Software Systems Flight Data Bases

Data Format Description

Format Revision 11.0
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TABLE OF CONTENTS

TABLES

Data Format Description for Software Systems Flight Data Bases

1 Introduction

This document describes the concepts and file formats of a simple, binary visual system data base. This data base format can be created and edited using the "mgflt" version of the Software Systems MultiGen program, and is called the MultiGen flight data format, or simply the *flight* format. Flight has been designed to support low end visual systems, and to be easily expandable. The data base format is generally designed to meet update requirements, and is therefore not necessarily optimized for real time use; however, it can easily be compiled into a different format, if desired, to accommodate a specific real time software's requirements.

2 Concepts Supported in Flight

The flight data base format is designed to support both simple and relatively sophisticated real time software applications. The full implementation of flight supports variable levels of detail, instancing (both within a file and to external files), replication, animation sequences, bounding boxes for real time culling, shadows, advanced scene lighting features, lights and light strings, transparency, texture mapping, material properties, and several other features.

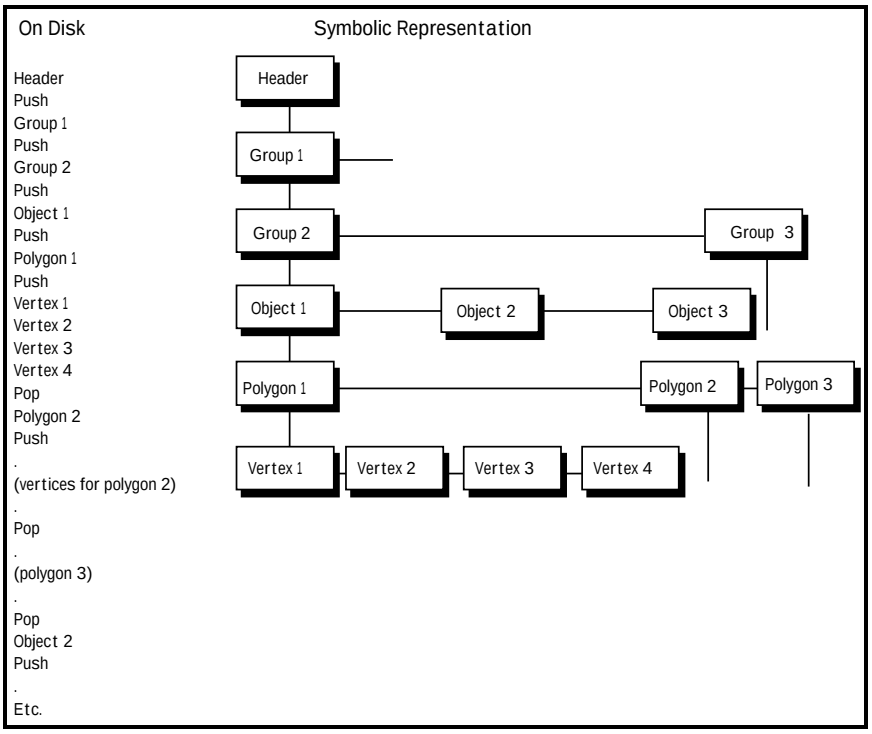
A simple real time software package that interprets a flight data base can implement a subset of the data base specification, and use data bases that contain that subset. Such an application would scan for the color table, polygons, and vertices, and ignore the groups, objects and other more sophisticated features described here.

3 Data Base Hierarchy

The flight data base hierarchy allows the visual data base to be organized in logical groupings, and to facilitate real time functions such as level of detail switching and instancing. The flight data base is organized in a tree structure. Each node of the tree can point down and/or across (see Figure 1).

Header: There is one header record per file. It is always the first record in the file and represents the top of the data base hierarchy and tree structure. The header always points down to a group.

Group: A group is a logical subset of a data base. MultiGen allows groups to be manipulated (translated, rotated, scaled, etc.) as a single entity. Groups can point down and across to other groups, level of detail beads, or to objects.



.Figure 1. Example of Data Base Hierarchy

Level of Detail: A level of detail (LOD) bead is similar to a group, but it serves as a switch to turn the display of everything below it on or off based on range (the switch in/switch out distance).

Object: An object is a logical collection of polygons. An object can point across to another object and down to a polygon.

Polygon: A polygon is a collection of vertices that describe a closed polygon in a counter clockwise direction. Polygons have a color code associated with them.

Nested Polygon: A *nested* polygon (sometimes called a sub-face), is a face that lies within, and is drawn on top of, another "super" polygon. Nested faces can themselves be nested.

Vertex: A vertex contains a coordinate x, y, and z. Some vertices also contain vertex normals and texture mapping information.

4 Data Base Files

When MultiGen writes a flight data base to disk, it converts the tree structure to a linear stream of op codes and data. The first part of each record is a header that contains an op code, record length, and, in some cases, an 8 byte ASCII id. A *push* op code is used to specify that the next bead is a down pointer from the last bead described. A *pop* op code returns to the level above. If neither a push or pop op code is found between nodes of the tree, an across pointer is implied.

Thus, a polygon op code will be followed by a push op code, then all the vertices that describe the polygon, then a pop op code, which might be followed by the next polygon op code of the same object. Refer to Figure 1.

Flight data base files have the extension *.flt* by convention.

5 Instancing

Instancing is the ability to describe a group or object one time, and then display it one or more times with various transformations. The flight format supports instancing of objects and groups with rotate, translate, and scale operations.

In the flight format, a group or object definition that can be instanced is called an instance definition. An instance definition op code is followed by an ID and a stand alone data base tree. An instance is invoked from a group by following its op code by a transformation matrix op code, and the op codes for each translate, rotate, and scale operation (these are for MultiGen's use and can be ignored by the real time program), followed by an instance reference op code and an instance ID. Instance definitions can themselves contain instance definitions and references. Refer to Figure 2.

The flight format also allows entire data base files to be instanced. This is known as external instancing.

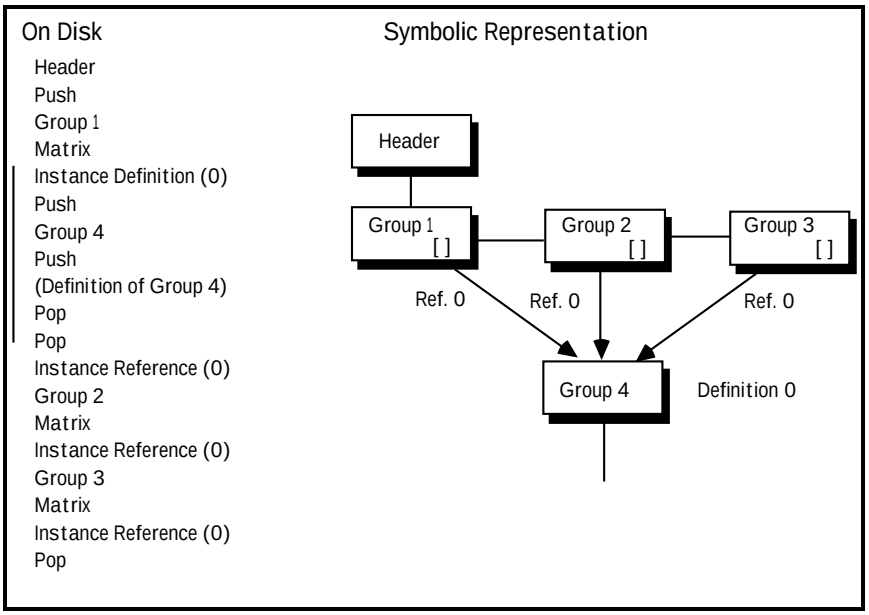


Figure 2. Instancing: Group 4 is Displayed Three Times

6 Replication

Replication is the ability to repeat the drawing of a group or object several times and applying a transformation each time. For example, a string of lights could be drawn by replicating a single light several times with a translation. In the flight format, replication is accomplished by following the group or object by one or more transformation op codes and a replication op code.

7 Bounding Boxes

Bounding box op codes can be used by the real time software to determine if a particular group is in view. The (optional) bounding box op code is placed immediately after the group op code, and includes the extents created by instancing and replication.

8 Flight Record Format

8.1 Header Record

The header record is found at the beginning of the data base file. The most important information for the real time software tells the value of LSB of integer coordinates. The *Units* field specifies whether the units are meters, feet, inches, etc. The Unit Multiplier/Divisor specifies how many of the units are represented by each LSB. A positive value represents a multiplier; thus a 4 in the units field and a 10 in the unit multiplier field would mean the vertex units are 10 feet. To avoid using floating point numbers, a negative multiplier is interpreted as meaning divide; thus a 4 in the units field and a -10 in the unit multiplier field would mean the vertex units are .1 feet.

Latitude and longitude values are stored in the data base header if it was created using the MultiGen Terrain Option. They are scaled integers which can be converted to floating point by the C language equation,

$$l_{float} = l_{int} \; / \; (float) \; (\; 1 << 30) * 360.0$$

Positive latitudes reference the northern hemisphere, and positive longitudes reference the western hemisphere.

Delta X and Y values are used to "place" the database when several separate databases are used to represent an area, each of which has a local origin of zero.

Table 8-1. Header Record Format

Data	Length

Type	(Bytes)	Description
Int	2	Op Code = 1
Int	2	Length of the record
Char	8	ID field (Not currently used)
Int	4	Format revision level = 6
Int	4	This data base revision level
Char	32	Date and time of last revision
Int	2	Next group ID number
Int	2	Next LOD ID number
Int	2	Next obj ID number
Int	2	Next polygon ID number
Int	2	Unit multiplier / divisor Positive for unit multiply Zero for no multiply / divide Negative for unit divide e.g. -100 = divide by 100
Int	1	Units of vertex coordinates 0 = Meters 1 = Kilometers 4 = Feet 5 = Inches 8 = Naut. miles
Int	1	if TRUE set texwhite on new polygons
Bool	4	Flags (left to right) 0 = Save vertex normals 1-31 Spare
Int	4	Southwest Data Base Corner Lat.
Int	4	Southwest Data Base Corner Long.
Int	4	Northeast Data Base Corner Lat.
Int	4	Northeast Data Base Corner Long.
Int	4	Latitude of Data Base Origin (0,0)
Int	4	Longitude of Data Base Origin (0,0)
Int	4	Projection Type 0 = Flat Earth 1 = Trapezoidal 2 = Round Earth 3 = Lambert
Int	4	Southwest Data Base Coordinate X
Int	4	Southwest Data Base Coordinate Y
Int	4	Delta X to Place Database
Int	4	Delta Y to Place Database
Int	4	Lambert Upper Lattitude
Int	4	Lambert Lower Lattitude
Int	4 *50	Spare

8.3 Group Record

The group flags can be queried by the real time software if required. The *animation* flags specify that the beads directly below the group are an animation

sequence; each bead is a frame of the sequence. The special effects IDs are normally zero, but can be set to support various application programs interpretation of the data. The group's *relative priority* specifies a fixed ordering of the object relative to the other groups at this level; since MultiGen sorts based on this field before saving the data base, it can be ignored by the real time software.

Table 8-2. Group Record Format

Data Type	Length (Bytes)	Description
Int	2	Op Code = 2
Int	2	Length of the record
Char	8	7 char ASCII ID; 0 terminates
Int	2	Group relative priority
Int	2	Spare for fullword alignment
Bool	4	Flags (left to right) 0 = Terrain 1 = Forward animation 2 = Cycling animation 3 = Bounding box follows 4-31 Spare
Int	2	Special effects ID 1 - RT defines
Int	2	Special effects ID 2 - RT defines
Int	2	Significance Flags
Int	4*12	Spare

8.3 Level of Detail Record

The slant range distance is calculated by the real time software by using the distance from the eyepoint to the LOD center found in the bead; this center takes instancing and replication into account. When the *Use previous slant range* flag is set it means that the slant range is the same as the previous level of detail at the same level. This can be used to save the real time software the calculation of redundant slant ranges when determining if a level of detail should be displayed.

Table 8-3. Level of Detail Record Format

Data Type	Length (Bytes)	Description
Int	2	Op Code = 3
Int	2	Length of the record
Char	8	7 char ASCII ID; 0 terminates
Int	4	Switch in distance
Int	4	Switch out distance
Int	2	Special effects ID 1 - RT defines
Int	2	Special effects ID 2 - RT defines
Bool	4	Flags (left to right)

		0 = Use previous slant range 1 Used for SPT Calculations = 0 if replacement LOD = 1 if additive LOD 2 = Freeze center (don't recalculate) 3-31 Spare
Int	12	Center coordinate of LOD block
Int	4*14	Spare

8.4 Object Record

The time of day object flags can be used to stop display of certain objects depending on the current time of day. The illumination flag, when set, means the object is self illuminating, and therefore not subject to the normal lighting effects. The shadow flag is used to indicate that the object represents the shadow of the rest of the group; when part of a moving model (e.g. an aircraft), this shadow can be displayed on the terrain or runway by the real time software with appropriate distortions to provide a realistic effect. The object's *relative priority* specifies a fixed ordering of the object relative to the others in its group; since MultiGen sorts based on this field, it can be ignored by the real time software.

Table 8-4. Object Record Format

Data Type	Length (Bytes)	Description
Int	2	Op Code = 4
Int	2	Length of the record
Char	8	7 char ASCII ID; 0 terminates
Bool	4	Flags (left to right) 0 = Don't display in daylight 1 = Don't display at dusk 2 = Don't display at night 3 = Don't illuminate 4 = Flat shaded 5 = Group's shadow object 6 = Terrain 7-31 Spare
Int	2	Object relative priority
Int	2	Transparency factor = 0 for solid = 0xffff for totally clear
Int	2	Special effects ID 1 - RT defines
Int	2	Special effects ID 2 - RT defines
Int	4*16	Spare

8.5 Polygon Record

Color codes are made up of 5 bits of color followed by 7 bits of intensity in both polygons and vertices. The color record which follows the header defines the brightest RBG components of each color code. The other intensities can be calculated by linearly interpolating these components. Although flight format allows as many as 128 intensities to be defined, the software interpreting the flight format can use fewer by ignoring the least significant bits of the intensities.

If a polygon contains a non-negative material code, its apparent color will be a combination of the face color and the material color as described in the Material Record section below.

Table 8-5. Polygon Record Format

Data Type	Length (Bytes)	Description
Int	2	Op Code = 5
Int	2	Length of the record
Char	8	7 char ASCII ID; 0 terminates
Int	4	Reserved for IR code
Int	2	Polygon relative priority
Int	1	How to draw the polygon = 0 Draw solid backfaced = 1 Draw solid no backface = 2 Draw wireframe and not closed = 3 Draw closed wireframe = 4 Surround with wireframe in alternate color = 8 Omni-directional light = 9 Uni-directional light = 10 Bi-directional light
Int	1	texwhite = if TRUE, draw textured polygon white (see note 1 below)
Int	2	Primary color / intensity code
Int	2	Secondary color code, if any
Int	1	Not used
Int	1	Set transparency =0 None =1 Fixed = 3 Axis type rotate = 5 Point rotate
Int	2	Not used
Int	2	Texture pattern no. 0 or -1 if none (see note 2 below)
Int	2	Material code [0-63]. -1 if none.
Int	2	Surface material code (for DFAD)
Int	2	Feature ID (for DFAD)
Int	4	IR Material codes

Int	2*2	Spare

Notes: (1) The texwhite field allows the polygon color to be ignored if drawn with texture, or used if drawn without texture enabled. (2) A 0 in the texture pattern field may indicate either that the face is not textured (if created before version 10 of flight) or that texture pattern 0 has been applied (in version 10.0 and after). In the latter case, texture u,v fields will be included in vertex records (see below).

8.6 Vertex Records

Table 8-6. Vertex Record Format

Record Type	Data Type	Length (Bytes)	Description
Absolute	Int	2	Op Code = 7
Vertex	Int	2	Length of the record
	Int	4	X coordinate
	Int	4	Y coordinate
	Int	4	Z coordinate
	Float	8	*Optional texture (u, v)
Shaded	Int	2	Op Code = 8
Vertex	Int	2	Length of the record
	Int	4	X coordinate
	Int	4	Y coordinate
	Int	4	Z coordinate
	Int	1	Hard edge flag
	Int	1	Don't touch normal when shading flag.
	Int	2	Vertex color
	Float	8	*Optional texture (u, v)
Normal	Int	2	Op Code = 9
Vertex	Int	2	Length of the record
	Int	4	X coordinate
	Int	4	Y coordinate
	Int	4	Z coordinate
	Int	1	Hard edge flag
	Int	1	Don't touch normal when shading flag.
	Int	2	Vertex color
	Int	12	Vertex normal, scaled * 2**30
	Float	8	*Optional texture (u, v)

*Check the length to determine if the texture u,v field is included in the record.

8.7 Control Records

Table 8-7. Control Record Format

Record Type	Data Type	Length (Bytes)	Description
Push Level	Int	2	Op Code = 10
	Int	2	Length of the record = 4
Pop Level	Int	2	Op Code = 11
	Int	2	Length of the record = 4
Push Subface	Int	2	Op Code = 19
	Int	2	Length of the record = 4
Pop Subface	Int	2	Op Code = 20
	Int	2	Length of the record = 4

8.8 Comment Records

Comment records contain text that can follow the header, group, level of detail, object, or polygon records.

Table 8-8. Comment Record Format

Data Type	Length (Bytes)	Description
Int	2	Op Code = 31
Int	2	Length of the record
Char	(variable)	Text description of data base

8.9 Color Table

Table 8-9. Color Table Record Format

Data Type	Length (Bytes)	Description
Int	2	Op Code = 32
Int	2	Length of the record
Int	6	Brightest RGB of color 0, intensity 127
Int	6	Brightest RGB of color 1, intensity 127
etc.		
Int	6	Brightest RGB of color 27
Spare	4*6	Space for colors 28-32
Int	6	Fixed intensity color 0 (4096)
Int	6	Fixed intensity color 1 (4097)
etc.		

Note that the first part of the color record contains the *brightest* RGB of colors 0-27, intensity 127. Intensities 0-126 for each of these colors are calculated by linearly interpolating between intensity 0, which is black for all colors (RGB 0, 0, 0), and the values provided for intensity 127. Space is provided for colors 28-32, but they are not currently used by MultiGen. The second part of the color table contains the RGBs of 56 fixed intensity colors which do not require any interpolation. The color/intensity field of the polygon or vertex attributes referencing these colors will contain a value of 4096 for the first fixed intensity color, 4097 for the second fixed intensity color, etc.

8.10 Material Table

The material table contains descriptions of 64 material types. The material table is not written with the data base unless a face has been assigned a non-negative material code. The appearance of a face in MultiGen is a combination of the face color and the material code. The face color is factored into the material properties as follows:

Ambient

The displayed material's ambient component is the product of the ambient component of the material and the face color:

Displayed ambient (red) = Material ambient (red)* face color(red)
Displayed ambient (green) = Material ambient (green)* face color(green)
Displayed ambient (blue) = Material ambient (blue)* face color(blue)

For example, suppose the material has an ambient component of {1.0, .5, .5} and the face color is {100, 100, 100}. The displayed material will have as its ambient color {100, 50, 50}.

Diffuse:

As with the ambient component, the displayed material's diffuse component is the product of the diffuse component of the material and the face color:

Displayed diffuse (red) = Material diffuse (red)* face color(red)
Displayed diffuse (green) = Material diffuse (green)* face color(green)
Displayed diffuse (blue) = Material diffuse (blue)* face color(blue)

Specular:

Unlike ambient and diffuse components, the displayed specular component is taken directly from the material:

Displayed specular (red) = Material specular (red)
Displayed specular (green) = Material specular (green)
Displayed specular (blue) = Material specular (blue)

Emissive:

Currently, emissivity is not taken into account in the MultiGen drawing code and no means for setting emissivity is provided by MultiGen.

Shininess:

MultiGen drawing takes the shininess directly from the material. Specular highlights are tighter with higher shininess values.

Alpha:

MultiGen drawing takes the alpha directly from the material. An alpha of 1.0 is fully opaque, 0.0 is fully transparent.

Table 8-10. Material Table Format

Data Type	Length (Bytes)	Description
Int	2	Op Code = 66
Int	2	Length of the record
Float	4	Ambient red component of material 0.*
Float	4	Ambient green component of material 0.*
Float	4	Ambient blue component of material 0.*
Float	4	Diffuse red component of material 0*.
Float	4	Diffuse green component of material 0*.
Float	4	Diffuse blue component of material 0.*
Float	4	Specular red component of material .*
Float	4	Specular green component of material 0.*
Float	4	Specular blue component of material 0.*
Float	4	Emissive red component of material 0.*
Float	4	Emissive green component of material.*
Float	4	Emissive blue component of material 0.*
Float	4	Shininess. (A single precision floating point value [0.0-128.0]).
Float	4	Alpha. (A single precision floating point value [0.0-1.0], where 1.0 is opaque).

Bool	4	Flags 0 = Materials used 1-31 Spare
Int	4*31	Spares for material 0.
Float etc.	4	Ambient red component of material 1.*

*Single precision floating point values, [0.0, 1.0]

8.11 Transformations

Table 8-11. Transformation Matrix Format

Data Type	Length (Bytes)	Description
Int	2	Op Code = 49
Int	2	Length of the record
Float	16*4	4x4 Single Precision Matrix

Note: Op codes 40-48 follow the transformation matrix, and specify the individual transformations that make up the make the matrix. These op codes are for MultiGen use only, and should be ignored by the real time software reading the file.

8.12 Geometry

Table 8-12. Vector Formats

Record Type	Data Type	Length (Bytes)	Description
Vector	Int	2	Op Code = 50
	Int	2	Length of the record
	Int	4	i component, 32 bit float
	Int	4	j component
	Int	4	k component
Bounding Box	Int	2	Op Code = 51
	Int	2	Length of the record
	Int	12	X, Y, Z of lowest corner
	Int	12	X, Y, Z of highest corner

8.13 Replication and Instancing

Table 8-13. Replication and Instancing Formats

Record Type	Data Type	Length (Bytes)	Description
Replicate	Int	2	Op Code = 60
	Int	2	Length of the record
	Int	2	Number of replications
	Int	2	Spare for fullword alignment
Instance Ref.	Int	2	Op Code = 61 (Rev 3 code = 16)
	Int	2	Length of the record
	Int	2	Spare
	Int	2	Instance definition number
Instance Def.	Int	2	Op Code = 62 (Rev 3 code = 17)
	Int	2	Length of the record
	Int	2	Spare
	Int	2	Instance definition number
External Ref.	Int	2	Op Code = 63
	Int	2	Length of the record
	Char	200	199 char ASCII Path; 0 terminates

8.14 Texture Pattern File Reference

There is one record for each texture pattern referenced in the database.

Table 8-14. Texture Pattern File Reference Format

Data Type	Length (Bytes)	Description
Int	2	Op Code = 64
Int	2	Length of the record
Char	80	Filename of texture pattern
Int	4	Pattern index
Int	4	x location in texture palette
Int	4	y location in texture palette

Add 1 to the pattern index and the polygon pattern reference number on Silicon Graphics machines because the texture pattern IDs start at 1.

A palette and pattern system can be used to reference the texture patterns. A MultiGen texture palette is made up of 64 patterns, currently 256 texels on a side. The pattern index for the first palette is 0 - 63, for the second palette 64 - 127, etc. Note that if less than 64 patterns exist on a palette, several pattern indices will be unused. The x and y palette locations can be used to store offset locations in the palette for display.

8.15 Eyepoint Positions

Table 8-15. Eyepoint Position Formats

Record Type	Data Type	Length (Bytes)	Description
Eyepoints	Int	2	Op Code = 65
	Int	2	Length of the record
Last Position 0	Int	3*4	X, Y, Z of rotation center
	Float	3*4	Yaw, Pitch, Roll angles
	Float	16*4	4x4 Single Prec. Rotation Matrix
	Float	4	Field of View
	Float	4	Scale
	Float	2*4	Near and Far clipping plane
	Float	16*4	4x4 Single Prec. Fly Through Matrix
	Float	3*4	X, Y, Z of eyepoint in database
	Float	4	Yaw of Fly Through
	Float	4	Pitch of Fly Through
	Float	3*4	i, j, k Vector for eyepoint direction
	Int	4	Flag (True if no Fly Through)
	Int	4	Flag (True if ortho drawing mode)
	Int	4	Flag (True if this is a valid eyepoint)
	Int	11*4	Spare
Eyepoint 1	Same as Last Position (256 bytes)		
Eyepoint 2	Same as Last Position (256 bytes)		
Eyepoint 3	Same as Last Position (256 bytes)		
Eyepoint 4	Same as Last Position (256 bytes)		
Eyepoint 5	Same as Last Position (256 bytes)		
Eyepoint 6	Same as Last Position (256 bytes)		
Eyepoint 7	Same as Last Position (256 bytes)		
Eyepoint 8	Same as Last Position (256 bytes)		
Eyepoint 9	Same as Last Position (256 bytes)		

Note: Total length of record is 256 bytes * 10 eyepoints plus header.

9.0 Texture Pattern Files

Flight format does not have its own texture pattern format but rather uses existing texture formats and refers to patterns by filename (see section 8.13). The following file formats are currently supported:

AT & T image 8 format (8 bit color lookup)
AT & T image 8 template format
SGI intensity modulation
SGI intensity modulation with alpha

SGI RGB
SGI RGB with alpha

The format of the file can be determined either from the file name extension, from magic numbers within the file, or from the texture attribute file as described below.

9.1 Texture Attribute Files

A corresponding attribute file is created for each texture pattern, with the name of the attribute file the same as the texture file followed by the extension *.attr*. These attribute files are used by MultiGen, and may not be necessary for the real time software using the data base. They are in the following format:

Table 9-1. Texture Attribute File Format

Data Type	Length (Bytes)	Description
Int	4	Number of pixels in u direction
Int	4	Number of pixels in v direction
Int	4	Real world size u direction
Int	4	Real world size v direction
Int	4	X component of up vector
Int	4	Y component of up vector
Int	4	File format -1 Not used 0 AT & T image 8 pattern 1 AT & T image 8 template 2 SGI intensity modulation 3 SGI intensity w/ alpha 4 SGI RGB 5 SGI RGB w/ alpha
Int	4	Minification filter type
Int	4	Magnification filter type
Int	4	Repetition type
Int	4	Repetition type in u direction
Int	4	Repetition type in v direction
Int	4	Modify flag
Int	4	x Pivot point for rotating textures
Int	4	y Pivot point for rotating textures
Int	17*4	17 spare words for expansion

The attribute file is used to determine how to parse the texture pattern file and to determine how the texture hardware and software environment is to be set for that pattern.