SPECIAL EFFECTS FOR STAR TREK II

THE GENESIS DEMO

Instant Evolution with Computer Graphics

by ALVY RAY SMITH

Since the special effects for Paramount's production *Star Trek II* were to be co-produced by Jim Veilleux and Ken Ralston at ILM (Industrial Light and Magic), the Lucasfilm special effects division, Jim Veilleux asked the Computer Graphics Project to consider doing the following scenes for his part of the production:

- A molecule sequence showing the transformation from crystalline inorganic molecules to DNAtype organic molecules, illustrating the "Genesis Effect."
- A planet size demo of similar nature, showing the transformation of a dead planet into a live one (originally to have been a liveaction rock-size demo).
- A voice recognition sequence for positive identification of Captain Kirk, for permission to see the Genesis Effect demo.
- A retina recognition sequence for further identification.

All sequences were to be on video monitors in the live-action set to accommodate our current ability to do only low resolution imagery. The voice recognition sequence was to use visual representations of vocal phenomena-e.g., sound tracks, frequency spectra. The retina sequence was to be a trucking shot from outside an eyeball, through its pupil, into the interior for a final pattern recognition scene with the retina. Because of fear of overcommitting our young group and partially prepared software, I proposed to Jim that we do only one of these sequences totally (the planetary Genesis Effect) and part of the retina recognition sequence (the retina pattern recognition

portion). The "Genesis Demo," as the first sequence came to be known, was selected because it seemed to fit well with our already scheduled software development plans (for texturemapping and matting), required only simple data structures (a sphere), and would need one-time-only code of fairly simple nature (e.g., 2-dimensional pixel wipes or related 2-dimensional hacks). A "hack" in this context is a quick-and-dirty program written just for the moment, with no generality, with no apparent future application, and filling no alloted slot in an overall software system. Our plans were later elaborated.

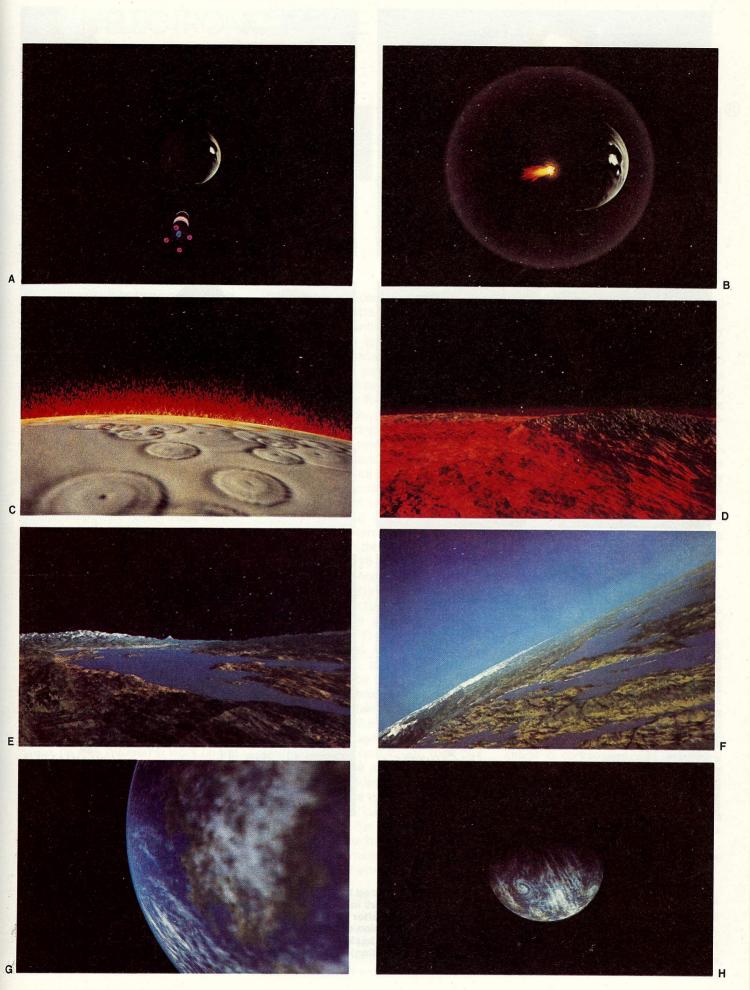
I also proposed that Bob Langridge of UCSF be asked to do the molecule sequence, which he gladly did, and that ILM do the flying into the eyeball. Jim and Paramount had decided by this time to scrap the voice recognition sequence. We were aware that Jim was filming star fields off the E&S (Evans & Sutherland) Digistar system in Salt Lake City and briefly considered doing these locally as well. This was rejected primarily because E&S had a superior machine (to our E&S Picture System II—the Digistar is a souped-up version designed for planetarium shows) and also because Jim was pleased with results obtained from them and did not see any reason to ask us to commit to yet another sequence.

Ed Catmull and I met with Jim Veilleux a couple of times to discuss our involvement—to be sure Jim understood that we did want to do something for the movie but did not want to overextend ourselves. We were convinced that he understood this well. He proposed that the sequence consist of a zoom-in on a planet, a 2-dimensional razzle-dazzle of some sort to indicate an explosion

of the planet, a white-out to allow a cut to live action for reaction shots, and a zoom-out on the transformed planet. The proposal was made after he listened to us and watched some of our early effects. In particular, Pat Cole had shown Jim a great variety of computer graphics techniques already in use. He had chosen his suggestions to ensure ease for us and to portray a certain amount of stylization which the producers desired in the sequence. In particular, all of his suggestions could be realized 2-dimensionally. Although the structure of the shot was still very loose at this time, Ed, Loren Carpenter, and I had all thought that it would be nice to incorporate some of Loren's astonishing fractal techniques into it and mentioned this to Jim. A "fractal technique" is a method using controlled randomness to enrich a synthetic scene. The artist enters only a small amount of data. The fractal program automatically amplifies this to a large, natural-looking database. We were already starting to generalize the effects to something fancier than Jim originally envisioned.

It should be mentioned at this point that we had already done one "miniproduction" (in August '81) for ILM to show off our abilities. We had rendered a model of the Starship Enterprise chasing a Klingon ship in 3dimensions, with appropriate lighting, coloring, etc. This was done using Loren's first working version of his 3-D rendering program "Reyes" (Renders Everything You Ever Saw). This mini-production had also featured several 2-D effects programmed by Pat Cole and Rob Cook. We believe that this demonstration was what prompted Paramount and ILM to ask us to do a piece of the final film. In it Continued on page 1048

Advanced computer graphics created by Lucasfilm Computer Division simulate the transformation of a planet for the Project Genesis Demo Tape. Each frame in the 67-second shot is defined by an array of 250,000 pixels for display on a 500-line video monitor. Anti-aliasing techniques increase apparent resolution of image so that raster lines are barely visible in these VistaVision frames. Approaching a barren, moonlike planet, we see the Genesis torpedo racing toward target (A); impact, explosion, and shockwave (B); and a wall of fire consuming the planet surface (C). Flying lower, we see geological shapes forming as the planet cools (D); an earthlike landscape emerging (E); and, as we turn and bank to pull away from the planet, a primitive atmosphere forming (F). Complex landscape was created by Lorne Carpenter with complex mathematics requiring an hour of computer time to calculate each frame. Rapid pullback in (G) and (H) reveals final Genesis planet rendered by matte artist Chris Evans with electronic paint program developed by Tom Porter.



Computer Graphics Continued from page 1039

we practiced our rule of "no aliasing" and hopefully convinced the Lucas-film people that we meant it. Aliasing in one of its more pernicious forms is somethimes referred to as the "jaggies." This is the look of little boxes or stairsteps which has plagued the early days of computer graphics. Unfortunately and erroneously, some people equate this look with computer graphics. It is like assuming the flicker of early movies is the nature of film.

Over a hurried lunch before a meeting one day with Jim Veillieux, I came up with a proposal for the Genesis Demo sequence which stretched our capabilities at that time and satisfied the ST2 requirements by supplying quite a bit more to them than requested. I suggested using the JPLstyle planetary flyby as metaphor. JPL (Jet Propulsion Laboratory, of CalTech) had just successfully flown the pair of Voyager spacecraft past Jupiter and Saturn, with computer simulations by Jim Blinn frequently shown on national television. The idea was that we could get away with quite complex camera moves because people were now familiar with strange angles from having been exposed to these flybys. The computer simulations of the flybys came to mind readily because Jim Blinn had spent a short time as part of our group before deciding to return to JPL several months earlier.

The full idea was that our imaginary camera would be attached to an imaginary spacecraft approaching the dead, moonlike planet from below. It would swing about the planet in a parabolic trajectory near its surface while the on-board camera would execute a large spiraling move to portray departure from the planet upside down-i.e., from above. The portion of the trajectory near the planet would last long enough and be close enough to show off the fractal mountain-building effect on its surface. then pull away revealing the resulting live, earthlike planet. As the spacecraft approached the dead planet, it would fire a sperm-shaped projectile at its surface to bring it to life then fly over the resulting chaos and eventual mountain-building process. The "chaos" was as yet unspecified but I envisioned something like the Jovian Red Spot turbulence seen by the Voyager flyby of Jupiter and lots of exploding volcanoes where the craters

formerly lay (as inspired by a painting by Don Davis).

I presented these ideas to Jim Veilleux and then to the Graphics Project to see if we could actually implement them and to ask for alterations and suggestions for the "chaos." The principal alteration at this time was to invert the camera move so that we approached the planet from above, departed from below. There was quite a bit of debate as to whether this motion was too dramatic or not. I argued that what would be happening on the surface was so overwhelming that the long twisting camera move would only be icing on the cake for those who chose to notice. The results of this first meeting were that Rob Cook would write the texturemapping program which would be used to surface the planet, Tom Porter would write the paint program for generating the textures on the planets and the compositing program for combining elements generated by other programmers, Loren Carpenter would build the mountains with his fractals, Ed Catmull and Tom Duff would do motion-blurring, and the "chaos" would be decided later.

Loren also took on the task of designing a flight path with a realtime geometric modeling program by Bill Reeves. This program, which runs on the E&S Picture System, represented the sphere by a wireframe. Loren was later to add indications to this planet representation for projectile impact point, its antipode, the terminator, and the polar cap which was to be the location for fractal mountains. He also represented several of the mountains. He designed dozens of flight paths, with me constantly kibitzing, using 7-dimensional cubic splines for smoothness and grace.

During this time, we obtained the Yale Bright Star Catalogue of 9100 visible stars of magnitude 6.6 or brighter. Loren converted the given database into xyz coordinates and deduced the colors of the individual stars. He had the notion of choosing a location for the Genesis planet in a part of the heavens which would place recognizable constellations in the background. He and I perused one of my astronomy books and came up with the five nearest stars for which there is some hope for existence of life. From one of these, Epsilon Indi, Loren determined that the Big Dipper would be visible in a form not too distorted from our Earth view of it. Furthermore, our sun would appear as an extra star in this constellation! As an extra bit of icing on this exercise, Loren went to an atlas, found the Indus river and the city at its mouth into the Indian Ocean. This city is Keti Bandar, which we took as our local name for the Genesis planet.

Meanwhile I had asked Tom Porter to design a volcano-exploding program based on a softedged line drawing routine he had already successfully implemented. I still did not quite know how to handle the transition from impact of projectile, to "chaos," to fractals. I was quite surprised when several days later, Bill Reeves. instead of Porter, came up with the fire rendering program. Bill's move was surprising because, although he had done a fine job of writing a blackand-white line-drawing package for the E&S Picture System, I had no idea he was interested in color images or raster-device images. I was delighted to learn that he wanted to make images as opposed to just building the tools for making them. (This has proved to be a characteristic of almost everyone in the Graphics Project.) He animated a few preliminary fires which were very beautiful and inspirational.

One night, getting quite frustrated that the "chaos" scene was not coming together, I sat down with Loren to brainstorm a solution. Since Bill had just demonstrated his fine fires it was clear these should be used somehow. We did away with the exploding volcanoes and came up with the notion of an expanding ring of fire which would spread like a prairie fire from the point of impact of the projectile melting the surface of the planet in its wake. I added the notion of losing the fire for a moment behind the limb of the planet, because of the camera move, and then having it dramatically reappear, very close and very large to swoop across the screen conveying great heat and fury-enough to melt a planet. Loren suggested using this racing wall of fire to sweep our attention across the planet in a swooping pan to the mountain-building portion. This was to be our transition sequence. It required Loren's adding a fire indication to his flight path program to allow us to choreograph the spread of the fire and time its sudden reappearance from behind the limb of the planet. As it turned out, Bill required a quite complex 10-step matting process, using Tom Porter's matting program, to achieve the desired effect.

Loren solidified the fractal sequence into its final form about this time: a cooling of the red hot liquid surface caused by the wall of fire, cooling through the yellows, reds, oranges, to gray while mountains begin to grow through the haze also created by the fire. This haze would later become the atmosphere of our final earthlike planet. The imaginary spacecraft would be speeding at 50,000 to 100,000 miles per hour across this forming surface. As the mountains reach their final altitude (Everest-like), oceans would rise to sandy shores, greens would spread, and snow appear on the peaks. Rob Cook supplied the color coordinates of these natural elements and found atmospherical models from which Loren later derived his atmosphere generation program.

Meanwhile, Rob's texture-mapping program became such a large project that it was clear that it would not be done in time for completion of the Genesis Demo sequence. So Tom Duff took on the task of writing a special purpose texture mapper for spheres. He eventually wrote a very difficult piece of code which preserved sharpness at all distances. was completely antialiased, supported local lighting of the surface by the wall of fire, and used "bump mapping" for pseudo-3D roughening of the surface of the cratered dead planet. His progress was slowed by an unfortunate fall, from a stage set, which broke his wrist. He wore his cast for the Christmas "holidays," which were not holidays for the Graphics Project. Our two large computers (VAX's) cranked day and night during this period on the fractal portion of the sequence, which eventually used about a month of computer time.

The beginning of the year 1982 found the fractals mostly done, and we began a race against the clock to finish the sequence by March 19. By this time, several rough tests had been shot and shown to both Jim Veilleux and Bob Sallin, the STAR TREK II producer. They were pleased with our work and very encouraging. Tom Porter had taken on the starfield generation program with motion blur. He also finished up the paint program. Bill Reeves continued to refine his fire generation code. Some of his fires required tracking a half-million fire particles through individual trajectories and incandescent color changes. Loren and Pat Cole added a shockwave sequence to the impact of the projectile, which was required for story continuity. Pat modeled the projectile on blueprints we received from ILM, using Bill's modeling program. Loren designed his atmosphere generation program. Tom Duff struggled to complete his texture mapper for spheres. Ed Catmull tried to make time in his busy managerial day to finish the motion-blurring program. I rode herd. Our group hardened into a team because of this experience and gained its first real production experiences as part of Lucasfilm.

We unveiled Tom Porter's paint program to the ILM matte artists Mike Pangrazio, Chris Evans, and Frank Ordaz in early February to their rave reviews. Chris proceeded to paint the earthlike texture map which was mapped, using Tom Duff's program, onto the surface of a sphere to create the final live planet.

A preliminary shoot on February 19 revealed several weaknesses in the sequence: moire in the cratered planet surface, loss of the stars because of overly "hot" foreground elements, unconvincing sweep of the fires across the planet, popping fractal polygons, miscellaneous blown frames, etc. Ed rushed to finish up his motion blurring program to alleviate the temporal aliasing. Rob Poor had his retinas photographed and digitized. (Actually four of us had our retinas photographed as a laser safety measure but Rob's retinas were the most interesting.) Pat, Loren, and I began serious discussions on the retina ID sequence which we planned to keep simple to fit into the remaining time. The principal idea was to tile the digitized retina photo with tiles of various sizes. Then we would move a vein template around over the tiled photo in an interesting way until a pattern match occurred, at which point some appropriate lettering and graphics would appear, indicating positive identification, and we would be done.

The filming of the final piece was performed by a film crew from ILM using the Empireflex VistaVision camera. ILM crews also shot three preliminary versions of the sequence during the course of this history. But the task of providing "dailies" (more like weeklies) for us was accomplished by David DiFrancesco, who purchased and installed a 16mm Bolex, and Rob Poor, who designed and built a straightforward computer interface to this camera. This same interface was

used also to drive the 35mm cameras from ILM on the "official" shoots. David also built a video scanner rig which was intended for digitizing the retina. The digital component of this assembly came from an outside manufacturer who was so late in delivery of a working version that the scanner was not finished in time for the shot. It is being readied for use in future work.

A word about the other equipment used, manpower, and computer power is in order. The VAX computers and E&S Picture System have already been mentioned. Other principal pieces of equipment were two Ikonas framebuffers, a Barco monitor. and a Hitachi tablet. It is estimated that we invested about 2 man-years of effort into this 80-second piece (60 seconds for the Genesis Demo and 20 seconds for the Retina ID sequences). There is no easy answer to "how long does a frame take?" except "it depends on the complexity of the scene." Some frames required five minutes, some required five hours. The Graphics Project hardware staff, headed by Rodney Stock and including Gary Newman, Adam Levinthal, Lane Molpus, and Glenn Sharp, is hard at work designing the Pixar, a machine to increase the speed of computing our frames by two to three orders of magnitude. Similarly, David DiFrancesco is constructing the laser-based input/output devices for the Pixar to greatly increase the resolutions at which we can work. The Genesis Demo task and its restrictions have underlined the importance of completing these projects.

Principal credits for the computer graphics on STAR TREK II should go to Loren Carpenter (fractal mountains, atmosphere, shockwave), Pat Cole (projectile, retina); Tom Duff (cratered sphere, texture-mapped sphere); Chris Evans (painted the pull-away planet surface); Tom Porter (stars, compositing, paint); Bill Reeves (fires); Alvy Ray Smith (concept, direction).

I like to think of the group as an offline rock group. We work very tightly together on our individual instruments for months, and only later do we face the music. The point is that all members of the team are creative contributors and a project requires all of them. A drummer is absolutely necessay but a fantastic drummer cannot carry a piece alone.

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Editorial—Advertising—Business Offices
1782 North Orange Drive
Hollywood, Calif. 90028
(213) 876-5080

Send mail to: P.O. Box 2230 Hollywood, CA 90028

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ON THE COVER

Bob Geldof as Pink watches television in an alien landscape created by production designer Brian Morris and cinematographer Peter Biziou for PINK FLOYD THE WALL. The film adapted from the album was written by Roger Waters, designed by Gerald Scarfe, produced by Alan Marshall and directed by Alan Parker, Photo by David Appleby.