

# REAL 3D PRO-1000

*Professional Series*



a Lockheed Martin Company



## Product Description



# REAL 3D PRO-1000

*Professional Series*

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## Product Description

**November 1996**

**Version 3.1e**

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# ***REAL 3D PRO-1000 Series***

## **PRODUCT OVERVIEW**

The REAL 3D® PRO-1000 series is the latest in a family of high performance image generator products. With over 25 years of experience in producing high quality, high reliability, fully programmable image generator systems, the REAL 3D PRO-1000 makes use of high-end features at an extremely low price. Compatible with the popular Multi-Gen™ modeling system and with the very popular Gemini GVS™ real-time system software module, REAL 3D PRO-1000 promises to be a break through in price performance for the location based entertainment (LBE), industrial and commercial training market place. With over 100,000 CompuScene product systems shipped for the entertainment and military marketplace, Lockheed Martin Corporation is the recognized leader in delivering volume products to the consumer marketplace. Steeped in its heritage of real-time image generation, with over 40 graphics patents including MIP-mapped tri-linear interpolation texture mapping algorithms, depth buffer, and a new patent-pending S-buffer anti-aliasing technology, the REAL 3D PRO-1000 will provide the very best image generation capabilities at an order of magnitude reduction in price from other systems on the market today. Most systems available today are designed as engineering workstations. The REAL 3D PRO-1000 was built as an image generator and, therefore, meets those applications that demand true real-time image generation performance. REAL 3D PRO-1000 interfaces with host computational devices via an industry standard SCSI II port, allowing the user to select from a personal computer to high performance workstation to control real-time operation. This, in turn, brings low cost industry standard development tools to the real-time processing environment.

At the heart of the system are several new custom Application Specific Integrated Circuits (ASIC's) which provide geometry processing of over 25,000 visible polygons at 30Hz. Pixel fill rates can reach 200 million pixels per second for 60 Hz operation with reasonable depth complexities. With Gemini Technology Corporation's GVS software package, applications programmed with GVS for other workstation platforms will port easily to the REAL 3D product line. The performance and image quality is superior to competitive offerings at a fraction of the cost. The following data describes the standard features incorporated in the REAL 3D PRO-1000 system.





## TECHNICAL SUMMARY

The REAL 3D PRO-1000 visual system is a true low cost, high performance image generator for serious simulation applications. All image related computations are performed in the image generator. The REAL 3D PRO-1000 is controlled by a user-supplied personal computer or workstation which acts as host for control programs and as a link to the rest of the simulation system. The Image Generator system off-loads intensive floating point computations and all “out-the-window” image management tasks from the host computer to achieve a sustained rate of 30 or 60 frames per second of display update rate. Basic pixel fill rate is 50 megapixels per second. Pixel fill rate can be expanded to 100 megapixels per second by simply adding a pixel fill daughter board to the system. A high resolution model which has four pixel boards offers 200 megapixels per second fill rate. This is especially important for high resolution and 60 Hz update requirements. Additionally, 8 MB of on-board MIP-mapped texture random access memory is available. REAL 3D’s patented MIP-mapped, tri-linear interpolation and microtexture algorithms are used to process unmatched visual scenes. Anti-aliasing is performed as a post process using a Patent Pending proprietary image processing algorithm.



## HARDWARE ELEMENTS

The REAL 3D PRO-1000 visual system hardware is comprised of three electronic subsystems housed in a single desktop or deskside enclosure. These subsystems segregate the functions of scene processing and have the following capabilities:

The host interface subsystem controls data transfer to and from the simulation host computer via a differential fast-wide SCSI II bus. The interface supports a 20 megabyte per second transfer rate and allows for up to seven REAL 3D PRO-1000 systems to be connected to a single host interface card. Multiple host interface cards may be added for those applications requiring more than seven devices. Genlock capability is available within the PRO-1000 to synchronize display updates among multiple REAL 3D PRO-1000 configurations.

The rendering subsystem incorporates the latest in custom ASIC processors utilizing 0.5 micron technology to perform geometry and display functions. The geometry processor culls the display list, clips the images to the screen, controls the viewport processing, manages I/O over the private PCI bus, and transforms the data for presentation to the display function.

The display subsystem maps textures to the 3D polygons, transforms 3D space into 2D screen coordinate space, and outputs images to the display.



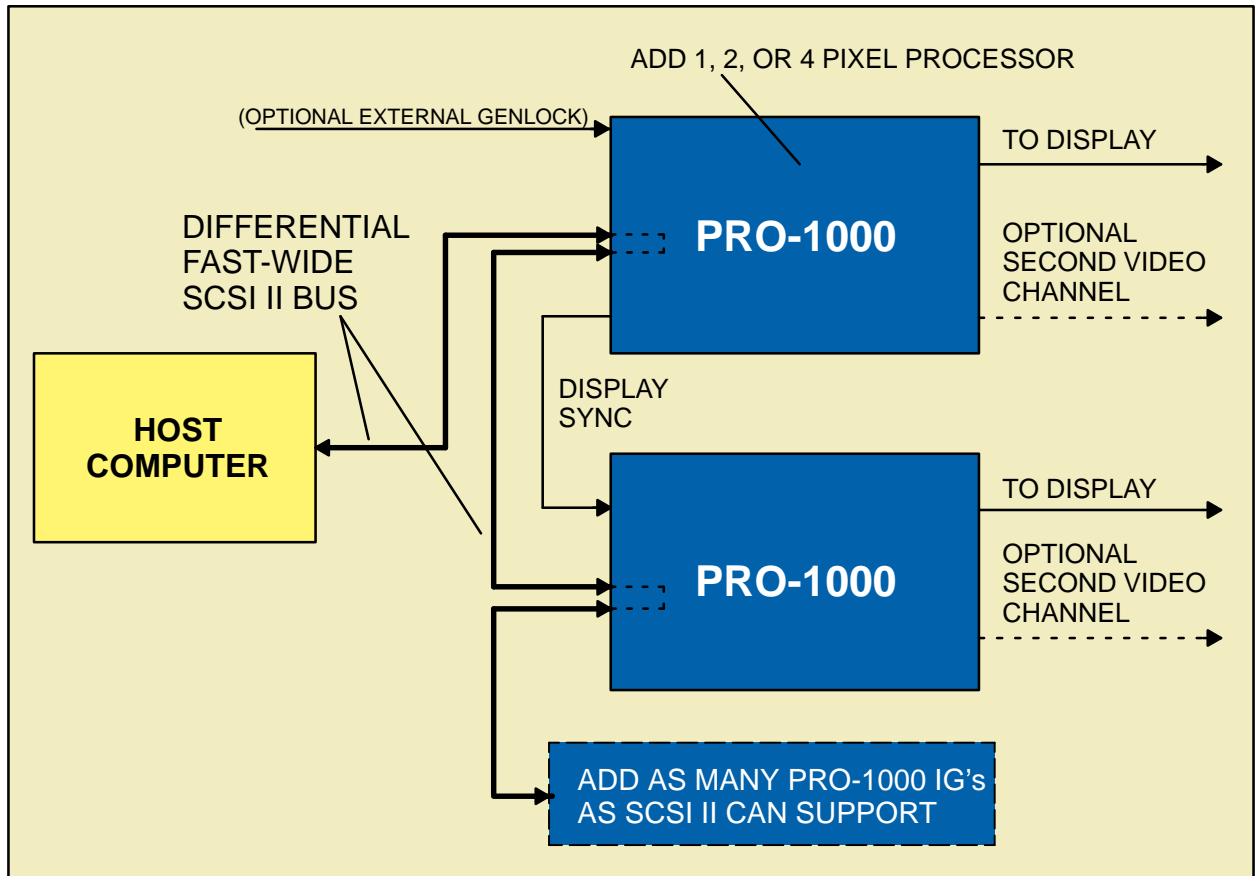
## SYSTEM CONFIGURATIONS

The REAL 3D PRO-1000 series image generator supports multiple configurations. The standard PRO-1000 configurations are listed by model number in Table 1. The system diagram is shown in Figure 1.

The PRO-1000 differential fast-wide SCSI II bus provides the interface to a host computer. The host computer may be a PC or a workstation.

**Table 1. PRO-1000 Series Standard System Configurations**

PRO-1000 Series Model Number	Pixel Processors	Pixel Writes
1100	1	50M
1200	2	100M
1400	4	200M



**Figure 1. PRO-1000 Series Image Generator System Diagram**



# UPDATE RATE AND DISPLAY MODES

## DISPLAY RESOLUTION

REAL 3D PRO-1000 can support multiple display resolutions at real-time rates of 30Hz and 60Hz. The standard resolutions are shown in Table 2 and Table 3. If multiple REAL 3D PRO-1000 systems are synchronized together, multiple channel configurations can be configured. The display parameters are programmable to allow for a variety of projectors and monitors. Contact REAL 3D for additional product information. This system supports both interlaced and non-interlaced formats. The digital to analog converters have a resolution of 8 bits per red, green, and blue component. Sync is negative composite. Model 1400 offers edge blending hardware to support alignment of adjacent display channels.

**Table 2. PRO-1000 Series Standard Resolutions (Single Channel)**

RESOLUTION	INTERLACE	UPDATE RATE	MODEL NUMBER
640H X 480V	non-interlace	30 Hz	1100/1200/1400
640H X 480V	non-interlace	60 Hz	1200/1400
512H X 384V	non-interlace	30 Hz	1100/1400
512H X 384V	non-interlace	60 Hz	1200/1400
1024H X 768V	non-interlace	30 Hz	1400
1024H X 768V	non-interlace	60 Hz	1400

Table 3 shows the allowable configurations for the dual monitor mode.

**Table 3. PRO-1000 Series Standard Resolutions (Dual Channel)**

RESOLUTION	INTERLACE	UPDATE RATE	MODEL NUMBER
512H X 384V	interlace	60 Hz	1200/1400
512H X 384V	non-interlace	30 Hz	1200/1400
640H X 480V	non-interlace	60 Hz	1400



### **TRANSPORT DELAY**

The transport delay is defined as the amount of time taken to render and display a new view of an image given a new viewing input command, such as a change in position or attitude. The transport delay for the REAL 3D PRO-1000 is 87 milliseconds for a 30 Hz frame update rate and 58 milliseconds for a 60 Hz frame update rate.

## **GEOMETRY PROCESSING**

### **DEFINITION OF THE TERM “POLYGON”**

A polygon is a fully rendered, textured, shaded, anti-aliased, fogged, illuminated, translucent, Z-buffered, 3 or 4 vertex geometric object. This is the true image generator manufacturer's definition of a polygon, however; it is quite different from that defined by workstation vendors. It is important to note this difference when comparing performance of various vendor offerings polygons.

### **DATABASE MEMORY**

Eight 8 MB of polygon memory is provided. With 8 MB of memory, a typical database can include over 100,000 polygons of active database storage. Additional database memory can be added in 8 MB increments by simply adding memory daughter boards up to a total of 32 MB of polygon memory capable of storing over 400,000 polygons.

### **GEOMETRY DATA FORMAT**

Position and attitude data for the ownship and other moving models are given to the image generator directly in 32-bit IEEE floating point format. Fixed point formats are also supported, where required, for those applications requiring geocentric databases.



### **DATABASE TRAVERSAL**

The REAL 3D PRO-1000 uses a proprietary algorithm that automatically disregards those polygons from geometric traversal that are excluded from the viewing pyramid. A database consisting of hundreds of thousands of polygons can be loaded into system memory, but the traversal only occurs on that which is visible in the scene. This eliminates a tremendous amount of unnecessary computational work for solving the image solution. In addition, the user does not have to know what is visible because REAL 3D PRO-1000 automatically tracks this for each field update. The database traversal also determines the correct level of detail (LOD) for each visible or moving database element.

### **MATRIX TREE DEPTH**

Real-time matrix tree decoding is done to a depth of 15.

### **POLYGONS / SYSTEM**

Each REAL 3D PRO-1000 system can process up to 25,000 polygons at 30 Hz or 12,500 polygons at 60 Hz. Polygon capacity for a multi-channel system is dictated by the number of REAL 3D PRO-1000 systems required to meet all system performance requirements. The number of channels per system is limited only by the host computer SCSI II port configuration. Thus 25,000 polygons per channel times the number of channels in a system yields the correct polygons per system.

### **INSTANCING (UNIVERSAL FEATURES)**

Any model may be instanced and its color may be changed for each instance.



# TEXTURE

## PERSPECTIVE TEXTURE

Perspective mapped texture is provided.

## TEXTURE ANTI-ALIASING

Texture will be tri-linearly interpolated to 8 bits of precision per color component.

## TEXTURE STORAGE

There are 4 million texture memory locations. A future option will increase texture storage to 16 million texture memory locations. Each texture memory location is a 16-bit word. Control bits determine how the 16-bit word is interpreted by the hardware. The 16-bit word may contain any combination of 4-bit monochrome texture, 8-bit monochrome texture, 15-bit color (5 bits red, 5 bits blue, 5 bits green, 1-bit translucency (on or off)), or 4 bits red, 4 bits blue, 4 bits green, and 4 bits of translucency.

Texture map size may range from 32 by 32 to 512 by 512 texels in increments of powers of 2, i.e. 64 x 128, 256 x 1k, etc. Microtexture and texture mip levels (LOD's) are included in the texel count.

## TEXTURE TRANSLUCENCY

Translucency may be specified as texture translucency or contour texture. Contour texture assumes that a white monochrome texel is transparent.

Up to 32 levels of translucency are available. Another texture map or alpha mask located in the same 16-bit word may be interpreted to modulate translucency instead of intensity or color. This allows the translucency of a texture map to be determined by the values of another texture band.





### **TEXTURE TRANSLATION**

The texture values, after tri-linear interpolation, may be translated to new values. This applies to color or intensity only (not texture translucency). There are several types of texture translation. The simplest translation multiplies the color of the polygon by the texel value and output.

Linear translation is also available. When using this type of translation, the color of the polygon is interpreted as a slope and a texture offset is provided. The texel is multiplied by the slope and offset by the texture offset, and then appropriately clamped to minimum and maximum values. This can be used only for color texture.

Another type is translator tables. Four translator tables are provided. This can be used only for monochrome texture. The most significant 6 bits of the texel are used as an address to a translator RAM. The user may initialize the RAM to any desired value via a host update.

### **MIRROR TEXTURE MAPS**

This function mirrors texture maps along the x or y or both axes. The texture address is complemented by addressing the texture map in reverse order; thus, mirroring the texture map.

### **MICRO TEXTURE**

Micro texture supplements the texture pattern on a polygon by adding random texture detail to the texture patterns on polygons that are very close to the view point. Four color 128 x 128 maps are reserved for micro texture.

### **REPETITIVE TEXTURE**

Texture map addressing will roll over, repeating the same texture map repetitively on the polygon. This allows textures to cover large areas such as terrain. Control bits in the polygon allow texture smoothing to wrap around to the opposite side of a texture map to provide texture maps that repeat without any boundaries between the maps.



### **POLYGON, TEXTURE MAP AND TRANSLATOR UPDATE**

Capability is provided to transparently update the database, including texture maps and translator maps, from an external source. Polygon and texture updates are used for special effects such as explosions and moving texture maps. The host computer may update the culling memory and polygon memory. The texture memory and translator memory may be updated by either sending texel or translator data directly from the host computer, or commanding texel or translator data to be sent from the polygon storage to the texture storage. When a texture map is updated, all levels of detail of the texture map must also be updated.



# DATABASE FEATURES

## **MOVING MODELS, ARTICULATED PARTS, AND SPECIAL EFFECTS**

Any model may be a moving model, articulated part of a moving model, or one of many models in an animated sequence for a special effect. Internal storage is provided for up to 4096 direction cosine matrices, which allows up to 4096 coordinates sets to be processed. Note that one matrix must be reserved for each viewport.

## **DATABASE PAGING (FUTURE ENHANCEMENT)**

Blocking structures are available to both swap in and out database sections and qualify a group of objects as potentially visible in the view pyramid. However, since it is possible to keep over 100,000 polygons in memory simultaneously, database swapping is not used often.

## **DATABASE MANAGEMENT**

LOD structures switched in by range and optional performance monitoring are available to maintain maximum scene detail at real-time performance.

## **FEATURE PROCESSING**

The REAL 3D PRO-1000 incorporates up to 128 different database feature types. These types can have different settings for LOD processing and range processing. When the system encounters an overload condition, features can be blended out to reduce the load and attempt to maintain frame update rate. Trees, buildings, brush, hills, etc., are examples of feature types which can be controlled.



# IMMEDIATE MODE PROCESSING

## REAL-TIME MORPHING AND POLYGON CONTROL

Limited direct control of the polygons being processed is possible in the REAL 3D PRO-1000 system. Polygons can be processed and sent into the rendering subsystem in real-time by way of the host software control. These polygons are then processed with those in local database memory to produce special effects. 3D sea states, where a mesh of polygons is manipulated in real-time to create a moving ocean surface, is an example.

## HIDDEN SURFACE REMOVAL

A 24-bit floating point Z-buffer is implemented in the system. Additionally, co-planar polygons are supported through a stencil buffer.

## LEVELS OF OCCULTING

Inherent in a Z-buffer system, co-planar polygons can cause significant occulting problems. The REAL 3D PRO-1000 handles occulting problems with the use of a stencil buffer. The stencil buffer determines the highest priority polygon from a co-planar set and properly occults the lower priority polygons with the “stencil” of the higher priority polygon. This ensures that lines on the road, or tail numbers on an aircraft, do not disappear when they are in the same plane as the polygon from the underlying terrain or aircraft model.



# ILLUMINATION

## LIGHTS / CHANNEL

Polygons are traded one for one with lights. In theory, one REAL 3D PRO-1000 can produce 25,000 lights or 25,000 polygons or any combination of the two totaling 25,000. In practically, some lights require multiple polygons per light structure. The actual light capacity of the system will vary depending on the application.

## LIGHTS / SYSTEM

One light point is equivalent to one polygon. Light points are limited only by the number of channels in a total system configuration.

## LIGHT STRING FORMAT(S)

The placement, or arrangement of lights, is totally unrestricted in the REAL 3D PRO-1000 system.

## LIGHT FEATURES AVAILABLE

The REAL 3D PRO-1000 lights are controlled by the host computer and can be made to flash, strobe, fade with distance, vary in intensity, and vary with view angles (i.e. VASI and FLOLS). All lights have a level of intensity to control fade and size relative to distance from the eyepoint. Directional, flashing, strobe, steerable, and scaleable multi-colored lights are controlled by the host computer.



### **HEADLIGHT ILLUMINATION OR SPOTLIGHTS**

This function is used to simulate headlights, spotlights, or landing lights, etc. The illumination pattern is an ellipse which can be scaled in the x and y directions. The maximum radius of the ellipse is 2047 pixels which allows the light lobe to cover adjacent displays. The direction of the light lobe and the size can be changed dynamically via the host interface. The extent of the illumination (the distance from the illumination source to the point where the illumination from the light source starts decreasing) can be specified. The intensity of the illumination decreases as a function of the inverse distance from the eyepoint to each pixel when the extent of the light lobe has been reached. Also the illumination decreases as the square of the radius.

Headlight Illumination is designed to work with illumination sources which are close to the eyepoint such as illumination sources on ownship. The color of the light may be red, green, blue, yellow, purple, cyan, and white.

### **SWITCH CONTROLS**

All REAL 3D PRO-1000 lights can be independently controlled. Lights can also be grouped within the host so one command controls several lights.

### **GLARE EFFECTS OFF HAZE**

This is a supported function of headlights / spotlights. Illumination is varied in the scene to provide the effect of glare as typically seen in fog.



# VIEWPORTS

## DEFINITION OF VIEWPORT

A viewport is a rectangular area of the screen. As many viewports as desired can be processed however, since each viewport is processed by the same image generator board, the number of viewports is limited by the processing resources of the system. Processing statistics and line of sight range data are only returned for four viewports. The viewports are processed sequentially. As a practical limit, 4 viewports can be opened in each display channel. These viewports can overlap. The priority of each viewport may be specified with a viewport priority code. Viewport priority ranges from 0 to 3. If the viewport priority of multiple viewports are the same and the viewports overlap, the polygons will merge and become one scene in the overlapping areas.

## REAR VIEW MIRRORS

A rear view mirror can be thought of as a viewport within a channel. All of the parameters used in a complete channel with special effects can be applied here. Since viewports have a full 3D transformation matrix applied to the database, a rear view mirror in correct perspective and field of view may be implemented.



## WEATHER EFFECTS

### FOG

Fogging is provided. The density of the fog, and color can be dynamically changed. The amount of fog is a function of the amount of fog density (input from the host), and the polygons distance from the eyepoint to the pixel.

### VISIBILITY

Sufficient visibility accuracy is maintained to display features 40 miles from the viewpoint with a 5 degree minimum field of view.

### SUPPORTED FEATURES OF WEATHER EFFECTS

- Haze
- Scud/layered clouds
- Programmable linear fade attenuation
- Sun position
- Updatable ambient light
- Day/dusk/night color tables

### 3-D SEA STATES

Three dimensional sea states are accomplished by using polygon data. The visual effect, in conjunction with color, is that sea states 0 through 6 can be depicted by applying a sinusoidal motion model along with a real-time calculation of color. The effects of white caps are depicted by the application of 2D textures. The visual effect water, which appears to be realistic, and has the properties of 3D wave motion along with white caps and wakes produced by objects in the water. The 3D sea state also is directional producing the effects of wind and current on the wave surfaces. Wave motion calculations are a function of the host computer. REAL 3D PRO-1000 only provides the rendering of the resultant sea state calculations.





### ANTI-ALIASING

The REAL 3D PRO-1000 uses a unique high-speed hardware anti-aliasing technique. The display is calculated at the same resolution as the pixel resolution. Polygon edge crossings are used to process and filter the image to generate a high quality anti-aliased image. The result of edges of different surfaces cutting through the pixel will be weighed and the pixel colored accordingly. This eliminates many of the irritating raster graphics effects, such as stepping along edges of surfaces, and the caterpillaring effects seen when objects move across the screen. It also means that lights on nocturnal displays move smoothly and maintain correct relative positions with respect to other moving or static lights. One of the principal advantages of this high-speed hardware anti-aliasing method is that it can be readily applied with different display configurations and it is not restricted to a specific resolution.



## LOAD MANAGEMENT

The processing time for up to 4 viewports can be read by the host computer to determine if an overload has occurred or is impending. Load management is accomplished by the host computer using these processing times to control level of detail of models and terrain. Model level of detail is controlled as a function of the subtended angle of the model, or as a function of the model's distance from the viewer. A set of LOD control parameters can be assigned to each model and the model level of detail can be individually controlled by pixel size or distance. Translucency blending is provided for model level of detail transitions. There may be up to 128 sets of LOD control parameters, and the level of detail parameters may be controlled by the host.

### OVERLOAD CONTROL

The REAL 3D PRO-1000 supports two overload modes, frame lock mode and overload protect mode. Frame lock mode will reset and start another update period if the processing time should run over the specified update period (16.7ms/60Hz update or 33.3ms/30Hz update). Any polygons which have been processed will be loaded into the frame buffer and the picture will be incomplete. Overload protect mode will allow another update period to finish processing. In this case the system will automatically drop to one-half the update rate (i.e., from 60Hz to 30Hz). No hysteresis is in effect for this mode. The host computer may read these signals for synchronization purposes.

## ANIMATION SEQUENCES

Animation sequences are supported for morphing polygon data and texture animation. Special effects, e.g., fire, explosions, craters, and 3D sea states, can be performed on the system by host control.



## MISSION FUNCTIONS

### HEIGHT ABOVE TERRAIN

Height above terrain (HAT) is determined via the host computer.

### COLLISION DETECTION

Collision detection is performed by the host computer.

### LINE OF SIGHT RANGING

The PRO-1000 supports line of sight ranging. Line of sight ranging is calculated as range to closest pixel. Special database features such as smoke and clouds may be flagged to not return a range value.

## TRANSPARENCY

Polygons can be transparent as a result of LOD blending, texture, inherent polygon translucency and edge on translucency. The system supports up to 32 levels of translucency and transparency.

## LUMINOUS POLYGONS

A polygon may be flagged as a luminous polygon. When flagged, it will remain bright, as scene illumination fades. (i.e. Stays bright at night.)

## COLORS AVAILABLE

Each model may reference a color table. Each color table can store up to 4096 colors. A polygon may reference two different colors in a color table and have its final color be controlled by the viewport in which it is visible. Each individual polygon may be independently given a 24-bit color instead of indexing into a color table.



## SHADING

The REAL 3D PRO-1000 Professional Series Image Generator supports four types of shading, fixed, Gouraud, flat and specular.

### FIXED SHADING

Fixed shading allows the user to define per-vertex color modulation scalar parameters which are used to shade the polygon in real-time. These per-vertex fixed shading parameters shade the polygon independent of the sun vector and sun intensity parameters. Fixed shading may be used alone or in combination with any texture mapping available on the system.

### GOURAUD SHADING

Gouraud shading provides the user with the ability to define vertex normals for all the vertices of a polygon. These normals are used along with the sun lighting parameters in order to calculate instantaneous shading intensities on a per vertex basis in real-time. Gouraud shading may be used alone or in combination with any texture mapping available on the system.

### FLAT SUN SHADING

The flat sun shading model used in this system uses the polygon normal and the sun lighting parameters (sun vector, ambient and sun illumination intensities) to calculate a instantaneous illumination value that is applied uniformly across the polygon in real-time. Flat sun shading may also be used along with any texture mapping available on the system.

### SPECULAR HIGHLIGHTS

The specular shading model uses a specular reflection coefficient, polygon normal and shininess to compute a specular highlight on the polygon. Specular shading may also be used with flat shading and texture mapping.



## **MODELING TOOLS**

With the use of Gemini Technology Corporation's GVS real-time environment, Multi-Gen databases can be imported and operated on REAL 3D PRO-1000.

The REAL 3D PRO-1000 is also supported by the Lockheed Martin Corporation Target Database Generation System.

## **HOST INTERFACE**

The REAL 3D PRO-1000 receives commands and data from a PC or workstation host computer via a differential fast-wide SCSI II bus. The host is able to control as many as seven separate REAL 3D PRO-1000 systems with only one SCSI II board. Multiple SCSI II interface boards can be installed and operating in one host. This allows many separate synchronized channels to be operating simultaneously.



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