attribute definition is an entity which defines the number and type of the data fields in a specific type of attribute, which entities may have such an

attribute attached, and what happens to the attribute when its owning entity is changed. An XT document must not contain duplicate attribute definitions. Each attribute of a given type should reference the same instance of the attribute definition for that type. It is incorrect, for example, to create a copy of an attribute definition for each instance of the attribute of that type. Only those attribute definitions referenced by attributes in the part occur in the transmit file.

- Owner.
- Fields. These are data fields consisting of one or more integers, doubles, vectors etc.

There are a number of system attribute definitions which Parasolid creates on startup. These are documented in the section `System Attribute Definitions'. Parasolid applications can create user attribute definitions during a Parasolid session. These are transmitted along with any attributes that use them.

Groups

A group is a collection of entities in the same part. Groups in assemblies may contain instances, surfaces, curves and points. Groups in bodies may contain regions, faces, edges, vertices, surfaces, curves and points. Groups have

- Owning part.
- A set of member entities.
- Type. The type of the group specifies the allowed type of its members, e.g. a ‘face’ group in a body may only contain faces, whereas a ‘mixed’ group may have any valid members.

Node-ids

All entities in a part, other than fins, have a non-zero integer node-id which is unique within a part. This is intended to enable the entity to be identified within a transmit file.

Entity matrix

Thus the relations between entities can be represented in matrix form as follows. The numbers represent the number of distinct entities connected (either directly or indirectly) to the given one.

	Body	**Region**	**Shell**	**Face**	**Loop**	**Fin**	**Edge**	**Vertex**
Body	-	>0	any	any	any	any	any	any

Region	1	-	any	any	any	any	any	any
Shell	1	1	-	any	any	any	any	any
Face	1	1-2	1-2	-	any	any	any	any
Loop	1	1-2	1-2	1	-	any	any	any
Fin	1	1-2	1-2	1	1	-	1	0-2
Edge	1	any	any	any	any	any	-	0-2
Vertex	1	any	any	any	any	any	any	-

Representation of manifold bodies

Body types

Parasolid bodies have a field body_type which takes values from an enumeration indicating whether the body is

- **solid**, representing a manifold 3-dimensional volume, possibly with internal voids. It need not be connected.
- **sheet**, representing a 2-dimensional subset of 3-space which is either manifold or manifold with boundary (certain cases are not strictly manifold – see below for details). It need not be connected.
- **wire**, representing a 1-dimensional subset of 3-space which is either manifold or manifold with boundary, and which need not be connected. An **acorn** body, which represents a single 0-dimensional point in space, also has body-type wire.
- **general** - none of the above.

A general body is not necessarily non-manifold, but at the same time it is not constrained to be manifold, connected, or of a particular dimensionality (indeed, it may be of mixed dimensionality).

Restrictions on entity relationships for manifold body types

Solid, sheet, and wire bodies are best regarded as special cases of the topological model; for convenience we call them the manifold body types (although as stated above, a general body may also be manifold).

In particular, bodies of these manifold types must obey the following constraints:

- An acorn body must consist of a single void region with a single shell consisting of a single vertex.

- A wire body must consist of a single void region, with one or more shells, consisting of one or more wireframe edges and zero or more vertices (and no faces). Every vertex in the body must be used by exactly one or two of the edges (so, in particular, there are no acorn vertices).

  So each connected component will be either: closed, where every vertex has exactly two edges; or open, where all but two vertices have exactly two edges each, and the

  A wire is called open if all its components are open, and closed if all its components are closed.

- Solid and sheet bodies must each contain at least one face; they may not contain any wireframe edges or acorn vertices.

- A solid body must consist of at least two regions; at least one of its regions must be solid. Every face in a solid body must have a solid region on its negative side and a void region on its positive side (in other words, every face forms part of the boundary of the solid, and the face normals always point away from the solid).

- Every edge in a solid body must have exactly two fins, which will have opposite senses. Every vertex in a solid body must either belong to a single isolated loop, or belong to one or more edges; in the latter case, the faces which use those edges must form a single edgewise-connected set (when considering only connections via the edges which meet at the vertex).

  These constraints ensure that the solid is manifold.

- All the regions of a sheet body must be void. It is known as an open sheet if it has one region, and a closed sheet if it has no boundary.

- Every edge in a sheet body must have exactly one or two fins; if it has two, these must have opposite senses. In a closed sheet body, all the edges will have exactly two fins. Every vertex in a sheet body must either belong to a single isolated loop, or belong to one or more edges; in the latter case, the faces which use those edges must either form a single edgewise-connected set where all the edges involved have exactly two fins, or any number of edgewise-connected sets, each of which must involve exactly two edges with one fin each (again, considering only connections via the edges which meet at the vertex).

  Note that, although the constraints on edges and vertices in a sheet body are very similar to those which apply to a solid, in this case they do not guarantee that the body will be manifold; indeed, the rather complicated rules about vertices in an open sheet body specifically allow bodies which are non-manifold (such as a body consisting of two square faces which share a single corner vertex, say).

Schema Definition

Underlying types

```
union CURVE_OWNER_u
        {
        struct EDGE_s                   *edge;
        struct FIN_s                    *fin;
        struct BODY_s                   *body;
        struct ASSEMBLY_s               *assembly;
        struct WORLD_s                  *world;
        };

union SURFACE_OWNER_u
        {
        struct FACE_s                   *face;
        struct BODY_s                   *body;
        struct ASSEMBLY_s               *assembly;
        struct WORLD_s                  *world;
        };

union ATTRIB_GROUP_u
        {
        struct ATTRIBUTE_s              *attribute;
        struct GROUP_s                  *group;
        struct                          *member_of_group;
        MEMBER_OF_GROUP_s
        };
```

```
typedef union ATTRIB_GROUP_u  ATTRIB_GROUP;
```

Geometry

```
union CURVE_u
        {
        struct LINE_s                   *line;
        struct CIRCLE_s                 *circle;
        struct ELLIPSE_s                *ellipse;
        struct INTERSECTION_s           *intersection;
        struct TRIMMED_CURVE_s          *trimmed_curve;
        struct PE_CURVE_s               *pe_curve;
        struct B_CURVE_s                *b_curve;
        struct SP_CURVE_s               *sp_curve;
        };
typedef union CURVE_u      CURVE;

union SURFACE_u
        {
        struct PLANE_s                  *plane;
        struct CYLINDER_s               *cylinder;
        struct CONE_s                   *cone;
        struct SPHERE_s                 *sphere;
        struct TORUS_s                  *torus;
        struct BLENDED_EDGE_s           *blended_edge;
        struct BLEND_BOUND_s            *blend_bound;
        struct OFFSET_SURF_s            *offset_surf;
        struct SWEPT_SURF_s             *swept_surf;
```

```
        struct SPUN_SURF_s          *spun_surf;
        struct PE_SURF_s            *pe_surf;
        struct B_SURFACE_s          *b_surface;
        };
typedef union SURFACE_u    SURFACE;

union GEOMETRY_u
        {
        union  SURFACE_u             surface;
        union  CURVE_u               curve;
        struct POINT_s              *point;
        struct TRANSFORM_s          *transform;
        };
typedef union GEOMETRY_u GEOMETRY;
```

Curves

In the following field tables, ‘pointer0’ means a reference to another node which may be null. ‘pointer’ means a non-null reference.

All curve nodes share the following common fields:

Field name	Data type	Description
node_id	int	Integer value unique to curve in part
attributes_groups	pointer0	Attributes and groups associated with curve
owner	pointer0	topological owner
next	pointer0	next curve in geometry chain
previous	pointer0	previous curve in geometry chain
geometric_owner	pointer0	geometric owner node
sense	char	sense of curve: ‘+’ or ‘-’ (see end of Geometry section)

```
struct ANY_CURVE_s          // Any Curve
    {
    int                             node_id;                    // $d
    union  ATTRIB_GROUP_u           attributes_groups;          // $p
    union  CURVE_OWNER_u            owner;                      // $p
    union  CURVE_u                  next;                       // $p
    union  CURVE_u                  previous;                   // $p
    struct                          *geometric_owner;           // $p
    GEOMETRIC_OWNER_s
    char                            sense;                      // $c
    };
typedef struct ANY_CURVE_s *ANY_CURVE;
```

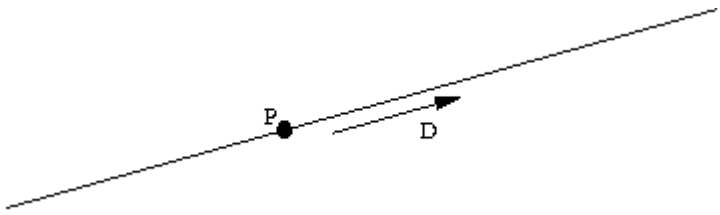
LINE

A straight line has a parametric representation of the form:

$R(t) = P + t D$

where

- P is a point on the line



- D is its direction

Field name	Data type	Description
pvec	vector	point on the line
direction	vector	direction of the line (a unit vector)

```
struct LINE_s == ANY_CURVE_s     // Straight line
        {
        int                             node_id;                // $d
        union  ATTRIB_GROUP_u           attributes_groups;      // $p
        union  CURVE_OWNER_u            owner;                  // $p
        union  CURVE_u                  next;                   // $p
        union  CURVE_u                  previous;               // $p
        struct                          *geometric_ owner;      // $p
        GEOMETRIC_OWNER_s
        char                            sense;                  // $c
        vector                          pvec;                   // $v
        vector                          direction;              // $v
        };
typedef struct LINE_s      *LINE;
```

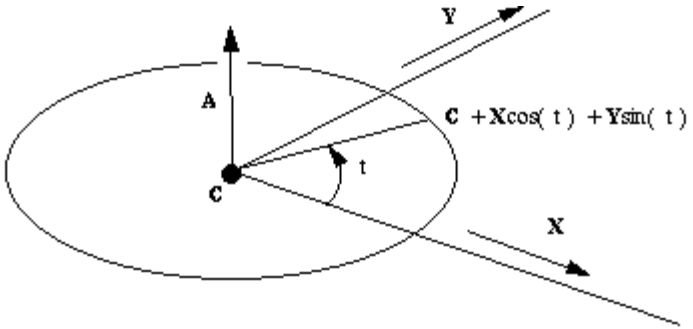
CIRCLE

A circle has a parametric representation of the form

$R(t) = C + r X \cos(t) + r Y \sin(t)$

Where

- C is the centre of the circle
- r is the radius of the circle
- X and Y are the axes in the plane of the circle.



Field name	Data type	Description
centre	vector	Centre of circle
normal	vector	Normal to the plane containing the circle (a unit vector)
x_axis	vector	X axis in the plane of the circle (a unit vector)
radius	double	Radius of circle

The Y axis in the definition above is the vector cross product of the normal and x_axis.

```
struct CIRCLE_s == ANY_CURVE_s                  // Circle
    {
    int                                 node_id;                    // $d
    union  ATTRIB_GROUP_u               attributes_groups;          // $p
    union  CURVE_OWNER_u                owner;                      // $p
    union  CURVE_u                      next;                       // $p
    union  CURVE_u                      previous;                   // $p
    struct                             *geometric_owner;            // $p
    GEOMETRIC_OWNER_s
    char                                sense;                      // $c
    vector                              centre;                     // $v
    vector                              normal;                     // $v
```

```
    vector                  x_axis;                 // $v
    double                  radius;                 // $f
    };
typedef struct CIRCLE_s    *CIRCLE;
```

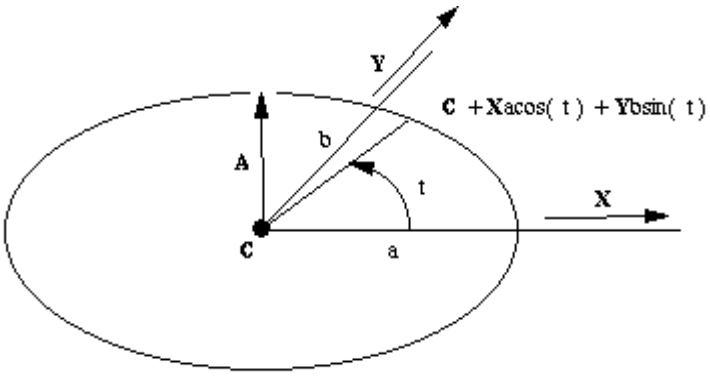
ELLIPSE

An ellipse has a parametric representation of the form

$R(t) = C + a X \cos(t) + b Y \sin(t)$

where

- C is the centre of the circle
- X is the major axis
- r is the major radius



- Y and b are the minor axis and minor radius respectively.

Field name	Data type	Description
centre	Vector	Centre of ellipse
normal	Vector	Normal to the plane containing the ellipse (a unit vector)
x_axis	Vector	major axis in the plane of the ellipse (a unit vector)
major_radius	Double	major radius

minor_radius	Double	minor radius

The minor axis (Y) in the definition above is the vector cross product of the normal and x_axis.

```
struct ELLIPSE_s == ANY_CURVE_s      // Ellipse
      {
      int                              node_id;                  // $d
      union  ATTRIB_GROUP_u            attributes_groups;        // $p
      union  CURVE_OWNER_u             owner;                    // $p
      union  CURVE_u                   next;                     // $p
      union  CURVE_u                   previous;                 // $p
      struct GEOMETRIC_OWNER_s        *geometric_owner;          // $p
      vector                           centre;                   // $v
      char                             sense;                    // $c
      vector                           normal;                   // $v
      vector                           x_axis;                   // $v
      double                           major_radius;             // $f
      double                           minor_radius;             // $f
   };
typedef struct ELLIPSE_s   *ELLIPSE;
```

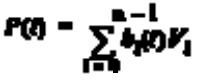
B_CURVE (B-spline curve)

Parasolid supports B spline curves in full NURBS format. The mathematical description of these curves is:

- Non Uniform Rational B-splines as (NURBS)

$$P(t) = \frac{\sum_{i=0}^{n-1} b_i(t) w_i V_i}{\sum_{i=0}^{n-1} b_i(t) w_i}$$

- and the more simple Non Uniform B-spline



Where:

n = number of vertices (n_vertices in the PK standard form)

$V_0 \ldots V_{n-1}$ are the B-spline vertices

$w_0 \ldots w_{n-1}$ are the weights

$b_i\,(t), I = 0 \ldots n\text{-}1$ are the B-spline basis functions

KNOT VECTORS

The parameter t above is global. The user supplies an ordered set of values of t at specific points. The points are called knots and the set of values of t is called the knot vector. Each successive value in the set must be greater than or equal to its predecessor. Where two or more such values are the same we say that the knots are coincident, or that the knot has multiplicity greater than 1. In this case it is best to think of the knot set as containing a null or zero length span. The principal use of coincident knots is to allow the curve to have less continuity at that point than is formally required for a spline. A curve with a knot of multiplicity equal to its *degree* can have a discontinuity of first derivative and hence of tangent direction. This is the highest permitted multiplicity except at the first or last knot where it can go as high as *(degree+1)* .

In order to avoid problems associated, for example with rounding errors in the knot set, Parasolid stores an array of distinct values and an array of integer multiplicities. This is reflected in the standard form used by the PK for input and output of B-curve data.

Most algorithms in the literature, and the following discussion refer to the expanded knot set in which a knot of multiplicity n appears explicitly n times.

THE NUMBER OF KNOTS AND VERTICES

The knot set determines a set of basis functions which are bell shaped, and non zero over a span of *(degree+1)* intervals. One basis function starts at each knot, and each one finishes *(degree +1)* knots higher. The control vectors are the coefficients applied to these basis functions in a linear sum to obtain positions on the curve. Thus it can be seen that we require the number of knots n_knots = n_vertices + degree + 1

THE VALID RANGE OF THE B-CURVE

So if the knot set is numbered $\{t_0$ to $t_{n\_knots-1}\}$ it can be seen then that it is only after t_{degree} that sufficient (*degree + 1*) basis functions are present for the curve to be fully defined, and that the B-curve ceases to be fully defined after $t_{n\_knots - 1 - degree}$.

The first *degree* knots and the last *degree* knots are known as the imaginary knots because their parameter values are outside the defined range of the B-curve.

PERIODIC B-CURVES

When the end of a B-curve meets its start sufficiently smoothly Parasolid allows it to be defined to have periodic parametrisation. That is to say that if the valid range were from t_{degree} to $t_{n\_knots - 1 - degree}$ then the difference between these values is called the period and the curve can continue to be evaluated with the same point reoccurring every period.

The minimal smoothness requirement for periodic curves in Parasolid is tangent continuity, but we strongly recommend $C_{degree-1}$, or continuity in the $(degree-1)^{th}$ derivative. This in turn is best achieved by repeating the first *degree* vertices at the end, and by matching knot intervals so that counting from the start of the defined range, t_{degree}, the first *degree* intervals between knots match the last *degree* intervals, and similarly matching the last *degree* knot intervals before the end of the defined range to the first *degree* intervals.

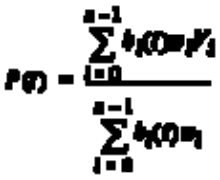
CLOSED B-CURVES

A periodic B-curve must also be closed, but is permitted to have a closed Bcurve that is not periodic.

In this case the rules for continuity are relaxed so that only C_0 or positional continuity is required between the start and end. Such closed non-periodic curves are not able to be attached to topology.

RATIONAL B-CURVE

In the rational form of the curve, each vertex is associated with a weight, which increases or decreases the effect of the vertex without changing the curve hull. To ensure that the convex hull property is retained, the curve equation is divided by a denominator which makes the coefficients of the vertices sum to one.

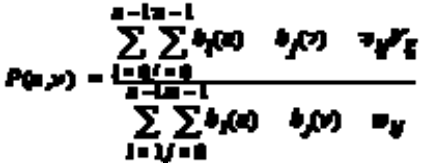


Where $w_0 \ldots w_{n-1}$ are weights.

Each weight may take any positive value, and the larger the value, the greater the effect of the associated vertex. However, it is the relative sizes of the weights which is important, as may be seen from the fact that in the equation given above, all the weights may be multiplied by a constant without changing the equation.

In Parasolid the weights are stored with the vertices by treating these as having an extra dimension. In the usual case of a curve in 3-d cartesian space this means that vertex_dim is 4, the x, y, z values are multiplied through by the corresponding weight and the 4th value is the weight itself.

B-SURFACE DEFINITION



The B-surface definition is best thought of as an extension of the B-curve definition into two parameters, usually called u and v. Two knot sets are required and the number of control vertices is the product of the number that would be required for a curve using each knot vector. The rules for periodicity and closure given above for curves are extended to surfaces in an obvious way.

For attachment to topology a B-surface is required to have G_1 continuity. That is to say that the surface normal direction must be continuous.

Parasolid does not support modelling with surfaces that are self-intersecting or contain cusps. Although they can be created they are not permitted to be attached to topology.

Field name	Data type	Description
nurbs	Pointer	Geometric definition
data	Pointer0	Auxiliary information

```
struct B_CURVE_s == ANY_CURVE_s                 // B curve
    {
    int                             node_id;                    // $d
    union  ATTRIB_GROUP_u           attributes_groups;          // $p
    union  CURVE_OWNER_u            owner;                      // $p
    union  CURVE_u                  next;                       // $p
    union  CURVE_u                  previous;                   // $p
    struct GEOMETRIC_OWNER_s        *geometric_owner;           // $p
    char                            sense;                      // $c
```

```
    struct NURBS_CURVE_s        *nurbs;                 // $p
    struct CURVE_DATA_s         *data;                  // $p
    };
typedef struct B_CURVE_s    *B_CURVE;
```

The data stored in an XT file for a NURBS_CURVE is

Field name	Data type	Description
degree	Short	degree of the curve
n_vertices	Int	number of control vertices (‘poles’)
vertex_dim	Short	dimension of control vertices
n_knots	Int	number of distinct knots
knot_type	Byte	form of knot vector
periodic	Logical	true if curve is periodic
closed	Logical	true if curve is closed
rational	Logical	true if curve is rational
curve_form	Byte	shape of curve, if special
bspline_vertices	Pointer	control vertices node
knot_mult	Pointer	knot multiplicities node
knots	Pointer	knots node

The knot_type enum is used to describe whether or not the knot vector has a certain regular spacing or other common property:

```
typedef enum
    {
    SCH_unset = 1,              // Unknown
    SCH_non_uniform = 2,        // Known to be not special
    SCH_uniform = 3,            // Uniform knot set
    SCH_quasi_uniform = 4,      // Uniform apart from bezier ends
```

```
    SCH_piecewise_bezier = 5,        // Internal multiplicity of order-1
    SCH_bezier_ends = 6              // Bezier ends, no other property
    }
  SCH_knot_type_t;
```

A uniform knot set is one where all the knots are of multiplicity one and are equally spaced. A curve has bezier ends if the first and last knots both have multiplicity ‘order’.

The curve_form enum describes the geometric shape of the curve. The parameterisation of the curve is not relevant.

```
typedef enum
    {
    SCH_unset        = 1,        // Form is not known
    SCH_arbitrary    = 2,        // Known to be of no particular shape
    SCH_polyline     = 3,
    SCH_circular_arc  = 4,
    SCH_elliptic_arc  = 5,
    SCH_parabolic_arc  = 6,
    SCH_hyperbolic_arc = 7
    }
  SCH_curve_form_t;


struct NURBS_CURVE_s                 // NURBS curve
    {
    short                    degree;          // $n
    int                      n_vertices;      // $d
    short                    vertex_dim;      // $n
    int                      n_knots;         // $d
    SCH_knot_type_t          knot_type;       // $u
    logical                  periodic;        // $l
```

```
    logical                         closed;                 // $l
    logical                         rational;               // $l
    SCH_curve_form_t                curve_form;             // $u
    struct BSPLINE_VERTICES_s       *bspline_vertices;      // $p
    struct KNOT_MULT_s              *knot_mult;             // $p
    struct KNOT_SET_s               *knots;                 // $p
    };
typedef struct NURBS_CURVE_s *NURBS_CURVE;
```

The bspline vertices node is simply an array of doubles; ‘vertex_dim’ doubles together define one control vertex. Thus the length of the array is n_vertices * vertex_dim.

```
struct BSPLINE_VERTICES_s           // B-spline vertices
    {
    double                      vertices[ 1 ];          // $f[]
    };
typedef struct BSPLINE_VERTICES_s *BSPLINE_VERTICES;
```

The knot vector of the NURBS _CURVE is stored as an array of distinct knots and an array describing the multiplicity of each distinct knot. Hence the two nodes

```
struct KNOT_SET_s                       // Knot set
    {
    double                      knots[ 1 ];             // $f[]
    };
typedef struct KNOT_SET_s *KNOT_SET;
```

and

```
struct KNOT_MULT_s                      // Knot multiplicities
    {
    short                       mult[ 1 ];              // $n[]
    };
typedef struct KNOT_MULT_s *KNOT_MULT;
```

The data stored in an XT file for a CURVE_DATA node is:

```
typedef enum
    {
    SCH_unset = 1,                          // check has not been performed
    SCH_no_self_intersections = 2,          // passed checks
    SCH_self_intersects = 3,                // fails checks
    SCH_checked_ok_in_old_version = 4       // see below
    }
  SCH_self_int_t;


struct CURVE_DATA_s                 // curve_data
    {
    SCH_self_int_t                  self_int;                   // $u
    Struct HELIX_CU_FORM_s          *analytic_form              // $p
    };
typedef struct CURVE_DATA_s *CURVE_DATA;
```

The self-intersection enum describes whether or not the geometry has been checked for self-intersections, and whether such self-intersections were found to exist:

The SCH_checked_ok_in_old_version enum indicates that the self-intersection check has been performed by a Parasolid version 5 or earlier but not since.

If the analytic_form field is not null, it will point to a HELIX_CU_FORM node, which indicates that the curve has a helical shape, as follows:

```
struct HELIX_CU_FORM_s
    {
    vector                          axis_pt                     // $v
    vector                          axis_dir                    // $v
    vector                          point                       // $v
    char                            hand                        // $c
    interval                        turns                       // $i
```

```
double          pitch           // $f
double          tol             // $f
};
typedef struct HELIX_CU_FORM_s *HELIX_CU_FORM;
```

The axis_pt and axis_dir fields define the axis of the helix. The hand field is '+' for a right-handed and '-' for a left-handed helix. A representative point on the helix is at turn position zero. The turns field gives the extent of the helix relative to the point. For instance, an interval [0 10] indicates a start position at the point and an end 10 turns along the axis. Pitch is the distance travelled along the axis in one turn. Tol is the accuracy to which the owning bcurve fits this specification.

INTERSECTION

An intersection curve is one of the branches of a surface / surface intersection. Parasolid represents these curves exactly; the information held in an intersection curve node is sufficient to identify the particular intersection branch involved, to identify the behavior of the curve at its ends, and to evaluate precisely at any point in the curve. Specifically, the data is:

- The two surfaces involved in the intersection.
- The two ends of the intersection curve. These are referred to as the 'limits' of the curve. They identify the particular branch involved.
- An ordered array of points along the curve. This array is referred to as the 'chart' of the curve. It defines the parameterization of the curve, which increases as the array index increases.

The natural tangent to the curve at any point (i.e. in the increasing parameter direction) is given by the vector cross-product of the surface normals at that point, taking into account the senses of the surfaces.

Singular points where the cross-product of the surface normals is zero, or where one of the surfaces is degenerate, are called terminators. Intersection curves do not contain terminators in their interior. At terminators, the tangent to the curve is defined by the limit of the curve tangent as the curve parameter approaches the terminating value.

Field name	Data type	Description
Surface	pointer array [2]	Surfaces of intersection curve
chart	Pointer	array of hvecs on the curve – see below
start	Pointer	start limit of the curve
end	Pointer	end limit of the curve

```
struct INTERSECTION_s == ANY_CURVE_s                    // Intersection
    {
    int                                 node_id;                    // $d
    union  ATTRIB_GROUP_u               attributes_groups;          // $p
    union  CURVE_OWNER_u                owner;                      // $p
    union  CURVE_u                      next;                       // $p
    union  CURVE_u                      previous;                   // $p
    struct GEOMETRIC_OWNER_s           *geometric_owner;            // $p
    char                                sense;                      // $c
    union  SURFACE_u                    surface[ 2 ];               // $p[2]
    struct CHART_s                     *chart;                      // $p
    struct LIMIT_s                     *start;                      // $p
    struct LIMIT_s                     *end;                        // $p
    };
typedef struct INTERSECTION_s  *INTERSECTION;
```

A point on an intersection curve is stored in a data structure called an ‘hvec’ (hepta-vec, or 7-vector):

```
typedef struct hvec_s           // hepta_vec
    {
    vector          Pvec;               // position
    double          u[2];               // surface parameters
    double          v[2];
```

```
vector          Tangent;        // curve tangent
double          t;              // curve parameter
} hvec;
```

where

- pvec is a point common to both surfaces
- u[] and v[] are the u and v parameters of the pvec on each of the surfaces.
- tangent is the tangent to the curve at pvec. This will be equal to the (normalised) vector cross product of the surface normals at pvec, when this cross product is non-zero. These surface normals take account of the surface sense fields.
- t is the parameter of the pvec on the curve

Note that only the pvec part of an hvec is actually transmitted.

The chart data structure essentially describes a piecewise-linear (chordal) approximation to the true curve. As well as containing the ordered array of hvecs defining this approximation, it contains extra information pertaining to the accuracy of the approximation:

```
struct CHART_s                  // Chart
    {
    double      Base_parameter;     // $f
    double      Base_scale;         // $f
    int         Chart_count;        // $d
    double      Chordal_error;      // $f
    double      Angular_error;      // $f
    double      Parameter_error[2]; // $f[2]
    hvec        Hvec[ 1 ];          // $h[]
    };
```

where

- base_parameter is the parameter of the first hvec in the chart
- base_scale determines the scale of the parameterisation (see below)
- chart_count is the length of the hvec array

- chordal_error is an estimate of the maximum deviation of the curve from the piecewise-linear approximation given by the hvec array. It may be null.
- angular_error is the maximum angle between the tangents of two sequential hvecs. It may be null.
- parameter_error[] is always [null, null].
- hvec[] is the ordered array of hvecs.

The limits of the intersection curve are stored in the following data structure:

```
struct LIMIT_s                  // Limit
    {
    char                        type;                   // $c
    hvec                        hvec[ 1 ];              // $h[]
    };
```

The ‘type’ field may take one of the following values

```
const char SCH_help         = 'H';          // help hvec
const char SCH_terminator       = 'T';      // terminator
const char SCH_limit        = 'L';          // arbitrary limit
const char SCH_boundary         = 'B';      // spine boundary
```

The length of the hvec array depends on the type of the limit.

- a SCH_help limit is an arbitrary point on a closed intersection curve. There will be one hvec in the hvec array, locating the curve.
- a SCH_terminator limit is a point where one of the surface normals is degenerate, or where their cross-product is zero. Typically, there will be more than one branch of intersection between the two surfaces at these singularities. Ther will be two values in the hvec array. The first will be the exact position of the singularity, and the second will be a point on the curve a small distance away from the terminator. This ‘branch point’ identifies which branch relates to the curve in question. The branch point is the one which appears in the chart, at the corresponding end – so the singularity lies just outside the parameter range of the chart.
- a SCH_limit limit is an artificial boundary of an intersection curve on an otherwise potentially infinite branch. The single hvec describes the end of the curve.

- a SCH_boundary limit is used to describe the end of a degenerate rolling-ball blend. It is not relevant to intersection curves.

The parameterization of the curve is given as follows. If the chart points are P_i, i = 0 to n, with parameters t_i, and natural tangent vectors T_i, then define

$$C_i = | P_{i+1} - P_i |$$

$$\cos(a_i) = T_i \,.\, (P_{i+1} - P_i)$$

$$\cos(b_i) = T_i \,.\, (P_i - P_{i-1})$$

Then at any chart point P_i the angles a_i and b_i are the deviations between the tangent at the chart point and the next and previous chords respectively.

Let f_0 = base_scale

$$f_i = (\cos(b_i) / \cos(a_i)) f_{i-1}$$

Then t_0 = base_parameter

$$t_i = t_{i-1} + C_{i-1} f_{i-1}$$

The parameter of a point between two chart points is given by projecting the point onto the tangent line at the previous chart point. The factors f_i are chosen so that the parameterization is C_1.

TRIMMED_CURVE

A trimmed curve is a bounded region of another curve, referred to as its basis curve. It is defined by the basis curve and two points and their corresponding parameters. Trimmed curves are most commonly attached to fins (fins) of tolerant edges in order to specify which portion of the underlying basis curve corresponds to the tolerant edge. They are necessary since the tolerant vertices of the edge do not necessarily lie exactly on the basis curve; the 'point' fields of the trimmed curve lie exactly on the basis curve, and within tolerance of the relevant vertex.

The rules governing the parameter fields and points are:

- point_1 and point_2 correspond to parm_1 and parm_2 respectively.
- If the basis curve has positive sense, parm_2 > parm_1.
- If the basis curve has negative sense, parm_2 < parm_1.

In addition,

For open basis curves.

- Both parm_1 and parm_2 must be in the parameter range of the basis curve.
- point_1 and point_2 must not be equal.

For periodic basis curves

- parm_1 must lie in the base range of the basis curve.
- If the whole basis curve is required then parm_1 and parm_2 should be a period apart and point_1 = point_2. Equality of parm_1 and parm_2 is not permitted.
- parm_1 and parm_2 must not be more than a period apart.

For closed but non-periodic basis curves

- Both parm_1 and parm_2 must be in the parameter range of the basis curve.
- If the whole of the basis curve is required, parm_1 and parm_2 must lie close enough to each end of the valid parameter range in order that point_1 and point_2 are coincident to Parasolid tolerance (1.0e-8 by default).

The sense of a trimmed curve is positive.

Field name	Data type	Description
basis_curve	pointer	Basis curve
point_1	vector	start of trimmed portion
point_2	vector	end of trimmed portion
parm_1	double	parameter on basis curve corresponding to point_1
parm_2	double	parameter on basis curve corresponding to point_2

```
struct TRIMMED_CURVE_s == ANY_CURVE_s          // Trimmed Curve
    {
    int                              node_id;              // $d
    union  ATTRIB_GROUP_u            attributes_groups;    // $p
    union  CURVE_OWNER_u             owner;                // $p
    union  CURVE_u                   next;                 // $p
    union  CURVE_u                   previous;             // $p
    struct GEOMETRIC_OWNER_s        *geometric_owner;      // $p
    char                             sense;                // $c
    union  CURVE_u                   basis_curve;          // $p
```

```
    vector                  point_1;                // $v
    vector                  point_2;                // $v
    double                  parm_1;                 // $f
    double                  parm_2;                 // $f
    };
typedef struct TRIMMED_CURVE_s      *TRIMMED_CURVE;
```

PE_CURVE (Foreign Geometry curve)

Foreign geometry in Parasolid is a type used for representing customers' in-house proprietary data. It is also known as PE (parametrically evaluated) geometry. It can also be used internally for representing geometry connected with this data (for example, offsets of foreign surfaces). These two types of foreign geometry usage are referred to as 'external' and 'internal' PE data respectively. Internal PE curves are not used at present.

Applications not using foreign geometry will never encounter either external or internal PE data structures at Parasolid V9 or beyond.

Field name	Data type	Description
type	char	whether internal or external
data	pointer	internal or external data
tf	pointer0	transform applied to geometry
internal geom	pointer array	reference to other related geometry

```
union PE_DATA_u                         // PE_data_u
    {
    struct EXT_PE_DATA_s        *external;          // $p
    struct INT_PE_DATA_s        *internal;          // $p
    };
typedef union PE_DATA_u PE_DATA;
```

The PE internal geometry union defined below is used by internal foreign geometry only.

```
union PE_INT_GEOM_u
```

```
	{
	union SURFACE_u		surface;		// $p
	union CURVE_u		curve;			// $p
	};
typedef union PE_INT_GEOM_u PE_INT_GEOM;

struct PE_CURVE_s == ANY_CURVE_s		// PE_curve
	{
	int				node_id;		// $d
	union  ATTRIB_GROUP_u		attributes_groups;	// $p
	union  CURVE_OWNER_u		owner;			// $p
	union  CURVE_u			next;			// $p
	union  CURVE_u			previous;		// $p
	struct GEOMETRIC_OWNER_s	*geometric_owner;	// $p
	char				sense;			// $c
	char				type;			// $c
	union  PE_DATA_u		data;			// $p
	struct TRANSFORM_s		*tf;			// $p
	union  PE_INT_GEOM_u		internal_geom[ 1 ];	// $p[]
	};
typedef struct PE_CURVE_s	*PE_CURVE;
```

The type of the foreign geometry (whether internal or external) is identified in the PE curve node by means of the char ‘type’ field, taking one of the values

```
	const char SCH_external  = 'E';		// external PE geometry
	const char SCH_interna   = 'I';		// internal PE geometry
```

The PE_data union is used in a PE curve or surface node to identify the internal or external evaluator corresponding to the geometry, and also holds an array of real and/or integer parameters to be passed to the evaluator. The data stored corresponds exactly to that passed to the PK routine PK_FSURF_create when the geometry is created.

```
struct EXT_PE_DATA_s                // ext_PE_data
    {
    struct KEY_s                    *key;                   // $p
    struct REAL_VALUES_s            *real_array;            // $p
    struct INT_VALUES_s             *int_array;             // $p
    };
typedef struct EXT_PE_DATA_s *EXT_PE_DATA;


struct INT_PE_DATA_s                // int_PE_data
    {
    int                             geom_type;              // $d
    struct REAL_VALUES_s            *real_array;            // $p
    struct INT_VALUES_s             *int_array;             // $p
    };
typedef struct INT_PE_DATA_s *INT_PE_DATA;
```

The only internal pe type in use at the moment is the offset PE surface, for which the geom_type is 2.

SP_CURVE

An SP curve is the 3D curve resulting from embedding a 2D curve in the parameter space of a surface.

The 2D curve must be a 2D BCURVE; that is it must either be a rational B curve with a vertex dimensionality of 3, or a non-rational B curve with a vertex dimensionality of 2.

Field name	Data type	Description
surface	pointer	surface
b_curve	pointer	2D Bcurve

original	pointer0	not used
tolerance_to_original	double	not used

```
struct   SP_CURVE_s == ANY_CURVE_s              // SP curve
      {
      int                              node_id;                  // $d
      union  ATTRIB_GROUP_u            attributes_groups;        // $p
      union  CURVE_OWNER_u             owner;                    // $p
      union  CURVE_u                   next;                     // $p
      union  CURVE_u                   previous;                 // $p
      struct                           *geometric_owner;         // $p
      GEOMETRIC_OWNER_s
      char                             sense;                    // $c
      union  SURFACE_u                 surface;                  // $p
      struct B_CURVE_s                 *b_curve;                 // $p
      union  CURVE_u                   original;                 // $p
      double                           tolerance_to_original;    // $f
      };
typedef struct SP_CURVE_s   *SP_CURVE;
```

Surfaces

All surface nodes share the following common fields:

Field name	Data type	Description
node_id	int	Integer value unique to surface in part
attributes_groups	pointer0	Attributes and groups associated with surface
owner	pointer	topological owner
next	pointer0	next surface in geometry chain
previous	pointer0	previous surface in geometry chain

geometric_owner	pointer0	geometric owner node
sense	char	sense of surface: '+' or '-'(see end of Geometry section)

```
struct ANY_SURF_s                    // Any Surface
    {
    int                              node_id;                  // $d
    union  ATTRIB_GROUP_u            attributes_groups;        // $p
    union  SURFACE_OWNER_u           owner;                    // $p
    union  SURFACE_u                 next;                     // $p
    union  SURFACE_u                 previous;                 // $p
    struct GEOMETRIC_OWNER_s         *geometric_owner;         // $p
    char                             sense;                    // $c
    };
typedef struct ANY_SURF_s  *ANY_SURF;
```

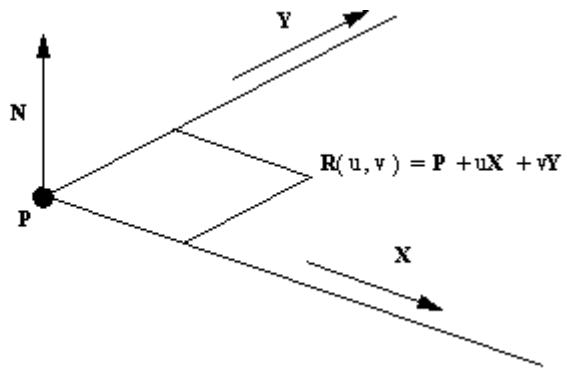
PLANE

A plane has a parametric representation of the form

$R(u, v) = P + uX + vY$

where

- P is a point on the plan



- X and Y are axes in the plane.

Field name	Data type	Description
pvec	vector	point on the plane
normal	vector	normal to the plane (a unit vector)
x_axis	vector	X axis of the plane (a unit vector)

The Y axis in the definition above is the vector cross product of the normal and x_axis.

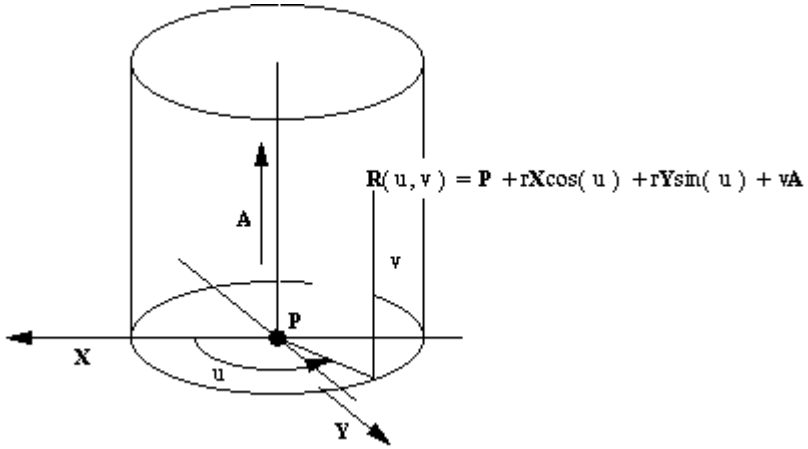
```
struct PLANE_s == ANY_SURF_s                    // Plane
        {
        int                                     node_id;                        // $d
        union  ATTRIB_GROUP_u                   attributes_groups;              // $p
        union  SURFACE_OWNER_u                  owner;                          // $p
        union  SURFACE_u                        next;                           // $p
        union  SURFACE_u                        previous;                       // $p
        struct                                  *geometric_owner;               // $p
        GEOMETRIC_OWNER_s
        char                                    sense;                          // $c
        vector                                  pvec;                           // $v
        vector                                  normal;                         // $v
        vector                                  x_axis;                         // $v
        };
typedef struct PLANE_s      *PLANE;
```

CYLINDER

A cylinder has a parametric representation of the form:

$R(u,v) = P + rXcos(u) + rYsin(u) + vA$

where



- P is a point on the cylinder axis
- r is the cylinder radius
- A is the cylinder axis
- X and Y are unit vectors such that A, X and Y form an orthonormal set

Field name	Data type	Description
pvec	vector	point on the cylinder axis
axis	vector	direction of the cylinder axis (a unit vector)
radius	double	radius of cylinder
x_axis	vector	X axis of the cylinder (a unit vector)

The Y axis in the definition above is the vector cross product of the axis and x_axis.

```
struct CYLINDER_s == ANY_SURF_s                 // Cylinder
    {
    int                             node_id;                        // $d
    union  ATTRIB_GROUP_u           attributes_groups;              // $p
```

```
union  SURFACE_OWNER_u        owner;              // $p
union  SURFACE_u              next;               // $p
union  SURFACE_u              previous;           // $p
struct GEOMETRIC_OWNER_s     *geometric_owner;    // $p
char                          sense;              // $c
vector                        pvec;               // $v
vector                        axis;               // $v
double                        radius;             // $f
vector                        x_axis;             // $v
};
typedef struct CYLINDER_s  *CYLINDER;
```

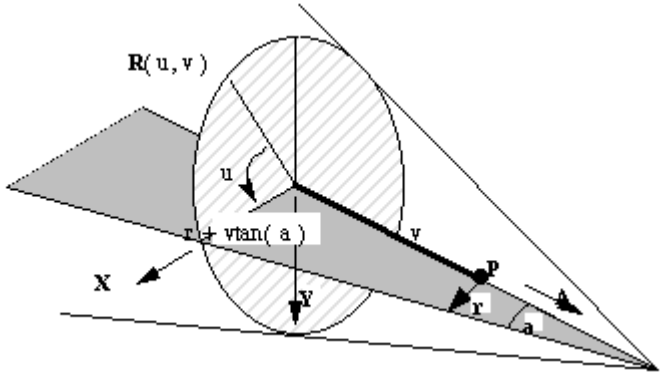
CONE

A cone in Parasolid is only half of a mathematical cone. By convention, the cone axis points away from the half of the cone in use. A cone has a parametric representation of the form:

$R(u, v) = P - vA + (Xcos(u) + Ysin(u))(r + vtan(a))$

where

- P is a point on the cone axis
- r is the cone radius at the point P
- A is the cone axis
- X and Y are unit vectors such that A, X and Y form an orthonormal set, i.e. Y = A x X.
- a is the cone half angle.



Field name	Data type	Description
pvec	vector	point on the cone axis
axis	vector	direction of the cone axis (a unit vector)
radius	double	radius of the cone at its pvec
sin_half_angle	double	sine of the cone's half angle
cos_half_angle	double	cosine of the cone's half angle
x_axis	vector	X axis of the cone (a unit vector)

The Y axis in the definition above is the vector cross product of the axis and x_axis.

```
struct CONE_s == ANY_SURF_s                    // Cone
    {
    int                                node_id;                    // $d
    union  ATTRIB_GROUP_u              attributes_groups;          // $p
    union  SURFACE_OWNER_u             owner;                      // $p
    union  SURFACE_u                   next;                       // $p
    union  SURFACE_u                   previous;                   // $p
    struct GEOMETRIC_OWNER_s           *geometric_owner;           // $p
    char                               sense;                      // $c
    vector                             pvec;                       // $v
    vector                             axis;                       // $v
    double                             radius;                     // $f
    double                             sin_half_angle;             // $f
    double                             cos_half_angle;             // $f
    vector                             x_axis;                     // $v
    };
typedef struct CONE_s      *CONE;
```

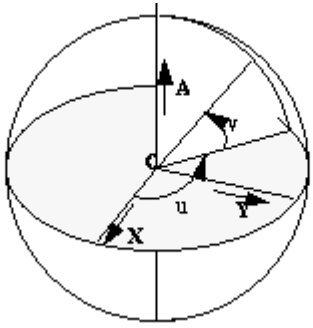
SPHERE

A sphere has a parametric representation of the form:

R(u, v) = C + (Xcos(u) + Ysin(u)) rcos(v) + rAsin(v)

where

- C is centre of the sphere
- r is the sphere radius



- A, X and Y form an orthonormal axis set.

Field name	Data type	Description
centre	vector	centre of the sphere
radius	double	radius of the sphere
axis	vector	A axis of the sphere (a unit vector)
x_axis	vector	X axis of the sphere (a unit vector)

The Y axis of the sphere is the vector cross product of its A and X axes.

```
struct SPHERE_s == ANY_SURF_s                    // Sphere
    {
    int                              node_id;                              // $d
    union  ATTRIB_GROUP_u            attributes_groups;                    // $p
```

```
    union  SURFACE_OWNER_u      owner;                  // $p
    union  SURFACE_u            next;                   // $p
    union  SURFACE_u            previous;               // $p
    struct                      *geometric_owner;       // $p
    GEOMETRIC_OWNER_s
    char                        sense;                  // $c
    vector                      centre;                 // $v
    double                      radius;                 // $f
    vector                      axis;                   // $v
    vector                      x_axis;                 // $v
    };
typedef struct SPHERE_s    *SPHERE;
```

TORUS

A torus has a parametric representation of the form

$R(u, v) = C + (X \cos(u) + Y \sin(u))(a + b \cos(v)) + b A \sin(v)$

where

- C is center of the torus
- A is the torus axis
- a is the major radius
- b is the minor radius
- X and Y are unit vectors such that A, X and Y form an orthonormal set.

In Parasolid, there are three types of torus:

Doughnut - the torus is not self-intersecting ($a > b$)

Apple - the outer part of a self-intersecting torus ($a <= b$, $a > 0$)

Lemon - the inner part of a self-intersecting torus ($a < 0$, $|a| < b$)

The limiting case a = b is allowed; it is called an ‘osculating apple’, but there is no ‘lemon’ surface corresponding to this case.

The limiting case a = 0 cannot be represented as a torus; this is a sphere.

Field name	Data type	Description
centre	vector	centre of the torus
axis	vector	axis of the torus (a unit vector)
major_radius	double	major radius
minor_radius	double	minor radius
x_axis	vector	X axis of the torus (a unit vector)

The Y axis in the definition above is the vector cross product of the axis of the torus and the x_axis.

```
struct TORUS_s == ANY_SURF_s                    // Torus
      {
         int                                node_id;                  // $d
      union  ATTRIB_GROUP_u                 attributes_groups;        // $p
      union  SURFACE_OWNER_u                owner;                    // $p
      union  SURFACE_u                      next;                     // $p
      union  SURFACE_u                      previous;                 // $p
      struct GEOMETRIC_OWNER_s             *geometric_owner;          // $p
      char                                  sense;                    // $c
      vector                                centre;                   // $v
      vector                                axis;                     // $v
      double                                major_radius;             // $f
      double                                minor_radius;             // $f
      vector                                x_axis;                   // $v
      };

typedef struct TORUS_s     *TORUS;
```

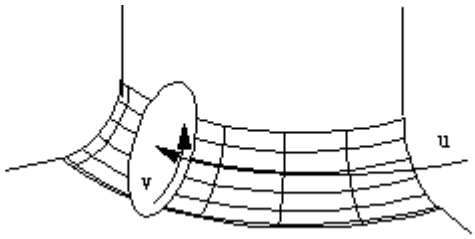
BLENDED_EDGE (Rolling Ball Blend)

Parasolid supports exact rolling ball blends. They have a parametric representation of the form

R(u, v) = C(u) + rX(u)cos(v a(u)) + rY(u)sin(va(u))

where

- C(u) is the spine curve
- r is the blend radius
- X(u) and Y(u) are unit vectors such that C'(u) . X(u) = C'(u) . Y(u) = 0
- a(u) is the angle subtended by points on the boundary curves at the spine



X, Y and a are expressed as functions of u, as their values change with u.

The spine of the rolling ball blend is the center line of the blend; i.e. the path along which the center of the ball moves.

Field name	Data type	Description
type	char	type of blend: 'R' or 'E'
surface	pointer[2]	supporting surfaces (adjacent to original edge)
spine	pointer	spine of blend
range	double[2]	offsets to be applied to surfaces
thumb_weight	double[2]	always [1,1]
boundary	pointer0[2]	always [0, 0]
start	pointer0	Start LIMIT in certain degenerate cases
end	pointer0	End LIMIT in certain degenerate cases

```
struct BLENDED_EDGE_s == ANY_SURF_s                    // Blended edge
    {
    int                                node_id;                    // $d
    union  ATTRIB_GROUP_u              attributes_groups;          // $p
    union  SURFACE_OWNER_u             owner;                      // $p
    union  SURFACE_u                   next;                       // $p
    union  SURFACE_u                   previous;                   // $p
    struct                            *geometric_owner;            // $p
    GEOMETRIC_OWNER_s
    char                               sense;                      // $c
    char                               blend_type;                 // $c
    union  SURFACE_u                   surface[2];                 // $p[2]
    union  CURVE_u                     spine;                      // $p
    double                             range[2];                   // $f[2]
    double                             thumb_weight[2];            // $f[2]
    union  SURFACE_u                   boundary[2];                // $p[2]
    struct LIMIT_s                    *start;                      // $p
    struct LIMIT_s                    *end;                        // $p
    };
typedef struct BLENDED_EDGE_s *BLENDED_EDGE;
```

.

The parameterisation of the blend is as follows. The u parameter is inherited from the spine, the constant u lines being circles perpendicular to the spine curve. The v parameter is zero at the blend boundary on the first surface, and one on the blend boundary on the second surface; unless the sense of the spine curve is negative, in which case it is the other way round. The v parameter is proportional to the angle around the circle.

Transmit files can contain blends of the following types:

```
const char SCH_rolling_ball = 'R';          //  rolling ball blend
const char SCH_cliff_edge   = 'E';          //  cliff edge blend
```

For rolling ball blends, the spine curve will be the intersection of the two surfaces obtained by offsetting the supporting surfaces by an amount given by the respective entry in range[]. Note that the offsets to be applied may be positive or negative, and that the sense of the surface is significant; i.e. the offset vector is the natural unit surface normal, times the range, times –1 if the sense is negative.

For cliff edge blends, one of the surfaces will be a blended_edge with a range of [0,0]; its spine will be the cliff edge curve, and its supporting surfaces will be the surfaces of the faces adjacent to the cliff edge. Its type will be R.

The limit fields will only be non-null if the spine curve is periodic but the edge curve being blended has terminators – for example if the spine is elliptical but the blend degenerates. In this case the two LIMIT nodes, of type ‘L’, determine the extent of the spine.

BLEND_BOUND (Blend boundary surface)

A blend_bound surface is a construction surface, used to define the boundary curve where a blend becomes tangential to its supporting surface. It is an implicit surface defined internally so that it intersects one of the supporting surfaces along the boundary curve. It is orthogonal to the blend and the supporting surface along this boundary curve. Since the actual shape of the surface is not significant for the blend geometry, it is not described here.

Blend boundary surfaces are most commonly referenced by the intersection curve representing the boundary curve of the blend.

The data stored in an XT file for a blend_bound is only that necessary to identify the relevant blend and supporting surface:

Field name	Data type	Description
boundary	short	index into supporting surface array
blend	pointer	corresponding blend surface

```
struct BLEND_BOUND_s == ANY_SURF_s          // Blend boundary
    {
    int                                 node_id;                    // $d
    union  ATTRIB_GROUP_u               attributes_groups;          // $p
    union  SURFACE_OWNER_u              owner;                      // $p
    union  SURFACE_u                    next;                       // $p
    union  SURFACE_u                    previous;                   // $p
    struct                             *geometric_owner;            // $p
    GEOMETRIC_OWNER_s
    char                                sense;                      // $c
    short                               boundary;                   // $n
    union  SURFACE_u                    blend;                      // $p
    };
typedef struct BLEND_BOUND_s  *BLEND_BOUND;
```

The supporting surface corresponding to the blend_bound is

blend_bound->blend.blended_edge->surface[1 - blend_bound->boundary].

OFFSET_SURF

An offset surface is the result of offsetting a surface a certain distance along its normal, taking into account the surface sense. It inherits the parameterization of this underlying surface.

Field name	Data type	Description
check	char	check status

true_offset	logical	not used
surface	pointer	underlying surface
offset	double	signed offset distance
scale	double	for internal use only – may be set to null

```
struct OFFSET_SURF_s == ANY_SURF_s       // Offset surface
      {
      int                                node_id;                  // $d
      union  ATTRIB_GROUP_u              attributes_groups;        // $p
      union  SURFACE_OWNER_u             owner;                    // $p
      union  SURFACE_u                   next;                     // $p
      union  SURFACE_u                   previous;                 // $p
      struct GEOMETRIC_OWNER_s           *geometric_owner;         // $p
      char                               sense;                    // $c
      char                               check;                    // $c
      logical                            true_offset;              // $l
      union  SURFACE_u                   surface;                  // $p
      double                             offset;                   // $f
      double                             scale;                    // $f
      };
typedef struct OFFSET_SURF_s    *OFFSET_SURF;
```

The offset surface is subject to the following restrictions:

- The offset distance must not be within modeller linear resolution of zero
- The sense of the offset surface must be the same as that of the underlying surface
- Offset surfaces may not share a common underlying surface

The ‘check’ field may take one of the following values:

```
const char SCH_valid      = 'V';          // valid
const char SCH_invalid    = 'I';          // invalid
const char SCH_unchecked  = 'U';          // has not been checked
```

B_SURFACE

Parasolid supports B spline curves in full NURBS format.

Field name	Data type	Description
nurbs	pointer	Geometric definition
data	pointer0	Auxiliary information

```
struct B_SURFACE_s == ANY_SURF_s                    // B surface
    {
    int                             node_id;                    // $d
    union ATTRIB_GROUP_u            attributes_groups;          // $p
    union  SURFACE_OWNER_u          owner;                      // $p
    union  SURFACE_u                next;                       // $p
    union  SURFACE_u                previous;                   // $p
    struct GEOMETRIC_OWNER_s        *geometric_owner;           // $p
    char                            sense;                      // $c
    struct NURBS_SURF_s             *nurbs;                     // $p
    struct SURFACE_DATA_s           *data;                      // $p
    };
typedef struct B_SURFACE_s      *B_SURFACE;
```

The data stored in an XT file for a NURBS surface is

Field name	Data type	Description
u_periodic	logical	true if surface is periodic in u parameter
v_periodic	logical	true if surface is periodic in v parameter
u_degree	short	u degree of the surface
v_degree	short	v degree of the surface
n_u_vertices	int	number of control vertices (‘poles’) in u direction
n_v_vertices	int	number of control vertices (‘poles’) in v direction
u_knot_type	byte	form of u knot vector – see “B curve”
v_knot_type	byte	form of v knot vector
n_u_knots	int	number of distinct u knots
n_v_knots	int	number of distinct v knots
rational	logical	true if surface is rational
u_closed	logical	true if surface is closed in u
v_closed	logical	true if surface is closed in v
surface_form	byte	shape of surface, if special
vertex_dim	short	dimension of control vertices
bspline_vertices	pointer	control vertices (poles) node
u_knot_mult	pointer	multiplicities of u knot vector
v_knot_mult	pointer	multiplicities of v knot vector
u_knots	pointer	u knot vector
v_knots	pointer	v knot vector

The surface form enum is defined below.

```
typedef enum
    {
    SCH_unset = 1,                  // Unknown
    SCH_arbitrary = 2,              // No particular shape
    SCH_planar = 3,
```

```
    SCH_cylindrical = 4,
    SCH_conical = 5,
    SCH_spherical = 6,
    SCH_toroidal = 7,
    SCH_surf_of_revolution = 8,
    SCH_ruled = 9,
    SCH_quadric = 10,
    SCH_swept = 11
    }
  SCH_surface_form_t;

struct NURBS_SURF_s                    // NURBS surface
    {
    logical                 u_periodic;          // $l
    logical                 v_periodic;          // $l
    short                   u_degree;            // $n
    short                   v_degree;            // $n
    int                     n_u_vertices;        // $d
    int                     n_v_vertices;        // $d
    SCH_knot_type_t         u_knot_type;         // $u
    SCH_knot_type_t         v_knot_type;         // $u
    int                     n_u_knots;           // $d
    int                     n_v_knots;           // $d
    logical                 rational;            // $l
    logical                 u_closed;            // $l
    logical                 v_closed;            // $l
    SCH_surface_form_t      surface_form;        // $u
    short                   vertex_dim;          // $n
```

```
    struct BSPLINE_VERTICES_s       *bspline_vertices;          // $p
    struct KNOT_MULT_s              *u_knot_mult;               // $p
    struct KNOT_MULT_s              *v_knot_mult;               // $p
    struct KNOT_SET_s               *u_knots;                   // $p
    struct KNOT_SET_s               *v_knots;                   // $p
    };
typedef struct NURBS_SURF_s *NURBS_SURF;
```

The ‘bspline_vertices’, ‘knot_set’ and ‘knot_mult’ nodes and the ‘knot_type’ enum are described in the documentation for BCURVE.

The ‘surface data’ field in a B surface node is a structure designed to hold auxiliary or ‘derived’ data about the surface: it is not a necessary part of the definition of the B surface. It may be null, or the majority of its individual fields may be null. It is recommended that it only be set by Parasolid.

```
struct  SURFACE_DATA_s              // auxiliary surface data
    {
    interval                    original_uint;              // $i
    interval                    original_vint;              // $i
    interval                    extended_uint;              // $i
    interval                    extended_vint;              // $i
    SCH_self_int_t              self_int;                   // $u
    char                        original_u_start;           // $c
    char                        original_u_end;             // $c
    char                        original_v_start;           // $c
    char                        original_v_end;             // $c
    char                        extended_u_start;           // $c
    char                        extended_u_end;             // $c
    char                        extended_v_start;           // $c
    char                        extended_v_end;             // $c
    char                        analytic_form_type;         // $c
```

```
	char		swept_form_type;		// $c
	char		spun_form_type;			// $c
	char		blend_form_type;		// $c
	void		*analytic_form;			// $p
	void		*swept_form;			// $p
	void		*spun_form;			// $p
	void		*blend_form;			// $p
	};
typedef struct SURFACE_DATA_s *SURFACE_DATA;
```

The ‘original_’ and ‘extended_’ parameter intervals and corresponding character fields original_u_start etc. are all connected with Parasolid’s ability to extend B surfaces when necessary – functionality which is commonly exploited in “local operation” algorithms for example. This is done automatically without the need for user intervention.

In cases where the required extension can be performed by adding rows or columns of control points, then the nurbs data will be modified accordingly – this is referred to as an ‘explicit’ extension. In some rational B surface cases, explicit extension is not possible - in these cases, the surface will be ‘implicitly’ extended. When a B surface is implicitly extended, the nurbs data is not changed, but it will be treated as being larger by allowing out-of-range evaluations on the surface. Whenever an explicit or implicit extension takes place, it is reflected in the following fields:

- “original_u_int” and “original_v_int” are the original valid parameter ranges for a B surface before it was extended
- “extended_u_int” and “extended_v_int” are the valid parameter ranges for a B surface once it has been extended.

The character fields ‘original_u_start’ etc. all refer to the status of the corresponding parameter boundary of the surface before or after an extension has taken place. For B surfaces, the character can have one of the following values:

```
const char SCH_degenerate = 'D';		// Degenerate edge
const char SCH_periodic   = 'P';		// Periodic parameterisation
const char SCH_bounded    = 'B';		// Parameterisation bounded
const char SCH_closed     = 'C';		// Closed, but not periodic
```

The separate fields original_u_start and extended_u_start etc. are necessary because an extension may cause the corresponding parameter boundary to become degenerate.

If the surface_data node is present, then the original_u_int, original_v_int, original_u_start, original_u_end, original_v_start and original_v_end fields should be set to their appropriate values. If the surface has not been extended, the extended_u_int and extended_v_int fields should contain null, and the extended_u_start etc. fields should contain

const char SCH_unset_char = '?'; // generic uninvestigated value

As soon as any parameter boundary of the surface is extended, all the fields should be set, regardless of whether the corresponding boundary has been affected by the extension.

The SCH_self_int_t enum is documented in the corresponding curve_data structure under B curve.

The ‘swept_form_type’, ‘spun_form_type’ and ‘blend_form_type’ characters and the corresponding pointers swept_form, spun_form and blend_form, are for future use and are not implemented in Parasolid V12.0. The character fields should be set to SCH_unset_char (‘?’) and the pointers should be set to null pointer.

If the analytic_form field is not null, it will point to a HELIX_SU_FORM node, which indicates that the surface has a helical shape. In this case the analytic_form_type field will be set to ‘H’.

```
struct HELIX_SU_FORM_s
    {
    vector                  axis_pt                 // $v
    vector                  axis_dir                // $v
    char                    hand                    // $c
    interval                turns                   // $i
    double                  pitch                   // $f
    double                  gap                     // $f
    double                  tol                     // $f
    };
typedef struct HELIX_SU_FORM_s *HELIX_SU_FORM;
```

The axis_pt and axis_dir fields define the axis of the helix. The hand field is ‘+’ for a right-handed and ‘-’ for a left-handed helix. The turns field gives the extent of the helix

relative to the profile curve which was used to generate the surface. For instance, an interval [0 10] indicates a start position at the profile curve and an end 10 turns along the axis. Pitch is the distance travelled along the axis in one turn. Tol is the accuracy to which the owning bsurface fits this specification. Gap is for future expansion and will currently be zero. The v parameter increases in the direction of the axis.

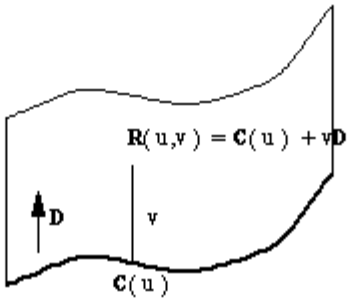
SWEPT_SURF

A swept surface has a parametric representation of the form:

R(u, v) = C(u) + vD

where

- C(u) is the section curve.
- D is the sweep direction (unit vector).



- C must not be an intersection curve or a trimmed curve.

Field name	Data type	Description
section	pointer	section curve
sweep	vector	sweep direction (a unit vector)
scale	double	for internal use only – may be set to null

```
struct SWEPT_SURF_s == ANY_SURF_s          // Swept surface
    {
    int                                    node_id;                    // $d
```

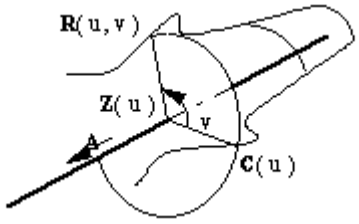
```
    union  ATTRIB_GROUP_u          attributes_groups;          // $p
    union  SURFACE_OWNER_u         owner;                      // $p
    union  SURFACE_u               next;                       // $p
    union  SURFACE_u               previous;                   // $p
    struct                         *geometric_owner;           // $p
    GEOMETRIC_OWNER_s
    char                           sense;                      // $c
    union  CURVE_u                 section;                    // $p
    vector                         sweep;                      // $v
    double                         scale;                      // $f
    };
typedef struct SWEPT_SURF_s *SWEPT_SURF;
```

SPUN_SURF

A spun surface has a parametric representation of the form:

R(u, v) = Z(u) + (C(u) - Z(u))cos(v) + A X (C(u) - Z(u)) sin(v)

where



- C(u) is the profile curve
- Z(u) is the projection of C(u) onto the spin axis
- A is the spin axis direction (unit vector)
- C must not be an intersection curve or a trimmed curve

NOTE: Z(u) = P + ((C(u) - P) . A)A where P is a reference point on the axis.

Field name	Data type	Description
profile	pointer	profile curve
base	vector	point on spin axis
axis	vector	spin axis direction (a unit vector)
start	vector	position of degeneracy at low u (may be null)
end	vector	position of degeneracy at low v (may be null)
start_param	double	curve parameter at low u degeneracy (may be null)
end_param	double	curve parameter at high u degeneracy (may be null)
x_axis	vector	unit vector in profile plane if common with spin axis
scale	double	for internal use only – may be set to null

```
struct SPUN_SURF_s == ANY_SURF_s              // Spun surface
    {
    int                                 node_id;                    // $d
    union  ATTRIB_GROUP_u               attributes_groups;          // $p
    union  SURFACE_OWNER_u              owner;                      // $p
    union  SURFACE_u                    next;                       // $p
    union  SURFACE_u                    previous;                   // $p
    struct
    GEOMETRIC_OWNER_s                  *geometric_owner;            // $p
    char                                sense;                      // $c
    union  CURVE_u                      profile;                    // $p
    vector                              base;                       // $v
    vector                              axis;                       // $v
    vector                              start;                      // $v
    vector                              end;                        // $v
    double                              start_param;                // $f
    double                              end_param;                  // $f
```

```
vector          x_axis;         // $v
double          scale;          // $f
};
typedef struct SPUN_SURF_s *SPUN_SURF;
```

The ‘start’ and ‘end’ vectors correspond to physical degeneracies on the spun surface caused by the profile curve crossing the spin axis at that point. The values start_param and end_param are the corresponding parameters on the curve. These parameter values define the valid range for the u parameter of the surface. If either value is null, then the valid range for u is infinite in that direction. For example, for a straight line profile curve intersecting the spin axis at the parameter t=1, values of null for start_param and 1 for end_param would define a cone with u parameterisation (-infinity, 1].

If the profile curve lies in a plane containing the spin axis, then x_axis must be set to a vector perpendicular to the spin axis and in the plane of the profile, pointing from the spin axis to a point on the profile curve in the valid range. If the profile curve is not planar, or its plane does not contain the spin axis, then x_axis should be set to null.

PE_SURF (Foreign Geometry surface)

Foreign (or ‘PE’) geometry in Parasolid is a type used for representing customers’ in-house proprietary data. It can also be used internally for representing geometry connected with this data (for example, offset foreign surfaces). These two types of foreign geometry usage are referred to as ‘external’ and ‘internal’ respectively. The only internal PE surface is the offset PE surface.

Applications not using foreign geometry will never encounter either external or internal PE data structures at Parasolid V9 or beyond.

Field name	Data type	Description
type	char	whether internal or external
data	pointer	internal or external data
tf	pointer0	transform applied to geometry
internal geom	pointer array	reference to other related geometry

```
struct PE_SURF_s == ANY_SURF_s              // PE_surface
    {
    int                                 node_id;                    // $d
    union  ATTRIB_GROUP_u               attributes_groups;          // $p
    union  SURFACE_OWNER_u              owner;                      // $p
    union  SURFACE_u                    next;                       // $p
    union  SURFACE_u                    previous;                   // $p
    struct GEOMETRIC_OWNER_s           *geometric_owner;            // $p
    char                                sense;                      // $c
    char                                type;                       // $c
    union  PE_DATA_u                    data;                       // $p
    struct TRANSFORM_s                 *tf;                         // $p
    union  PE_INT_GEOM_u                internal_geom[ 1 ];         // $p[]
    };
typedef struct PE_SURF_s  *PE_SURF;
```

The PE_DATA and PE_INT_GEOM unions are defined under ‘PE curve’.

Point

Field name	Data type	Description
node_id	int	integer unique within part
attributes_groups	pointer0	attributes and groups associated with point
owner	pointer	Owner
next	pointer0	next point in chain
previous	pointer0	previous point in chain
pvec	vector	position of point

```
union POINT_OWNER_u
```

```
        {
        struct VERTEX_s                 *vertex;
        struct BODY_s                   *body;
        struct ASSEMBLY_s               *assembly;
        struct WORLD_s                  *world;
        };

struct POINT_s                      // Point
        {
        int                             node_id;                    // $d
        union  ATTRIB_GROUP_u           attributes_groups;          // $p
        union  POINT_OWNER_u            owner;                      // $p
        struct POINT_s                  *next;                      // $p
        struct POINT_s                  *previous;                  // $p
        vector                          pvec;                       // $v
        };
typedef struct POINT_s    *POINT;
```

Transform

Field name	Data type	Description
node_id	int	integer unique within part
owner	pointer	owning instance or world
next	pointer0	next transform in chain
previous	pointer0	previous pointer in chain
rotation_matrix	double[3][3]	rotation component
translation_vector	vector	translation component
scale	double	scaling factor
flag	byte	binary flags indicating non-trivial components

perspective_vector	vector	perspective vector (always null vector)

The transform acts as

x’ = (rotation_matrix . x + translation_vector) * scale

The ‘flag’ field contains various bit flags which identify the components of the transformation:

Flag Name	Binary Value	Description
translation	00001	set if translation vector non-zero
rotation	00010	set if rotation matrix is not the identity
scaling	00100	set if scaling component is not 1.0
reflection	01000	set if determinant of rotation matrix is negative
general affine	10000	set if the rotation_matrix is not a rigid rotation

```
union TRANSFORM_OWNER_u
    {
    struct INSTANCE_s          *instance;
    struct WORLD_s             *world;
    };

struct TRANSFORM_s             // Transformation
    {
    int                            node_id;                    // $d
    union                          owner;                      // $p
    TRANSFORM_OWNER_u
    struct TRANSFORM_s            *next;                       // $p
    struct TRANSFORM_s            *previous;                   // $p
```

```
    double          rotation_matrix[3][3];      // $f[9]
    vector          translation_vector;         // $v
    double          scale;                      // $f
    unsigned        flag;                       // $d
    vector          perspective_vector;         // $v
    };
typedef struct TRANSFORM_s *TRANSFORM;
```

Curve and Surface Senses

The 'natural' tangent to a curve is that in the increasing parameter direction, and the 'natural' normal to a surface is in the direction of the cross-product of dP/du and dP/dv. For some purposes these are modified by the curve and surfaces senses, respectively – for example in the definition of blend surfaces, offset surfaces and intersection curves.

At the PK interface, the edge/curve and face/surface sense orientations are regarded as properties of the topology/geometry combination. In the XT format, this orientation information resides in the curves, surfaces and faces as follows:

The edge/curve orientation is stored in the curve->sense field. The face/surface orientation is a combination of sense flags stored in the face->sense and surface->sense fields, so the face/surface orientation is true (i.e. the face normal is parallel to the natural surface normal) if neither, or both, of the face and surface senses are positive.

Geometric_owner

Where geometry has dependants, the dependants point back to the referencing geometry by means of Geometric Owner nodes. Each geometric node points to a doubly-linked ring of Geometric Owner nodes which identify its referencing geometry. Referenced geometry is as follows:

Intersection:	2 surfaces
SP-curve:	Surface
Trimmed curve:	basis curve
Blended edge:	2 supporting surfaces, 2 blend_bound surfaces, 1 spine curve
Blend bound:	blend surface
Offset surface:	underlying surface

Swept surface: section curve

Spun surface: profile curve

Note that the 2D B-curve referenced by an SP-curve is not a dependent in this sense, and does not need a geometric owner node.

Field name	**Data type**	**Description**
owner	pointer	referencing geometry
next	pointer	next in ring of geometric owners referring to the same geometry
previous	pointer	previous in above ring
shared_geometry	pointer	referenced (dependent) geometry

```
struct GEOMETRIC_OWNER_s        //  geometric owner of geometry
    {
    union  GEOMETRY_u               owner;                  //  $p
    struct GEOMETRIC_OWNER_s    *next;                      //  $p
    struct GEOMETRIC_OWNER_s    *previous;                  // $p
    union  GEOMETRY_u               shared_geometry;        //  $p
    };
typedef struct GEOMETRIC_OWNER_s *GEOMETRIC_OWNER;
```

Topology

In the following tables, ‘ignore’ means this may be set to null (zero) if an XT file is created outside Parasolid. For an XT file created by Parasolid, this may take any value, but should be ignored.

Unless otherwise stated, all chains of nodes are doubly-linked and null-terminated.

WORLD

Field name	Type	Description
assembly	pointer0	Head of chain of assemblies
attribute	pointer0	Ignore
body	pointer0	Head of chain of bodies
transform	pointer0	Head of chain of transforms
surface	pointer0	Head of chain of surfaces
curve	pointer0	Head of chain of curves
point	pointer0	Head of chain of points
alive	logical	True unless partition is at initial pmark
attrib_def	pointer0	Head of chain of attribute definitions
highest_id	int	Highest pmark id in partition
current_id	int	Id of current pmark
index_map_offset	int	Must be set to 0
index_map	pointer0	Must be set to null
schema_embedding_map	pointer0	Must be set to null

The World node is only used when a partition is transmitted. Because some of the attribute definitions may be referenced by nodes which have been deleted, but which may reappear on rollback, the attribute definitions are chained off the World node rather than simply being referenced by attributes.

The fields index_map_offset, index_map, and schema_embedding_map are used for Indexed Transmit; applications writing XT data must set them to 0 and null.

```
struct WORLD_s                          // World
    {
```

```
	struct ASSEMBLY_s		*assembly;		// $p
	struct ATTRIBUTE_s		*attribute;		// $p
	struct BODY_s			*body;			// $p
	struct TRANSFORM_s		*transform;		// $p
	union  SURFACE_u		 surface;		// $p
	union  CURVE_u			 curve;			// $p
	struct POINT_s			*point;			// $p
	logical				 alive;			// $l
	struct ATTRIB_DEF_s		*attrib_def;		// $p
	int				 highest_id;		// $d
	int				 current_id;		// $d
	};
typedef struct WORLD_s  *WORLD;
```

ASSEMBLY

highest_node_id	int	Highest node-id in assembly
attributes_groups	pointer0	Head of chain of attributes of, and groups in, assembly
attribute_chains	pointer0	List of attributes, one for each attribute definition used in the assembly
list	pointer0	Null
surface	pointer0	Head of construction surface chain
curve	pointer0	Head of construction curve chain
point	pointer0	Head of construction point chain
key	pointer0	Ignore
res_size	double	Value of ‘size box’ when transmitted (normally 1000)
res_linear	double	Value of modeller linear precision when transmitted (normally 1.0e-8).
ref_instance	pointer0	Head of chain of instances referencing this assembly
next	pointer0	Ignore
previous	pointer0	Ignore
state	byte	Set to 1.
owner	pointer0	Ignore
type	byte	Always 1.

sub_instance	pointer0	Head of chain of instances in assembly

The value of the ‘state’ field should be ignored, as should any nodes of type ‘KEY’ referenced by the assembly. If an XT file is constructed outside Parasolid, the state field should be set to 1, and the key to null.

The highest_node_id gives the highest node-id of any node in the assembly. Certain nodes within the assembly (namely instances, transforms, geometry, attributes and groups) have unique node-ids which are non-zero integers.

```
typedef enum
    {
    SCH_collective_assembly  = 1,
    SCH_conjunctive_assembly = 2,
    SCH_disjunctive_assembly = 3
    }
    SCH_assembly_type;

typedef enum
    {
    SCH_new_part      = 1,
    SCH_stored_part   = 2,
    SCH_modified_part  = 3,
    SCH_anonymous_part = 4,
    SCH_unloaded_part  = 5
    }
    SCH_part_state;

struct ASSEMBLY_s                    // Assembly
    {
    int                              highest_node_id;                    // $d
```

```
	union ATTRIB_GROUP_u	 attributes_groups;		// $p
	struct LIST_s		*attribute_chains;		// $p
	struct LIST_s		*list;				// $p
	union SURFACE_u		 surface;			// $p
	union CURVE_u		 curve;				// $p
	struct POINT_s		*point;				// $p
	struct KEY_s		*key;				// $p
	double			 res_size;			// $f
	double			 res_linear;			// $f
	struct INSTANCE_s	*ref_instance;			// $p
	struct ASSEMBLY_s	*next;				// $p
	struct ASSEMBLY_s	*previous;			// $p
	SCH_part_state		 state;				// $u
	struct WORLD_s		*owner;				// $p
	SCH_assembly_type	 type;				// $u
	struct INSTANCE_s	*sub_instance;			// $p
	};
typedef struct ASSEMBLY_s *ASSEMBLY;
struct KEY_s						// Key
	{
	string[1];		char			// $c[]
	};
typedef struct KEY_s *KEY;
```

INSTANCE

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of instance and

		member_of_groups of instance
type	byte	Always 1
part	pointer	Part referenced by instance
transform	pointer0	Transform of instance
assembly	pointer	Assembly in which instance lies
next_in_part	pointer0	Next instance in assembly
prev_in_part	pointer0	Previous instance in assembly
next_of_part	pointer0	Next instance of instance->part
prev_of_part	pointer0	Previous instance of instance->part

```
typedef enum
    {
    SCH_positive_instance = 1,
    SCH_negative_instance = 2
    }
    SCH_instance_type;

union  PART_u
    {
    struct BODY_s               *body;
    struct ASSEMBLY_s           *assembly;
    };
typedef union PART_u    PART;

struct INSTANCE_s                   //  Instance
    {
    int                         node_id;                    //  $d
    union  ATTRIB_GROUP_u       attributes_groups;          //  $p
    SCH_instance_type           type;                       //  $u
    union  PART_u               part;                       //  $p
    struct TRANSFORM_s          *transform;                 //  $p
```

```
    struct ASSEMBLY_s       *assembly;          // $p
    struct INSTANCE_s       *next_in_part;      // $p
    struct INSTANCE_s       *prev_in_part;      // $p
    struct INSTANCE_s       *next_of_part;      // $p
    struct INSTANCE_s       *prev_of_part;      // $p
    };
typedef struct INSTANCE_s *INSTANCE;
```

BODY

Field name	Type	Description
highest_node_id	int	Highest node-id in body
attributes_groups	pointer0	Head of chain of attributes of, and groups in, body
attribute_chains	pointer0	List of attributes, one for each attribute definition used in the body
surface	pointer0	Head of construction surface chain
curve	pointer0	Head of construction curve chain
point	pointer0	Head of construction point chain
key	pointer0	Ignore
res_size	double	Value of ‘size box’ when transmitted (normally 1000)
res_linear	double	Value of modeller linear precision when transmitted (normally 1.0e-8)
ref_instance	pointer0	Head of chain of instances referencing this part
next	pointer0	Ignore
previous	pointer0	Ignore
state	byte	Set to 1 (see below)
owner	pointer0	Ignore
body_type	byte	Body type
nom_geom_state	byte	Set to 1 (for future use)

shell	pointer0	For general bodies: null For solid bodies: the first shell in one of the solid regions For other bodies: the first shell in one of the regions This field is **obsolete**, and should be ignored by applications reading XT files. When writing XT files, it must be set as above.
boundary_surface	pointer0	Head of chain of surfaces attached directly or indirectly to faces or edges or fins
boundary_curve	pointer0	Head of chain of curves attached directly or indirectly to edges or faces or fins
boundary_point	pointer0	Head of chain of points attached to vertices
region	pointer	Head of chain of regions in body; this is the infinite region
edge	pointer0	Head of chain of all non-wireframe edges in body
vertex	pointer0	Head of chain of all vertices in body
index_map_offset	int	Must be set to 0
index_map	pointer0	Must be set to null
node_id_index_map	pointer0	Must be set to null
schema_embedding_map	pointer0	Must be set to null

The value of the ‘state’ field should be ignored, as should any nodes of type ‘KEY’ referenced by the body. If an XT file is constructed outside Parasolid, the state field should be set to 1, and the key to null.

The highest_node_id gives the highest node of any node in this body. Most nodes in a body which are visible at the PK interface have node-ids, which are non-zero integers unique to that node within the body. Applications writing XT files must ensure that node-ids are present and distinct. The details of which nodes have node ids are given in an appendix.

The fields index_map_offset, index_map, node_id_index_map, and schema_embedding_map are used for Indexed Transmit; applications writing XT files must ensure that these fields are set to 0 and null.

typedef enum

{

SCH_solid_body = 1,

```
        SCH_wire_body      = 2,
        SCH_sheet_body     = 3,
        SCH_general_body   = 6
        }
        SCH_body_type;


typedef short short enum
          {
          SCH_nom_geom_off = 1,          --- Entirely off
          SCH_nom_geom_on  = 2           --- Entirely on
          }
          SCH_nom_geom_state_t;

struct BODY_s                          //  Body
        {
        int                             highest_node_id;                //  $d
        union ATTRIB_GROUP_u            attributes_groups;              //  $p
        struct LIST_s                  *attribute_chains;               //  $p
        union SURFACE_u                 surface;                        //  $p
        union CURVE_u                   curve;                          //  $p
        struct POINT_s                 *point;                          //  $p
        struct KEY_s                   *key;                            //  $p
        double                          res_size;                       //  $f
        double                          res_linear;                     //  $f
        struct INSTANCE_s              *ref_instance;                   //  $p
        struct BODY_s                  *next;                           //  $p
        struct BODY_s                  *previous;                       //  $p
        SCH_part_state                  state;                          //  $u
        struct WORLD_s                 *owner;                          //  $p
        SCH_body_type                   body_type;                      //  $u
```

```
        SCH_nom_geom_state_t    nom_geom_state;             // $u
        struct SHELL_s          *shell;                     // $p
        union SURFACE_u          boundary_surface;          // $p
        union CURVE_u            boundary_curve;            // $p
        struct POINT_s          *boundary_point;            // $p
        struct REGION_s         *region;                    // $p
        struct EDGE_s           *edge;                      // $p
        struct VERTEX_s         *vertex;                    // $p
        int                     index_map_offset;           // $d
        struct INT_VALUES_s     *index_map;                 // $p
        struct INT_VALUES_s     *node_id_index_map;         // $p
        struct INT_VALUES_s     *schema_embedding_map;      // $p
        };
typedef struct BODY_s    *BODY;
```

Attaching Geometry to Topology

The faces which reference a surface are chained together, surface->owner is the head of this chain. Similarly the edges which reference the same curve are chained together. Fins do not share curves.

Geometry in parts may be chained into one of the three boundary geometry chains, or one of the three construction geometry chains. A geometric node will fall into one of the following cases:

Geometry	**Owner**	**Whether chained**
Attached to face	face	In boundary_surface chain
Attached to edge or fin	edge or fin	In boundary_curve chain
Attached to vertex	vertex	In boundary_point chain
Indirectly attached to face or edge or fin	body	In boundary_surface chain or boundary_curve chain
Construction geometry	body or assembly	In surface, curve or point chain
2D B-curve in SP-curve	null	Not chained

Here ‘indirectly attached’ means geometry which is a dependent of a dependent of (... etc) of geometry attached to an edge, face or fin.

Geometry in a construction chain may reference geometry in a boundary chain, but not vice-versa.

REGION

Field name	**Type**	**Description**
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of region and member_of_groups of region
body	pointer	Body of region
next	pointer0	Next region in body
prev	pointer0	Previous region in body
shell	pointer0	Head of singly-linked chain of shells in region
type	char	Region type – solid (‘S’) or void (‘V’)

```
struct REGION_s                    // Region
    {
    int                             node_id;                    // $d
    union  ATTRIB_GROUP_u           attributes_groups;          // $p
    struct BODY_s                  *body;                       // $p
    struct REGION_s                *next;                       // $p
    struct REGION_s                *previous;                   // $p
    struct SHELL_s                 *shell;                      // $p
    char                            type;                       // $c
    };
typedef struct REGION_s   *REGION;
```

SHELL

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of shell
body	pointer0	For shells in wire and sheet bodies, and for shells bounding a solid region of a solid body, this is set to the body of the shell. For shells in general bodies, or void shells in solid bodies, it is null. This field is **obsolete**, and should be ignored by applications reading XT files. When writing XT files, it must be set as above.
next	pointer0	Next shell in region
face	pointer0	Head of chain of back-faces of shell (i.e. faces with face normal pointing out of region of shell).
edge	pointer0	Head of chain of wire-frame edges of shell
vertex	pointer0	If shell consists of a single vertex, this is it; else null
region	pointer	Region of shell
front_face	pointer0	Head of chain of front-faces of shell (i.e. faces with face normal pointing into region of shell)

```
struct SHELL_s                  //  Shell
    {
    int                          node_id;                  //  $d
    union  ATTRIB_GROUP_u        attributes_groups;        //  $p
    struct BODY_s               *body;                     //  $p
    struct SHELL_s              *next;                     //  $p
    struct FACE_s               *face;                     //  $p
    struct EDGE_s               *edge;                     //  $p
    struct VERTEX_s             *vertex;                   //  $p
    struct REGION_s             *region;                   //  $p
    struct FACE_s               *front_face;               //  $p
    };
typedef struct SHELL_s    *SHELL;
```

FACE

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of face and member_of_groups of face
tolerance	double	Not used (null double)
next	pointer0	Next back-face in shell
previous	pointer0	Previous back-face in shell
loop	pointer0	Head of singly-linked chain of loops
shell	pointer	Shell of which this is a back-face
surface	pointer0	Surface of face
sense	char	Face sense – positive (‘+’) or negative (‘-’)
next_on_surface	pointer0	Next in chain of faces sharing the surface of this face
previous_on_surface	pointer0	Previous in chain of faces sharing the surface of this face
next_front	pointer0	Next front-face in shell
previous_front	pointer0	Previous front-face in shell
front_shell	pointer	Shell of which this is a front-face

```
struct FACE_s                       //  Face
      {
      int                            node_id;                  //  $d
      union  ATTRIB_GROUP_u          attributes_groups;        //  $p
      double                         tolerance;                //  $f
      struct FACE_s                 *next;                     //  $p
      struct FACE_s                 *previous;                 //  $p
      struct LOOP_s                 *loop;                     //  $p
      struct SHELL_s                *shell;                    //  $p
      union  SURFACE_u               surface;                  //  $p
      char                           sense;                    //  $c
      struct FACE_s                 *next_on_surface;          //  $p
      struct FACE_s                 *previous_on_surface;      //  $p
      struct FACE_s                 *next_front;               //  $p
      struct FACE_s                 *previous_front;           //  $p
      struct SHELL_s                *front_shell;              //  $p
      };
typedef struct FACE_s     *FACE;
```

LOOP

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of loop
fin	pointer	One of ring of fins of loop
face	pointer	Face of loop
next	pointer0	Next loop in face

Isolated Loops

An isolated loop (one consisting of a single vertex) does not refer directly to a vertex, but points to a fin which refers to that vertex. This isolated fin has fin->forward = fin-

>backward = fin, and fin->other = fin->curve = fin->edge = null. Its sense is not significant. The fin is chained into the chain of fins referencing the isolated vertex.

```
struct LOOP_s                       //  Loop
    {
    int                              node_id;                    //  $d
    union  ATTRIB_GROUP_u            attributes_groups;          //  $p
    struct FIN_s                    *fin;                        //  $p
    struct FACE_s                   *face;                       //  $p
    struct LOOP_s                   *next;                       //  $p
    };
typedef struct LOOP_s     *LOOP;
```

FIN

Field name	Type	Description
attributes_groups	pointer0	Head of chain of attributes of fin
loop	pointer0	Loop of fin
forward	pointer0	Next fin around loop
backward	pointer0	Previous fin around loop
vertex	pointer0	Forward vertex of fin
other	pointer0	Next fin around edge, clockwise looking along edge
edge	pointer0	Edge of fin
curve	pointer0	For a non-dummy fin of a tolerant edge, this will be a trimmed SP-curve, otherwise null.
next_at_vx	pointer0	Next fin referencing the vertex of this fin
sense	char	Positive (‘+’) if the fin direction is parallel to that of its edge, else negative (‘-’)

Dummy Fins

An application will see edges as having any number of fins, including zero. However internally, they have at least two. This is so that the forward and backward vertices of an edge can always be found as edge->fin->vertex and edge->fin->other->vertex respectively - the first one being a positive fin, the second a negative fin. If an edge does not have both a positive and a negative externally-visible fin, **dummy** fins will exist for

this purpose. Dummy fins have fin->loop = fin->forward = fin->backward = fin->curve = fin->next_at_vx = null. For example the boundaries of a sheet always have one dummy fin.

```
struct FIN_s                        //  Fin
    {
    union  ATTRIB_GROUP_u            attributes_groups;          //  $p
    struct LOOP_s                   *loop;                       //  $p
    struct FIN_s                    *forward;                    //  $p
    struct FIN_s                    *backward;                   //  $p
    struct VERTEX_s                 *vertex;                     //  $p
    struct FIN_s                    *other;                      //  $p
    struct EDGE_s                   *edge;                       //  $p
    union  CURVE_u                   curve;                      //  $p
    struct FIN_s                    *next_at_vx;                 //  $p
    char                             sense;                      //  $c
    };
typedef struct FIN_s *FIN;
```

VERTEX

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of vertex and member_of_groups of vertex
fin	pointer0	Head of singly-linked chain of fins referencing this vertex
previous	pointer0	Previous vertex in body
next	pointer0	Next vertex in body
point	pointer	Point of vertex
tolerance	double	Tolerance of vertex (null-double for accurate vertex)

owner	pointer	Owning body (for non-acorn vertices) or shell (for acorn vertices)

```
union SHELL_OR_BODY_u
    (
    struct BODY_s                   *body;
    struct SHELL_s                  *shell;
    };
typedef union SHELL_OR_BODY_u SHELL_OR_BODY;


struct VERTEX_s                     //  Vertex
    {
    int                             node_id;                    //  $d
    union  ATTRIB_GROUP_u           attributes_groups;          //  $p
    struct FIN_s                    *fin;                       //  $p
    struct VERTEX_s                 *previous;                  //  $p
    struct VERTEX_s                 *next;                      //  $p
    struct POINT_s                  *point;                     //  $p
    double                          tolerance;                  //  $f
    union  SHELL_OR_BODY_u          owner;                      //  $p
    };
typedef struct VERTEX_s   *VERTEX;
```

EDGE

Field name	**Type**	**Description**
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of edge and member_of_groups of edge
tolerance	double	Tolerance of edge (null-double for accurate edges)
fin	pointer	One of singly-linked ring of fins around edge
previous	pointer0	Previous edge in body or shell

next	pointer0	Next edge in body or shell
curve	pointer0	Curve of edge, zero for tolerant edge. If edge is accurate, but any of its vertices are tolerant, this will be a trimmed curve
next_on_curve	pointer0	Next in chain of edges sharing the curve of this edge
previous_on_curve	pointer0	Previous in chain of edges sharing the curve of this edge
owner	pointer	Owning body (for non-wireframe edges) or shell (for wireframe edges)

```
struct EDGE_s                   // Edge
    {
    int                         node_id;                    // $d
    union  ATTRIB_GROUP_u       attributes_groups;          // $p
    double                      tolerance;                  // $f
    struct FIN_s                *fin;                       // $p
    struct EDGE_s               *previous;                  // $p
    struct EDGE_s               *next;                      // $p
    union  CURVE_u              curve;                      // $p
    struct EDGE_s;              *next_on_curve              // $p
    struct EDGE_s               *previous_on_curve;         // $p
    union                       owner;                      // $p
    SHELL_OR_BODY_u
    };
typedef struct EDGE_s     *EDGE;
```

Associated Data

LIST

Field name	Type	Description
node_id	int	Zero
owner	pointer	Owning part
next	pointer0	Ignore
previous	pointer0	Ignore
list_type	int	Always 4
list_length	int	Length of list (>= 0)
block_length	int	Length of each block of list. Always 20
size_of_entry	int	Ignore
list_block	pointer	Head of singly-linked chain of blocks in list
finger_block	pointer	Any block e.g. the first one. Ignore
finger_index	int	Any integer between 1 and list->list_length (set to 1 if length is zero). Ignore
notransmit	logical	Ignore

Lists only occur in part files as the list of attributes referenced by a part.

```
typedef enum
    {
    LIS_pointer    = 4
    }
LIS_type_t;

union LIS_BLOCK_u
    {
    struct POINTER_LIS_BLOCK_s        *pointer_block;
    };
typedef union LIS_BLOCK_u       LIS_BLOCK;
```

```
union LIST_OWNER_u
	{
	struct BODY_s			*body;
	struct ASSEMBLY_s		*assembly;
	struct WORLD_s			*world;
	};
typedef union LIST_OWNER_u LIST_OWNER;

struct LIST_s				//  List Header
	{
	int				node_id;		//  $d
	union LIST_OWNER_u		owner;			//  $p
	struct LIST_s			*next;			//  $p
	struct LIST_s			*previous;		//  $p
	LIS_type_t			list_type;		//  $d
	int				list_length;		//  $d
	int				block_length;		//  $d
	int				size_of_entry;		//  $d
	union LIS_BLOCK_u		list_block;		//  $p
	union LIS_BLOCK_u		finger_block;		//  $p
	int				finger_index;		//  $d
	logical				notransmit;		//  $l
	};
typedef struct LIST_s *LIST;
```

POINTER_LIS_BLOCK:

Field name	Type	Description
n_entries	int	Number of entries in this block (0 <= n_entries <=

		20). Only the first block may have n_entries = 0.
index_map_offset	int	Must be set to 0
next_block	pointer0	Next block in list
Entries[20]	pointer0	Pointers in block, those beyond n_entries must be zero

When the pointer_lis_block is used as the root node in a transmit file containing more than one part, the restriction n_entries <= 20 does not apply.

The index_map_offset field is used for Indexed Transmit; applications writing XT files must ensure this field is set to 0.

```
struct POINTER_LIS_BLOCK_s                  //  Pointer List
    {
    int                                     n_entries;              //  $d
    struct POINTER_LIS_BLOCK_s              *next_block;            //  $p
    void                                    *entries[ 1 ];          //  $p[]
    };
typedef struct POINTER_LIS_BLOCK_s *POINTER_LIS_BLOCK;
```

ATT_DEF_ID

Field name	Type	Description
string[]	char	String name e.g. "SDL/TYSA_COLOUR"

```
struct ATT_DEF_ID_s         //  name field type for attrib def.
    {
    char                                    String[1];              //  $c[]
    };
typedef struct ATT_DEF_ID_s *ATT_DEF_ID;
```

FIELD_NAMES

Field name	Type	Description
names[]	pointer	Array of field names – unicode or char

```
typedef union FIELD_NAME_u
    {
    struct CHAR_VALUES_s        *name
    struct UNICODE_VALUES_s     *uname
    };
  FIELD_NAME_t;

struct FIELD_NAME_s         //  attribute field name
    {
    union FIELD_NAME_u              names[1];                   //  $p[]
    };
typedef struct FIELD_NAME_s *FIELD_NAME;
```

ATTRIB_DEF

Field name	Type	Description
next	pointer0	Next attribute definition. This can be ignored, except in a partition transmit file.
identifier	pointer	Pointer to string name
type_id	int	Numeric id, e.g. 8001 for color. 9000 for user-defined attribute definitions
actions[8]	byte	Required actions on various events
field_names	pointer0	Names of fields (unicode or char)
legal_owners[14]	logical	Allowed owner types
fields[]	byte	Array of field types. Note that the number of fields is given by the length of the variable length part of this node, i.e. the integer following the node type in the transmit file.

The legal_owners array is an array of logicals determining which node types may own this type of attribute.

e.g. if faces are allowed attrib_def -> legal_owners [SCH_fa_owner] = true.

Note that if the file contains user fields, the ‘fields’ field of an attribute definition may contain extra values, set to zero. These are to be ignored.

The ‘actions’ field in an attribute definition defines the behaviour of the attribute when an event (rotate, scale, translate, reflect, split, merge, transfer, change) occurs. The actions are:

do_nothing	Leave attribute as it is
delete	Delete the attribute
transform	Transform the transformable fields (point, vector, direction, axis) by appropriate part of transformation
propagate	Copy attribute onto split-off node
keep_sub_dominant	Move attribute(s) from deleted node onto surviving node in a merge, but any such attributes already on the surviving node are deleted.
keep_if_equal	Keep attribute if present on both nodes being merged, with the same field values.
combine	Move attribute(s) from deleted node onto surviving node, in a merge

The PK attribute classes 1-7 correspond as follows:

	split	merge	transfer	change	Rotate	scale	translate	reflect
class 1	propagate	keep_equal	do_nothing	do_nothing	do_nothing	do_nothing	do_nothing	do_nothing
class 2	delete	delete	delete	delete	do_nothing	delete	do_nothing	do_nothing
class 3	delete	delete	delete	delete	Delete	delete	delete	delete
class 4	propagate	keep_equal	do_nothing	do_nothing	Transform	transform	transform	transform
class 5	delete	delete	delete	delete	Transform	transform	transform	transform
class 6	propagate	combine	do_nothing	do_nothing	do_nothing	do_nothing	do_nothing	do_nothing
class 7	propagate	combine	do_nothing	do_nothing	Transform	transform	transform	transform

Certain attribute definitions are created by Parasolid on startup, these are documented in an appendix.

```
typedef enum
        {
        SCH_rotate      = 0,
        SCH_scale       = 1,
        SCH_translate   = 2,
        SCH_reflect     = 3,
        SCH_split       = 4,
        SCH_merge       = 5,
        SCH_transfer    = 6,
        SCH_change      = 7,
        SCH_max_logged_event        //  last entry; value in $d[] code for
                                    actions
        }
        SCH_logged_event_t;


typedef enum
        {
        SCH_do_nothing          = 0,
        SCH_delete              = 1,
        SCH_transform           = 2,
        SCH_propagate           = 3,
        SCH_keep_sub_dominant = 4,
        SCH_keep_if_equal       = 5,
        SCH_combine             = 6
        }
        SCH_action_on_fields_t;


typedef enum
```

```
    {
    SCH_as_owner  = 0,
    SCH_in_owner  = 1,
    SCH_by_owner  = 2,
    SCH_sh_owner  = 3,
    SCH_fa_owner  = 4,
    SCH_lo_owner  = 5,
    SCH_ed_owner  = 6,
    SCH_vx_owner  = 7,
    SCH_fe_owner  = 8,
    SCH_sf_owner  = 9,
    SCH_cu_owner  = 10,
    SCH_pt_owner  = 11,
    SCH_rg_owner  = 12,
    SCH_fn_owner  = 13,
    SCH_max_owner               //  last entry; value in $l[] for
                                .legal_owners
    } SCH_attrib_owners_t;


typedef enum
    {
    SCH_int_field          = 1,
    SCH_real_field         = 2,
    SCH_char_field         = 3,
    SCH_point_field        = 4,
    SCH_vector_field       = 5,
    SCH_direction_field    = 6,
    SCH_axis_field         = 7,
    SCH_tag_field          = 8,
```

```
	SCH_pointer_field    = 9,
	SCH_unicode_field    = 10
	} SCH_field_type_t;

struct ATTRIB_DEF_s		//  attribute definition
	{
	struct ATTRIB_DEF_s		*next;			//  $p
	struct ATT_DEF_ID_s		*identifier;		//  $p
	int				 type_id;		//  $d
	SCH_action_on_fields_t		 actions
					[(int)SCH_max_logged_event];	//  $u[8]
	struct FIELD_NAMES_s		*field_names		//  $p
	logical				 legal_owners		//  $l[14]
					[(int)SCH_max_owner];
	SCH_field_type_t		 fields[1];		//  $u[]
	};
typedef struct ATTRIB_DEF_s    *ATTRIB_DEF;
```

ATTRIBUTE

Field name	Type	Description
node_id	int	Node-id
definition	pointer	Attribute definition
owner	pointer	Attribute owner
next	pointer0	Next attribute, group, or member_of_group
previous	pointer0	Previous ditto
next_of_type	pointer0	Next attribute of this type in this part
previous_of_type	pointer0	Previous attribute of this type in this part
fields[]	pointer	Fields, of type int_values etc. The number of fields is given by the length of the variable part of the node. There may be no fields.

The attributes of a node are chained using the next and previous pointers in the attribute. The attribute_groups pointer in the node points to the head of this chain. This chain also contains the member_of_groups of the node.

Attributes within the same part, with the same attribute definition, are chained together by the next_of_type and previous_of_type pointers. The part points to the head of this chain as follows. The attribute_chains pointer in the part points to a list which contains the heads of these attribute chains, one for each attribute definition which has attributes in the part. The list may be null.

Note that the attributes_groups chains in parts, groups and nodes contain the following types of node:

Part:	attributes and groups
Group:	attributes
Node:	attributes and member_of_groups

Fields of type ‘pointer’ can be used in Parasolid V12.0, but they are always transmitted as empty.

```
union ATTRIBUTE_OWNER_u
        {
      struct ASSEMBLY_s          *assembly;
      struct INSTANCE_s          *instance;
      struct BODY_s              *body;
      struct SHELL_s             *shell;
      struct REGION_s            *region;
      struct FACE_s              *face;
      struct LOOP_s              *loop;
      struct EDGE_s              *edge;
      struct FIN_s               *fin;
      struct VERTEX_s            *vertex;
      union  SURFACE_u            Surface;
      union  CURVE_u              Curve;
      struct POINT_s             *point;
```

```
	struct GROUP_s			*group;
	};
typedef union ATTRIBUTE_OWNER_u ATTRIBUTE_OWNER;

union FIELD_VALUES_u
	{
	struct INT_VALUES_s		*int_values;
	struct REAL_VALUES_s		*real_values;
	struct CHAR_VALUES_s		*char_values;
	struct POINT_VALUES_s		*point_values;
	struct VECTOR_VALUES_s		*vector_values;
	struct DIRECTION_VALUES_s	*direction_values;
	struct AXIS_VALUES_s		*axis_values;
	struct TAG_VALUES_s		*tag_values;
	struct UNICODE_VALUES_s		*unicode_values;
	};
typedef union FIELD_VALUES_u FIELD_VALUES;

struct ATTRIBUTE_s			// Attribute
	{
	int				node_id;		// $d
	struct ATTRIB_DEF_s		*definition;		// $p
	union  ATTRIBUTE_OWNER_u	owner;			// $p
	union  ATTRIB_GROUP_u		next;			// $p
	union  ATTRIB_GROUP_u		previous;		// $p
	struct ATTRIBUTE_s		*next_of_type;		// $p
	struct ATTRIBUTE_s		*previous_of_type;	// $p
	union  FIELD_VALUES_u		fields[1];		// $p[]
```

```
};
typedef struct ATTRIBUTE_s *ATTRIBUTE;
```

INT_VALUES

values[]	int	Integer values

```
struct INT_VALUES_s                 //  Int values
    {
    int                             values[1];                  //  $d[]
    };
typedef struct INT_VALUES_s *INT_VALUES;
```

REAL_VALUES

values[]	double	Real values

```
struct REAL_VALUES_s                //  Real values
    {
    double                          values[1];                  //  $f[]
    };
typedef struct REAL_VALUES_s *REAL_VALUES;
```

CHAR_VALUES

values[]	char	Character values

```
struct CHAR_VALUES_s                //  Character values
    {
    char                            values[1];                  //  $c[]
    };
```

typedef struct CHAR_VALUES_s *CHAR_VALUES;

UNICODE_VALUES

values[]	short	Unicode character values

```
struct UNICODE_VALUES_s                 //  Unicode character values
      {
      short                             values[1];                          //  $w[]
      };
typedef struct UNICODE_VALUES_s *UNICODE_VALUES;
```

POINT_VALUES

values[]	vector	Point values

```
struct POINT_VALUES_s                   //  Point values
       {
      vector                            values[1];                          // $v[]
      };
typedef struct POINT_VALUES_s *POINT_VALUES;
```

VECTOR_VALUES

values[]	vector	Vector values

```
struct VECTOR_VALUES_s                  //  Vector values
      {
      vector                            values[1];                          //  $v[]
      };
typedef struct VECTOR_VALUES_s *VECTOR_VALUES;
```

DIRECTION_VALUES

values[]	vector	Direction values

```
struct DIRECTION_VALUES_s              //  Direction values
    {
    vector                  values[1];                  //  $v[]
    };
typedef struct DIRECTION_VALUES_s *DIRECTION_VALUES;
```

AXIS_VALUES

values[]	vector	Axis values

Note that an axis takes up two vectors.

```
struct AXIS_VALUES_s                //  Axis values
    {
    vector                  values[1];                  //  $v[]
    };
typedef struct AXIS_VALUES_s *AXIS_VALUES;
```

TAG_VALUES

values[]	int	Integer tag values

The tag field type and the tag_values node are not available for use in user-defined attributes, they occur only in certain system attributes.

```
struct TAG_VALUES_s                 //  Tag values
    {
    int                     values[1];                  //  $t[]
    };
```

typedef struct TAG_VALUES_s *TAG_VALUES;

GROUP

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of this group
owner	pointer	Owning part
next	pointer0	Next group or attribute
previous	pointer0	Previous group or attribute
type	byte	Type of node allowed in group
first_member	pointer0	Head of chain of member_of_group nodes in group

The groups in a part are chained by the next and previous pointers in a group. The attributes_groups pointer in the part points to the head of the chain. This chain also contains the attributes attached directly to the part - groups and attributes are intermingled in this chain, the order is not significant.

Each group has a chain of member_of_groups. These are chained together using the next_member and previous_member pointers. The first_member pointer in the group points to the head of the chain. Each member_of_group has an owning_group pointer which points back to the group.

Each member_of_group has an owner pointer which points to a node. Thus the group references its member nodes via the member_of_groups.

The member_of_groups which refer to a particular node are chained using the next and previous pointers in the member_of_group. The attributes_groups pointer in the node points to the head of this chain. This chain also contains the attributes attached to the node.

typedef enum

{

SCH_instance_fe = 1,

SCH_face_fe = 2,

SCH_loop_fe = 3,

SCH_edge_fe = 4,

```
        SCH_vertex_fe     = 5,
        SCH_surface_fe    = 6,
        SCH_curve_fe      = 7,
        SCH_point_fe      = 8,
        SCH_mixed_fe      = 9,
        SCH_region_fe     = 10
        }  SCH_group_type_t;

struct GROUP_s                  //  Group
        {
        int                                 node_id;                    //  $d
        union   ATTRIB_GROUP_u              attributes_groups;          //  $p
        union   PART_u                      owner;                      //  $p
        union   ATTRIB_GROUP_u              next;                       //  $p
        union   ATTRIB_GROUP_u              previous;                   //  $p
        SCH_group_type_t                    type;                       //  $u
        struct  MEMBER_OF_GROUP_s    *first_member;                     //  $p
        };
typedef struct GROUP_s *GROUP;
```

MEMBER_OF_GROUP

Field name	Type	Description
dummy_node_id	int	Entity label
owning_group	pointer	Owning group
owner	pointer	Referenced member of group
next	pointer0	Next attribute, group or member_of_group
previous	pointer0	Previous ditto
next_member	pointer0	Next member_of_group in this group
previous_member	pointer0	Previous ditto

```
union GROUP_MEMBER_u
```

```
	{
	struct INSTANCE_s		*instance;
	struct FACE_s			*face;
	struct REGION_s			*region;
	struct LOOP_s			*loop;
	struct EDGE_s			*edge;
	struct VERTEX_s			*vertex;
	union  SURFACE_u		 surface;
	union  CURVE_u			 curve;
	struct POINT_s			*point;
	};
typedef union GROUP_MEMBER_u GROUP_MEMBER;

struct MEMBER_OF_GROUP_s	// Member of group
	{
	int				 dummy_node_id;		// $d
	struct GROUP_s			*owning_group;		// $p
	union  GROUP_MEMBER_u		 owner;			// $p
	union  ATTRIB_GROUP_u		 next;			// $p
	union  ATTRIB_GROUP_u		 previous;		// $p
	struct MEMBER_OF_GROUP_s	*next_member;		// $p
	struct MEMBER_OF_GROUP_s	*previous_member;	// $p
	};
typedef struct MEMBER_OF_GROUP_s *MEMBER_OF_GROUP;
```

Node Types

Node name	Node type	Visible at PK	Has node-id
ASSEMBLY	10	Yes	No
INSTANCE	11	Yes	Yes
BODY	12	Yes	No
SHELL	13	Yes	Yes
FACE	14	Yes	Yes
LOOP	15	Yes	Yes
EDGE	16	Yes	Yes
FIN	17	Yes	No
VERTEX	18	Yes	Yes
REGION	19	Yes	Yes
POINT	29	Yes	Yes
LINE	30	Yes	Yes
CIRCLE	31	Yes	Yes
ELLIPSE	32	Yes	Yes
INTERSECTION	38	Yes	Yes
CHART	40	No	
LIMIT	41	No	
BSPLINE_VERTICES	45	No	
PLANE	50	Yes	Yes
CYLINDER	51	Yes	Yes

CONE	52	Yes	Yes
SPHERE	53	Yes	Yes
TORUS	54	Yes	Yes
BLENDED_EDGE	56	Yes	Yes
BLEND_BOUND	59	No	
OFFSET_SURF	60	Yes	Yes
SWEPT_SURF	67	Yes	Yes
SPUN_SURF	68	Yes	Yes
LIST	70	Yes	Yes
POINTER_LIS_BLOCK	74	No	
ATT_DEF_ID	79	No	
ATTRIB_DEF	80	Yes	No
ATTRIBUTE	81	Yes	Yes
INT_VALUES	82	No	
REAL_VALUES	83	No	
CHAR_VALUES	84	No	
POINT_VALUES	85	No	
VECTOR_VALUES	86	No	
AXIS_VALUES	87	No	
TAG_VALUES	88	No	
DIRECTION_VALUES	89	No	
GROUP	90	Yes	Yes
MEMBER_OF_GROUP	91	No	

UNICODE_VALUES	98	No	
FIELD_NAMES	99	No	
TRANSFORM	100	Yes	Yes
WORLD	101	No	
KEY	102	No	
PE_SURF	120	Yes	Yes
INT_PE_DATA	121	No	
EXT_PE_DATA	122	No	
B_SURFACE	124	Yes	Yes
SURFACE_DATA	125	No	
NURBS_SURF	126	No	
KNOT_MULT	127	No	
KNOT_SET	128	No	
PE_CURVE	130	Yes	Yes
TRIMMED_CURVE	133	Yes	Yes
B_CURVE	134	Yes	Yes
CURVE_DATA	135	No	
NURBS_CURVE	136	No	
SP_CURVE	137	Yes	Yes
GEOMETRIC_OWNER	141	No	
HELIX_CU_FORM	163	No	
HELIX_SU_FORM	184	No	

Node Classes

Node class name	Node class
GEOMETRY	1003
PART	1005
SURFACE	1006
SURFACE_OWNER	1007
CURVE	1008
CURVE_OWNER	1010
POINT_OWNER	1011
LIS_BLOCK	1012
LIST_OWNER	1013
ATTRIBUTE_OWNER	1015
GROUP_OWNER	1016
GROUP_MEMBER	1017
FIELD_VALUES	1018
ATTRIB_GROUP	1019
TRANSFORM_OWNER	1023
PE_DATA	1027
PE_INT_GEOM	1028
SHELL_OR_BODY	1029
FIELD_NAME	1037

System Attribute Definitions

All system attribute definitions are of class 1.

Hatching

Identifier	SDL/TYSA_HATCHING	
Type_id	8003	
Entity types	face	
Fields	real	real 1
		real 2
		real 3
		real 4
	integer	Hatching type
Set by	Application	
Used by	Parasolid hidden line and wireframe images	

For **planar hatching** - the four real values define the hatch orientation as a vector and a spacing between consecutive planes.

For **radial hatching** - the first three real values define the spacing of the hatch lines. The fourth value is not used.

For **parametric hatching** - the first two real values define the spacing in *u* and *v* respectively. The last two values are not used.

Planar Hatch

Identifier	SDL/TYSA_PLANAR_HATCH		
Type_id	8021		
Entity types	face		
Fields	real	x component	‘direction’ or plane normal
		y component	
		z component	
		‘pitch’ or separation	
		x component	position vector
		y component	
		z component	
Set by	Application		
Used by	Parasolid hidden line and wireframe images		

For planar hatching, an attribute with this definition takes precedence over an attribute with the SDL/TYSA_HATCHING definition, if a face has both types of attribute attached.

Radial Hatch

Identifier	SDL/TYSA_RADIAL_HATCH	
Type_id	8027	
Entity types	face	
Fields	real	radial around
		radial along
		radial about
		radial around start
		radial along start
		radial about start
Set by	Application	
Used by	Parasolid hidden line and wireframe images	

For radial hatching, an attribute with this definition takes precedence over an attribute with the SDL/TYSA_HATCHING definition, if a face has both types of attribute attached.

Parametric Hatch

Identifier	SDL/TYSA_PARAM_HATCH	
Type_id	8028	
Entity types	face	
Fields	real	u spacing
		v spacing
		u start
		v start
Set by	Application	
Used by	Parasolid hidden line and wireframe images	

For parametric hatching, an attribute with this definition takes precedence over an attribute with the SDL/TYSA_HATCHING definition, if a face has both types of attribute attached.

Density Attributes

There are density attributes for each of regions, faces, edges and vertices in addition to the system attribute for density of a body.

The region/face/edge/vertex attributes will be taken into account when finding the mass, centre of gravity and moment of inertia of a body or of the entity to which the attribute is attached:

- The mass of a region will not include that of any of its faces or edges, and the same applies to faces and edges and their boundaries.
- A void region will always have zero mass whatever its density and a solid region will inherit its density from the body if it does not have a density of its own.
- The default density for faces, edges and vertices is always zero.

Density (of a body)

Identifier	SDL/TYSA_DENSITY	
Type_id	8004	
Entity types	body	
Fields	real	Density
	string	Units
Set by	Application	
Used by	Parasolid Mass Properties - calculation of mass	

A body without a density attribute is taken to have, by default, a density of 1.0.

The character field units is not used by Parasolid but it can be set and read by the application.

Region Density

Identifier	SDL/TYSA_REGION_DENSITY	
Type_id	8023	
Entity types	region	
Fields	real	Density of region
	string	Units
Set by	Application	

Used by	Parasolid Mass Properties - calculation of mass

This attribute only makes sense for solid regions; void regions always have a mass of zero.

A solid region without a density attribute is taken to have, by default, the same density as its owning body.

The character field units is not used by Parasolid but it can be set and read by the user.

Face Density

Identifier	SDL/TYSA_FACE_DENSITY	
Type_id	8024	
Entity types	face	
Fields	real	Density of face
	string	Units
Set by	Application	
Used by	Parasolid Mass Properties - calculation of mass	

The value of this attribute is treated as a mass per unit area.

A mass will be calculated for a face only when a face possesses this attribute. In all other cases the mass of a face is not defined.

The character field units is not used by Parasolid but it can be set and read by the user.

Edge Density

Identifier	SDL/TYSA_EDGE_DENSITY	
Type_id	8025	
Entity types	edge	
Fields	real	Density of edge
	string	Units
Set by	Application	
Used by	Parasolid Mass Properties - calculation of mass	

The value of this attribute is treated as a mass per unit length.

A mass will be calculated for an edge only when an edge possesses this attribute. In all other cases the mass of an edge is not defined.

The character field units is not used by Parasolid but it can be set and read by the user.

Vertex Density

Identifier	SDL/TYSA_VERTEX_DENSITY	
Type_id	8026	
Entity types	vertex	
Fields	real	Mass of vertex
	string	Units
Set by	Application	
Used by	Parasolid Mass Properties - calculation of mass	

The value of this attribute is treated as a point mass.

A mass will be calculated for a vertex only when a vertex possesses this attribute. In all other cases the mass of a vertex is not defined.

The character field units is not used by Parasolid but it can be set and read by the user.

Region

Identifier	SDL/TYSA_REGION	
Type_id	8013	
Entity types	face	
Fields	string	Unused
Set by	Application	
Used by	Parasolid hidden line images	

Regional data will allow the application to analyze a hidden-line picture for distinct regions in the 2D view.

Colour

Identifier	SDL/TYSA_COLOUR		
Token	8001		
Entity types	face edge		
Fields	real	Red value	These three values should be in the range 0.0 to 1.0
		Green value	
		Blue value	
Set by	Application		
Used by	Application		

Reflectivity

Identifier	SDL/TYSA_REFLECTIVITY	
Token	8014	
Entity types	face	
Fields	real	Coefficient of specular reflection
		Proportion of colored light in highlights
		Coefficient of diffuse reflection
		Coefficient of ambient reflection
	integer	Reflection power
Set by	Application	
Used by	Application	

The attribute types for Reflectivity and Translucency are also used by the Parasolid routine RRPIXL, but the use of this routine is not recommended.

Translucency

Identifier	SDL/TYSA_TRANSLUCENCY
Token	8015

Entity types	face		
Fields	real	Transparency coefficient	range 0.0 to 1.0, where 0 is opaque and 1 is transparent
Set by	Application		
Used by	Application		

Name

Identifier	SDL/TYSA_NAME	
Token	8017	
Entity types	assembly, body, instance, shell, face, loop, edge, vertex, group, surface, curve, point	
Fields	string	Name of entity
Set by	Application	
Used by	Application	

Entities read into Parasolid from a Romulus 6.0 transmit file have their names held in name attributes. Only entities to which the user has given names will be treated in this way.

Incremental faceting

Identifier	SDL/TYSA_INCREMENTAL_FACETTING	
Token	TYSAIF	
Entity types	face	
Fields	string	Unused
Set by	Parasolid incremental faceting/Application	
Used by	Parasolid incremental faceting/Application	

Transparency

Identifier	SDL/TYSA_TRANSPARENCY
Token	TYSATY

Entity types	Body, face	
Fields	integer	Non-zero transparency coefficient value is transparent
Set by	Application	
Used by	Parasolid hidden-line drawings	

A body may be rendered transparent if it has an attached transparency attribute with a non-zero transparency coefficient

Non-mergeable edges

Identifier	SDL/TYSA_NO_MERGE	
Token	TYSAEN	
Entity types	edge	
Fields	string	Unused
Set by	Application	
Used by	Parasolid modeling operations	

If an edge has an attribute of this definition attached, it indicates that the edge should not be merged in any modelling operations.

Group merge behavior

Identifier	SDL/TYSA_GROUP_MERGE	
Token	TYSAGM	
Entity types	group	
Fields	string	Unused
Set by	Application	
Used by	Parasolid modeling operations	

If a group has an attribute of this definition attached, it indicates that alternative behavior should be used if an entity in the group is merged with an entity not in that group.