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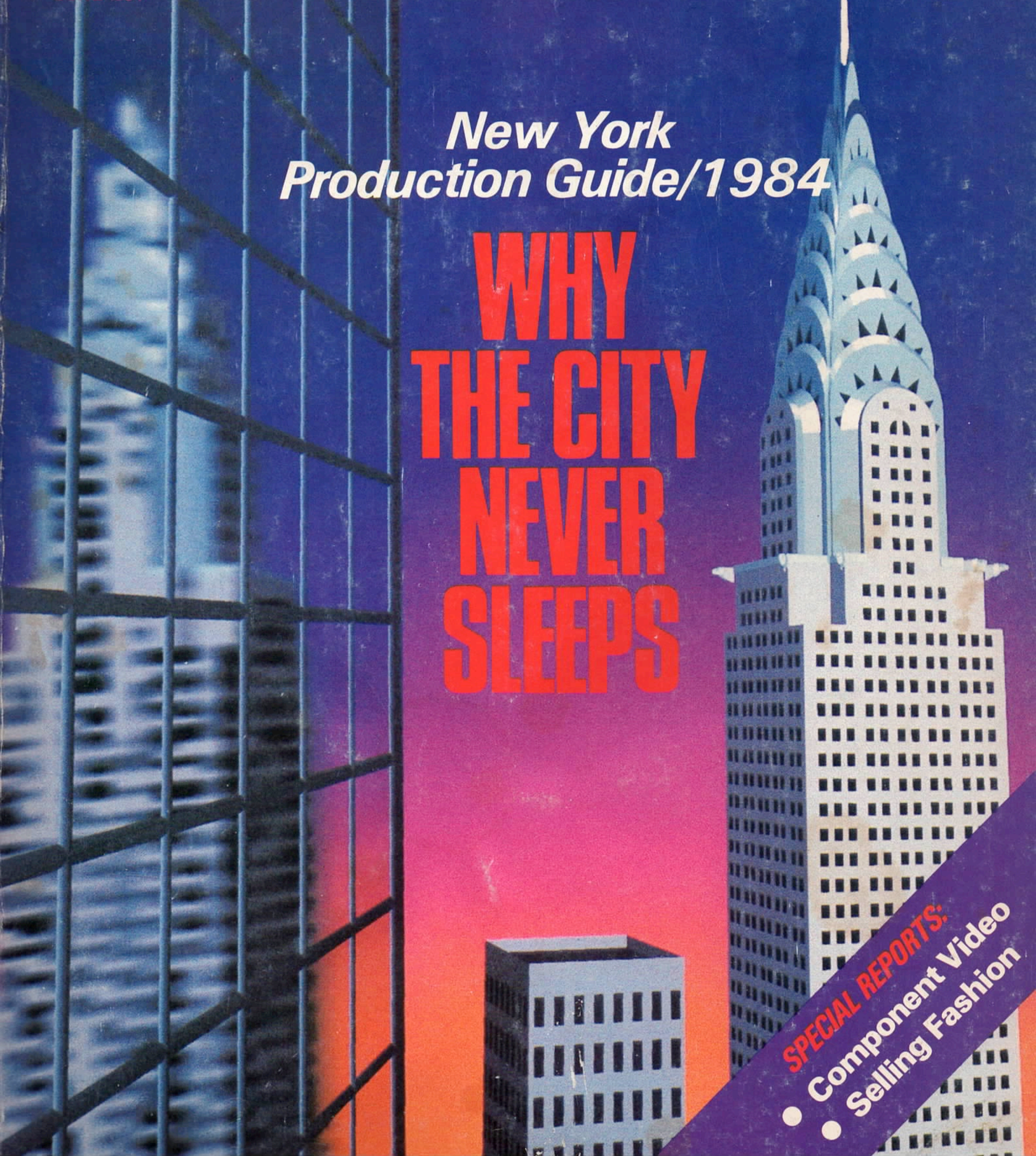


THE LAST STARFIGHTER

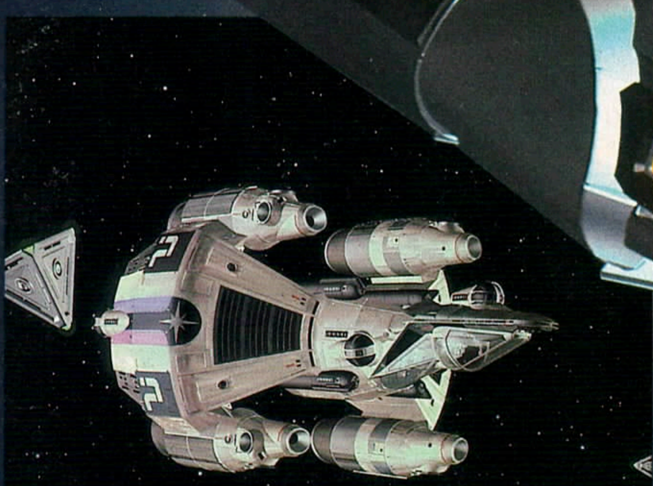
HOW FAR CAN SYNTHETIC IMAGING GO? A MOTION PICTURE TELLS THE STORY.

By RIC GENTRY

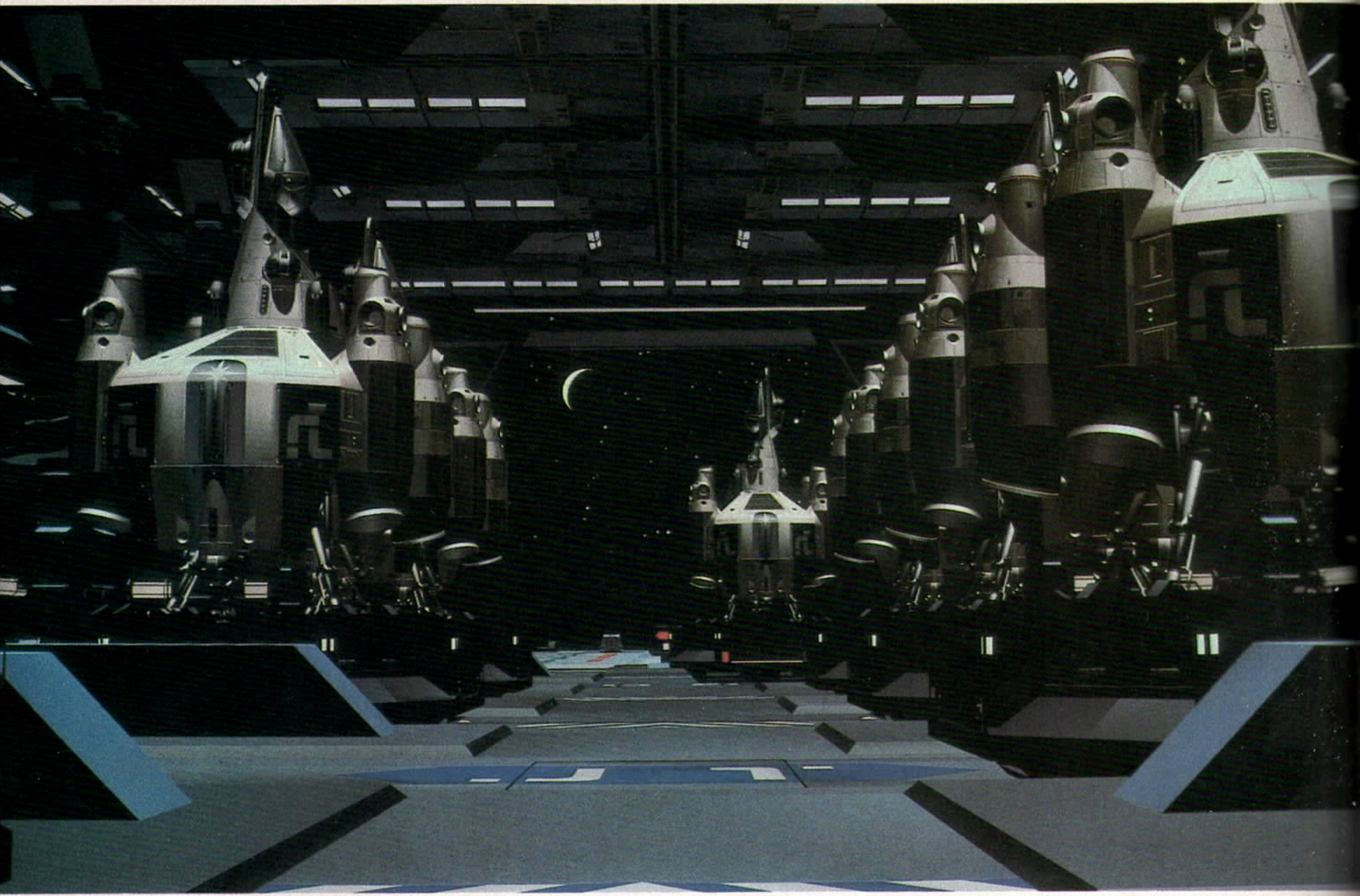
Lorimar's *The Last Starfighter* is an earthbound adventure in which a young man with expertise in combative video games is recruited by morally evolved, unaggressive aliens to defend their besieged planet. The script, written by newcomer Jonathan Betuel and directed by Nick Castle (his second feature film), is every video-game afficionado's fantasy. It is a straightforward attempt to combine the mass appeal of films about space with the games they imitate. But what makes *Starfighter* significant in the history of moving-visual imagery are the special effects. Unlike the effects in *Star Wars*, these were produced without reference to models, mattes, sets, or motion-control photography. Instead, they were conjured—with utmost photographic realism—with a computer.

Sequences of interplanetary flight, exotic extraterrestrial landscapes, vast military installations secluded in mountainsides, high-speed aerial pursuit through a labyrinth of tunnels within an asteroid, and full-blown galactic war are all depicted with exhilarating fluid dynamism, radiant color, sophisticated multiple illumination, extraordinary detail, and sensuous texture. It is the work of Di-

Ric Gentry is a screenwriter and documentary filmmaker living in L.A.



The Gunstar and target lights



gital Productions of Los Angeles and the culminating achievement to date of company cofounders, John Whitney, Jr., and Gary Demos. The technique, called digital scene simulations (DSS), is a process of mimicking filmed reality that the human eye is incapable of detecting. *Starfighter* is the outcome of some 10 years of research and development in computer graphics, but the summary yield of just two brief years in business.

Remarkable realism

Using the most powerful computer in the world today—the Cray X-MP, capable of one *billion* computations per second, with original (and proprietary) programs of enormous, truly esoteric complexity—*Starfighter's* creators believe the movie exceeds anything even remotely close in the field or history of computer-generated imagery (CGI). Each frame of special-effects footage averages 250,000 polygons (geometric building blocks that make a surface)—double the sophistication of any similarly produced imagery —at a computing time of two and a half minutes.

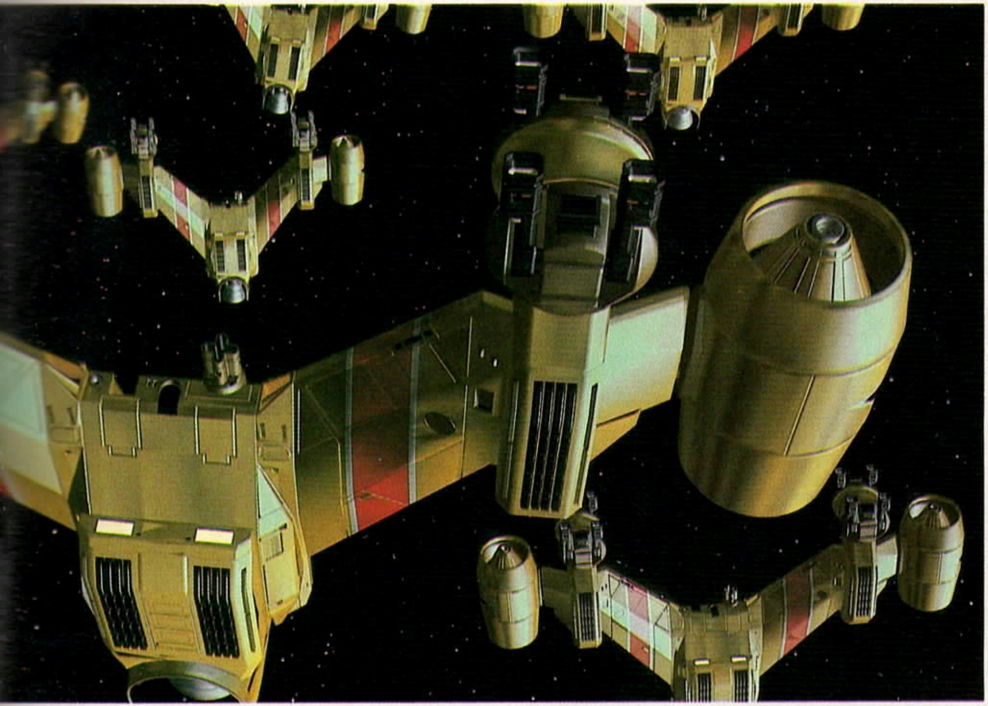
Some of the images contain a million polygons. The Gunstar, the film's mother ship, alone comprises almost 400,000 polygons, four times that of any previously produced object with CGI. Pictures of this magnitude belabor even the X-MP, taking up to five or more minutes to compute per frame. *Tron*, by comparison, often required an hour to make frames one-tenth as rich and complex. Moreover, Digital's visual locution is some eight times more cost effective. Of a total budget of $13.9 million, only about $3 million went to special effects. And this includes over 200 scenes and almost 25 minutes of imagery.

Many of the special effects, such as the vast mountainside hangar, are intercut with sets that detail activities of the characters. "It's impossible to distinguish between what was generated by the computer and what was physically built," says production designer and art director Ron Cobb, whose earlier credits include *Alien, Star Wars, Close Encounters of the Third Kind, Special Edition*, and *Raiders of the Lost Ark*. "*Tron* has a nice line between the two worlds, live action and computer effects, but with *Starfighter* we didn't have that luxury. There's a line-by-line comparison here with what a camera can record and what a computer can do. I didn't know if it was possible, but they look identical."

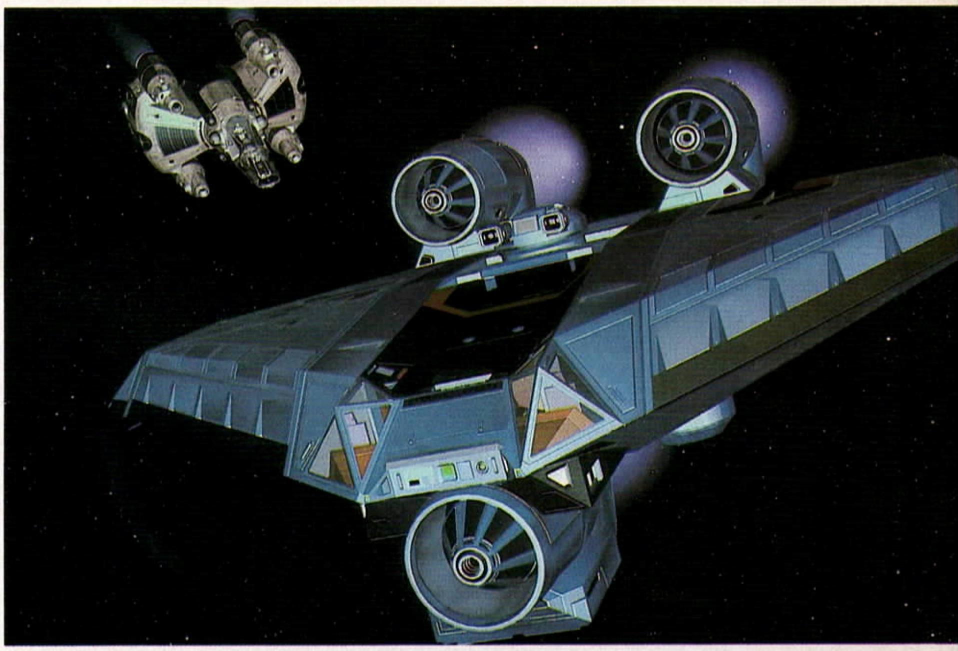
Director Castle was particularly taken with the luster of metals in the surface texture of the spacecraft. "The ships look literally made of an alloy," he says. "They shine, reflect, register shadows, have a sheen to them." The color spectrum also contributes to the realism. "You get the impression that they're burning fuels unique to their engine's power, or to the planet from which they're derived. I think with details like these we've exceeded anything else in special effects in this genre, and that certainly includes motion control."

Yet, for Whitney and Demos, *Starfighter* is only the beginning. While maintaining an interest and availing themselves readily to other special-effects projects, their goal is to simulate what Whitney calls "mundane reality," i.e., the immediate, tangible, physical world we all know. And with the exception of fully credible human beings (a virtually divine aspiration, when one considers it), they are not very far from that now. It is conimage. Third is the technical directing stage, in which surface texture, color, and lighting are added, all motions are resolved, and the entire composition of the image is determined. Fourth is the actual filming, wherein a custom-built camera records the previously designed images from a 5-inch monitor on a per frame basis. Each technical stage requires special skill, equipment, and software. Like a production process, the work flows serially through the stages, though it is possible (and frequent) for the work to be carried out in parallel.

The X-MP "super" computer is reserved for the final, high-resolution additions to the images that render them photorealistic. The X-MP, however, is the cornerstone of DSS. Ensconced in a high-security antechamber, it stands about six and a half feet tall and measures five feet in diameter. On first approach, one may see a resemblance, not inappropriately, to the monolith in *2001*. Inside are 3,400 circuit boards containing more than 200,000 chips stacked in 12 vertical col-



Above: Deck-fighter armada



Right: the Gunstar chasing a Zurian cargo ship

Facing page: Rylon base hangar

ceivable that within a decade, Digital Productions will be capable of producing up to three feature-length films per year, entirely simulated by the computer—from westerns to police stories to intimate dramas.

A good example of graphics produced by Digital Productions, though most viewers do not realize that it is entirely simulated, is the recently aired Pontiac Fiero commercial, in which the automobile is constructed, part by part, over a grid above the clouds (which diminishes into the horizon), and then rides smoothly forth, as the viewpoint of the action moves with birdlike exhilaration.

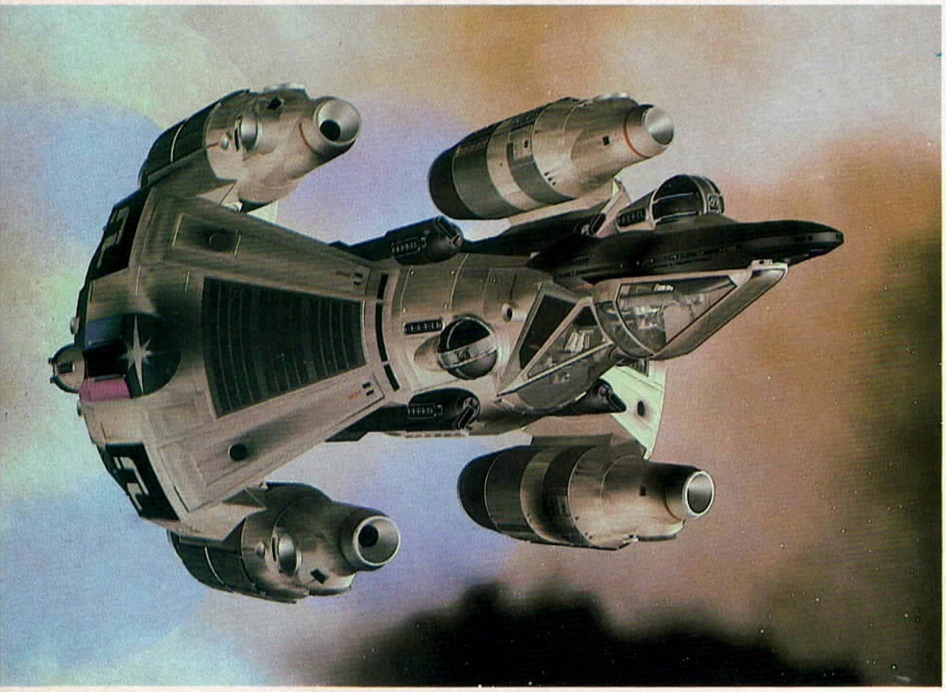
"*The Last Starfighter* was ideally suited to our techniques," Whitney says. "It hit right on target." Production began in March 1983 and was completed almost exactly one year later. "We put our best foot forward," Whitney adds. "We held nothing back in creating realistic scene simulation." *Starfighter* was produced by Gary Adelson and Edward Denault, and features Lance Guest, Dan O'Herlihy, Catherine Mary Stewart, and Robert Preston, with principal cinematography by King Baggot. It is being released through Universal.

Creating the effects

There are four fundamental steps in creating digital scene simulations, three of which have titles newly invented by Digital to suit the unique activity. First is the artistic design, executed by Ron Cobb, and the storyboard, by Nick Castle (with Carl Aldana). For *Starfighter*, the second stage is the drafter-encoder stage, in which the objects and set derived from the art work are reconstructed three-dimensionally and tested for movement in the "space" of the computer in a wirelike framework called a "vector"

umns, with 288 boards per column. Sixty-seven miles of wire connect the circuits, and due to the circular arrangement of the components, many of the wires are only a foot long. If they were much longer, the pulse of electrical currents running through them—at about half the speed of light—would mitigate the function of the computer and slow it down.

Operating at that speed generates enormous heat. To dissipate it, the circuit boards are braced in pairs by heavy copper heat-transfer plates that are cooled by compressed Freon gas pumped through



The Gunstar leaving the moon of Rylos

The Gunstar traveling through Rylosian clouds

tubes at 25° centigrade. The average temperature inside is 68°, but the mass of copper is what makes the X-MP so heavy; it weighs almost six tons. The speed of the computer forbids direct human communication. "Front end" computers—potent in themselves—are interfaced with the X-MP to relay signals from Digital's production stations. The encoding and motion information are completed on Ramtek 9400s and Vax 11/782 computers.

Whereas the computer animation team at LucasFilm finds a single Vax adequate for handling their simulations, Digital needs two later-model Vax mini-mainframes just to reach the X-MP, which is 400 times more powerful than the Vax, and (for the record) 10 million times more powerful than an Apple-II.

Drafting and encoding

Once the preliminary artwork and storyboards are approved, they are submitted to a drafting team specially skilled at mechanical and architectural drawing. They take the artwork and convert every object into a three-dimensional blueprint, with detail sufficient enough to be physically constructed. Instead, they are traced by a hand-operated electronic cursor on a magnetized table so that every line on the blueprint is visible on the computer screen. A wire frame, or black-and-white vector image, now appears and can be rotated on any axis and viewed from all sides. This is the "data base" from which all further simulation will proceed.

"The vector display system that we have," Whitney explains, "is designed to give as much feedback as possible and as early as possible. It allows for motions in real time, the three-dimensional orientation and positioning of the object on screen. This gives the operator the ability to see exactly what he's doing, because this is a fairly precise and refined process. The more feedback he has, the less likely he is to make a mistake. It's obviously desirable, when the data base is finished, that it be perfect."

Ron Cobb adds that this stage of DSS "greatly enhances your sense of design, because you're able to experience your work in 3-D space, observe it as you would any object in the real world, and get a very good sense of how it'll appear on screen without ever having to go to all the trouble of building it and finding out it's not quite right. You can modify what you have in a very short time."

Depending on the level of detail, it generally takes from one day to three weeks to draft-encode an object. A low-detail product shot might require a few hours, whereas a high-detailed one might take weeks. The enormously detailed Gunstar in *Starfighter* required almost three months.

The Gunstar, as noted, contains up to 400,000 polygons. A polygon is any enclosed geometric structure on the vector image that, when filled in, creates a surface. A minimal polygon is three interconnected dots forming a triangle. More complex polygons are obviously more difficult to encode and to later fashion into surfaces.

"I thought we should avoid compound curves," Cobb remarks. "The first thing I posed for myself was to try and design an elegant, interesting ship that disguised my simplified molecular geometry. So I pored over a lot of drawings with compasses and a straightedge, trying to visualize a cone intersecting a sphere and slowly building up from there."

Because of the time involved in drafting-encoding, up to 30 people will be working simultaneously. Once completed, the object or setting (perhaps layered a thousandfold with objects that occupy it) is given a name and stored in the computer. "An ever after," says Whitney, "available to us through the computer in completing the job."

Technical directing

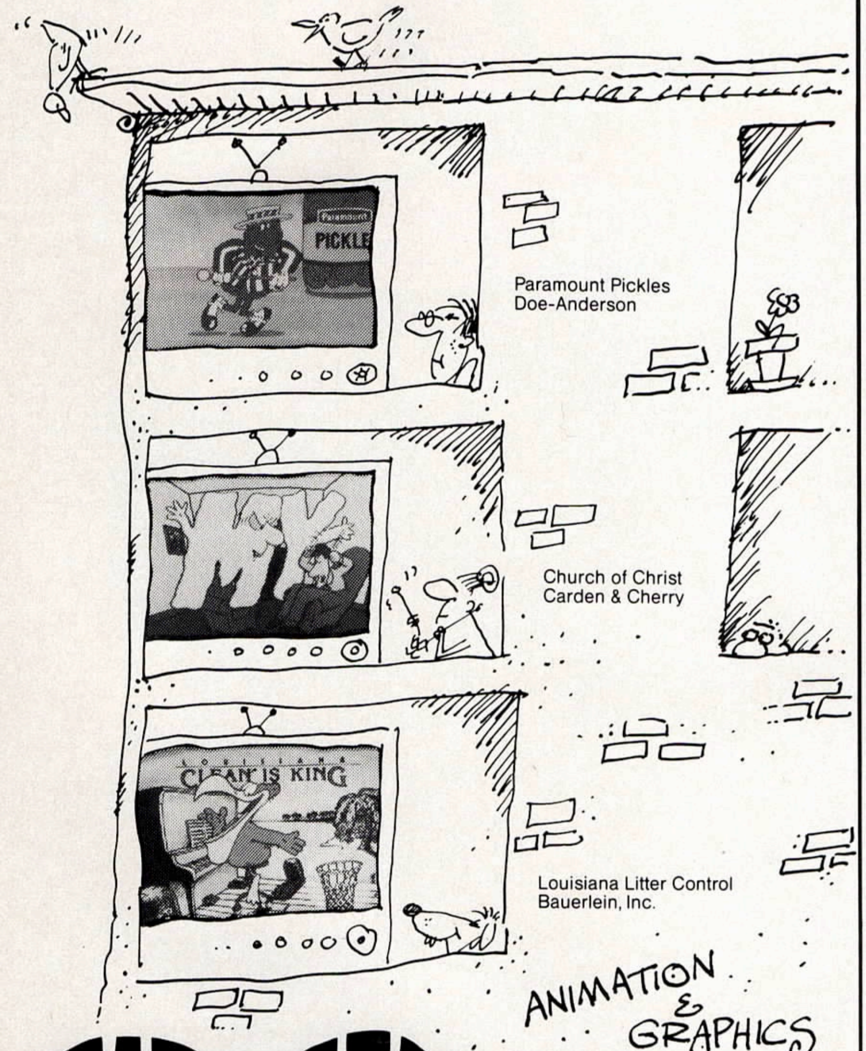
The technical director, usually working in concert with the director or the production designer, must first finalize the various motions of the objects (still in vector form) within the scene. This is followed by smooth-shading the polygons to create ostensible surfaces; an object that is given surfaces is commonly called a "raster" image. "You need to have surfaces in order to deal with color, texture, and light," says Whitney.

Each of the technical directors works at the most advanced Ramtek 1000×1000 color video monitors. "The software used is the 'front end' of our main rendering algorithms," Whitney continues. "The front-end language has a number of basic features that are critical to the successful realization of realism in simulation."

These features are the "commands" that produce and regulate the light sources and densities, surface quality and color, the arrangement of all the objects in the setting, and the angle of composition. "Given the software with all these commands in it, it ultimately falls on the technical director [to use his] judgment to properly set all the commands to achieve a desired look," says Whitney. "He doesn't necessarily [impose] his judgment on the client. He's there as a liaison officer, so to speak, [adapting] the client's needs to the computer world."

Procedures, in this respect, are ultimately simplified for the client. "I didn't know much about computers and still don't," remarks *Starfighter* director Castle, "but I do know how to speak to people that do know how to use them. And on that level, the director doesn't need to do much more than what he always does: tell them how to frame the shot or how to light something."

Latitudes in the lighting commands for the technical director are easily comparable to the lighting options of a cinematographer working in physical space—and, perhaps, then some. "It's amazing what you can do," comments Ron Cobb. "It's much more than you need. You can control the rate at which the light falls, or the smoothness or the density of the light. You can take a sphere and light it from the side, like a moon. You can have a highlight on something and then immediately drop off into darkness. Or [you can] go all the way to parallel light, where one half is perfectly illuminating and the other half perfectly dark, with a sharp line between them, and where the angle changes so subtly that none of us looking at the monitor will know how to interpret it. You can soften the source so much that it almost disappears and you can barely detect where the light's coming from.



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"For the reflectivity of the object, you can get a light kick that makes the substance look like wood or chrome or plastic or glass or even rubber, which is really light absorbent. What's really interesting is that you can establish a light in the middle of the room and see the effect of the light but not the source. You'll get shadows on the face from a particular direction, but the source is missing. You'll know the light's there, but no one else consciously does. Plus, with every light, there's a full range of color and intensity, and distances clear to infinity." Certain scenes for *Starfighter* had up to 20 sources of light.

Images can also be viewed and shaped through a variety of styles approximating camera lenses—wide through long, with every focal point in between. There's even a zoom, to distinguish from tracking shots, and a fisheye.

The dialectic between image blocking and staging, and the means by which they are viewed (together, often, in radical simultaneous movement) lends DSS its capacity for dazzling montageless shot choreography. "We're able to generate moves of enormous subtlety," says Cobb. "For one scene in *Starfighter*, we tracked everything from all points of view. We follow the Star Car around the base of a cliff, and then it banks and swings up the side so that you follow, going around the cliff face. Rising above that, you see the approach of the landing tunnel in the distance. The car catches up to your height, you travel forward together, very rapidly in perfect coordination, getting closer to the tunnel where the approach lights become visible. You zoom on in, as the nose settles over the runway, hits an uneven ground, bounces and springs on the shock absorbers, and then rolls in for the landing in this vast interior hangar, where activity is going on everywhere. You're casing the action all along. One shot."

At the conclusion of the technical director's work, the images are formulated, but not yet in a resolution that is fully photorealistic. It would take far too much time to have it otherwise. The introduction of resolution high enough to appear photorealistic occurs in the last stage of DSS.

Final filming

Digital Productions has two equally useful cameras for this last stage, both of which are high quality pin registered and shutterless. One is an Acme 35 mm process camera. The other is designed by George Randall and engineered by Doug Fries, both L.A. technicians. The 210 mm lens was also custom made by Pacific Optical. The film stock is Eastman Kodak 5247.

The camera is interfaced with a cathode ray tube (CRT) capable of 4,000 ×6,000 raster elements of resolution. By comparison, an ordinary home television has but a 512×512 resolution display. What these numbers mean is that on each axis, going across the screen both horizontally and vertically, there are that many "pixles," or minute dots. The resolution on the home TV comprises about a quarter of a million pixles, while the CRT at digital has 24 million.

The latter is also rectangular, in keeping with a motion-picture-film aperture, instead of a square. It is also much smaller, physically, at about 5 inches in diameter.

Now, while such high-resolution imaging systems are often major design problems in themselves, they are not unique. DP's is far from the only one in the world. What is unique, however, is that this system operates at tremendous speeds. Tele-

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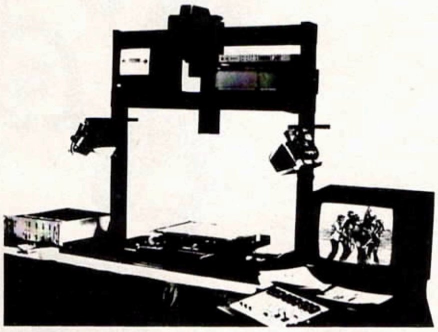

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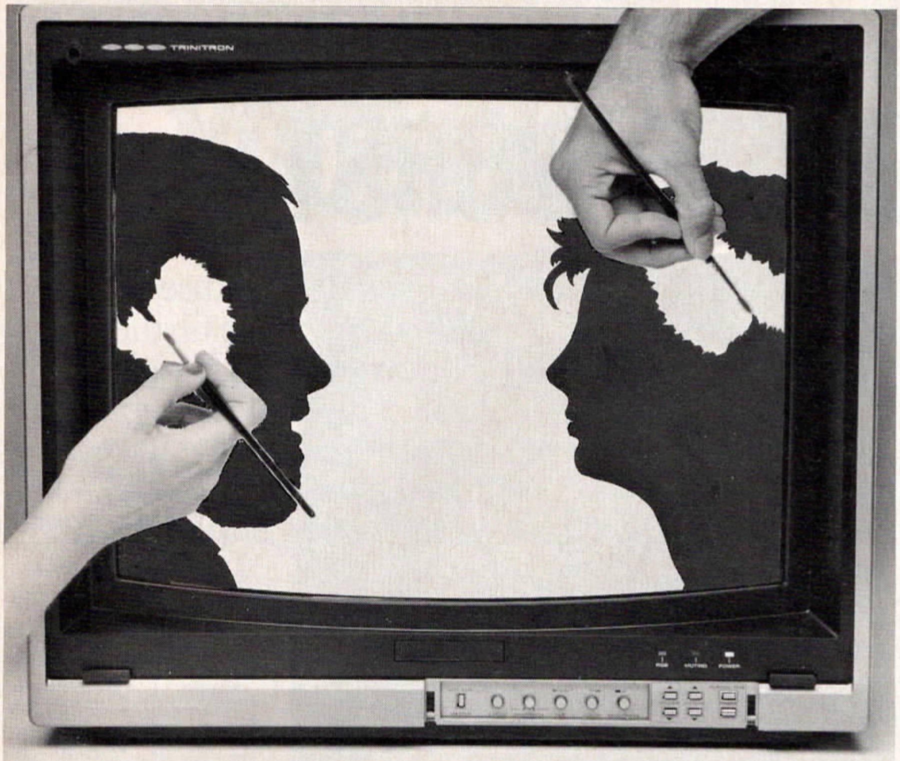

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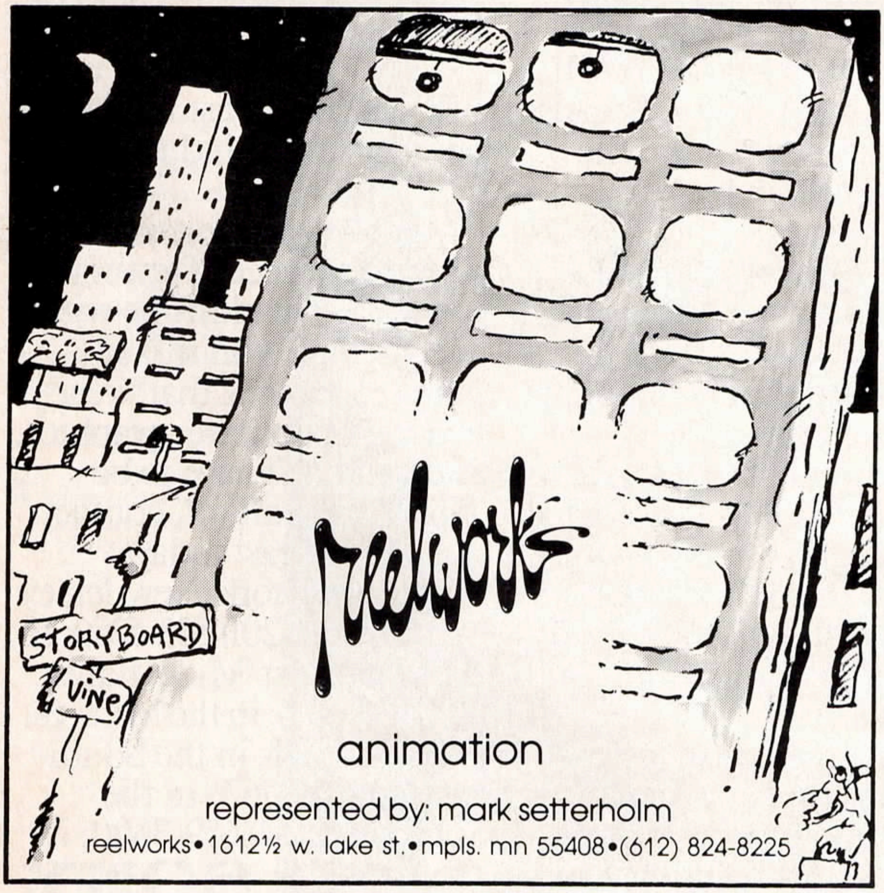

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STARFIGHTER

vision (analog video) runs at 30 frames per second and in real time. DP's system does only one frame in 30 seconds, which means there are 100 TV pictures *in* one of DP's. (If 30:1 versus 1:30 appears to be a contradiction in speeds, it is actually the high speed of the resolution that slows down the perceptual time frame.)

But spatial resolution is only one kind. There are 4,096 intensity levels on Digital's CRT, compared with 256 in broadcast television, or 16 times as exact. There's also precision color correction, preventing color drift or irregularity at levels 25 times as great. Resolution of any less output would draw short of effective digital scene simulation.

The camera records from the CRT on a per-frame basis, first with a red filter, then a green filter superimposed over the red, and then a blue filter superimposed over the other two. Equal balance of the three primary colors always results in pure white. The final color is the combined photo-intensities of the 24 million pixles on the CRT.

But the mathematics do not end there. To get a low estimate of the number of computations there are by the X-MP per frame, figure 4,000×6,000 (in spatial resolution) ×4,096 (in density resolution) ×3 (for red, green, and blue) ×10 (which is the approximate number of calculations of all other effects, such as transparency value, highlight value, and hidden surface removal, though there can be up to 100 of these effects), and the figure one arrives at is a *minimum* of 72 billion computer calculations per frame.

"You see why we need the 'super' computer," says Whitney, "because without it, you cannot economically solve all those problems fast enough to make a product of quality. Certainly the Vax could make something look quite realistic if you had an ongoing amount of time, but the Vax is 400 times slower than the Cray, so it takes the Cray one day to compute what it takes the Vax 400 days to compute."

The average frame for digital scene simulation required two-and-a-half minutes to record, with many requiring up to five minutes. "But theoretically, there's no reason why you can't compute a frame that takes a whole day or 100 hours," Whitney says. "People have done 100-hour frames. At that point, they're virtually making a still. We've never done a frame that long, but I know researchers that have, in academic and theoretical work. Obviously, that's totally impractical for a production like *Starfighter*. I never like to have a frame go over five minutes for our purposes. If it does, then you've done something wrong."

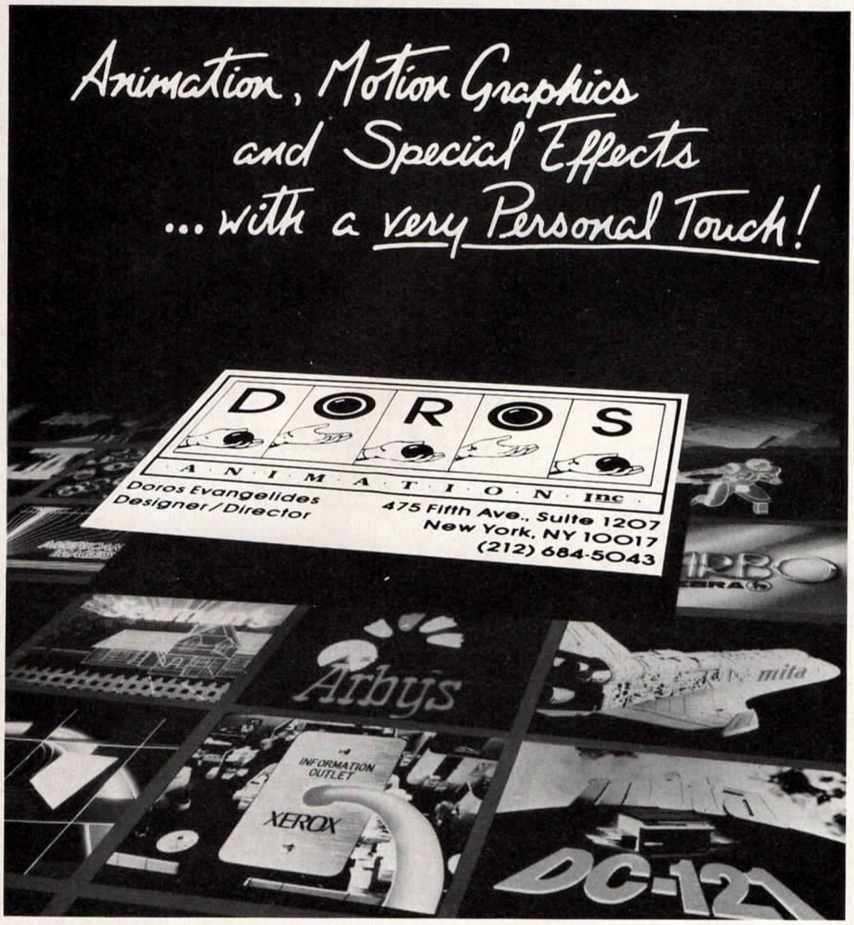
The camera in the filming stage is equipped to operate automatically and, once put to work in juxtaposition to the CRT, may run indefinitely. Twenty minutes of Digital's simulated footage takes about five days, with the system working around the clock. When the film is fully exposed, it is simply brought to a lab and processed.

"And that's basically what we do," says Whitney. "The most expensive thing in computers is the scene which has to achieve the highest degree of realism. And the longer it takes to compute, the more it costs. Remember the time-per-frame range. I never like to take more than five minutes to compute a frame. To do that for a film is more than you have to."

The future of DSS

Beyond the economic imperatives, DSS is capable of realism greater than *Starfighter*. This is true of the resolution, photographically, and may very soon be true of the kind of images Digital will be able to generate. The computer has succeeded in producing credible outer-space scenes (a movie reality) but not a persuasive street scene. However, it is inevitable and foreseeable—perhaps but a matter of a few years—that Digital Productions will be able to create a convincing street scene. What may take a bit longer is the simulation of human beings. There are silhouettes and characters glimpsed at a distance in *Starfighter*, but nothing yet that resembles Meryl Streep in a moment of quiet dialogue.

"It's an extremely difficult problem," Whitney comments. "How do you de-



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scribe the idiosyncrasies of a man's footfall or a woman's face? Why and how is one woman's face different from another? If you want a harder problem: Why is one actress more successful than another? What does she do with her face and with her expression of emotion or her voice that makes her more effective than another?

"To model all of that accurately right now with computer simulation is not possible. The human face is composed of irregular surfaces, very difficult to encode. The human face is not symmetrical on any axis. It's characterized by great idiosyncrasy."

Digital scene simulation, especially as it is refined, will continue to influence the film and television industry in profound ways.

With the cost of production increasing 175 to 200 percent in the last eight years, it may make progressively better sense to simulate films than to take a crew on location and photograph it. Labor costs alone are expected to jump 30 percent in the next two years.

"If that trend continues," Whitney says, "then traditional methods of filmmaking could change. There is a built-in economic need for new methodologies for producing movies. People's demand for new entertainment product is going to be increasing in the next decade because of the proliferation of reproduction devices. And there'll be a dearth of product to meet that need without successful low-cost alternatives like simulation."

Furthermore, Digital anticipates the operation of a timed-shared remote "image utility," providing real-time interactive visual services to professionals as well as to the general public. The X-MP easily generates graphics in real-time video, and up to 1,800 subscribers could be served with a new frame every minute. Home computers could be given enough memory to function as "frame buffers," capturing and storing the single frames to be later displayed on the computer terminal or a television set. The frame-buffer device could cost as little as $10 and, by next year, could be built into every TV manufactured. The demand for quality computer graphics observable in 3-D by doctors, engineers, designers, and other specialists could be vast and possibly enough to make it happen.

"Working in simulation has involved the latest technology," Whitney says. "Yet, married to it and integral to it, is the presence of nature in its purest, its very purest. The real teacher, the guidepost, has always been what nature does. It's our ability to observe that, and in some way, try to model that in this new form, this new language, that has been an interesting convergence of the two extremes—nature and technology." □

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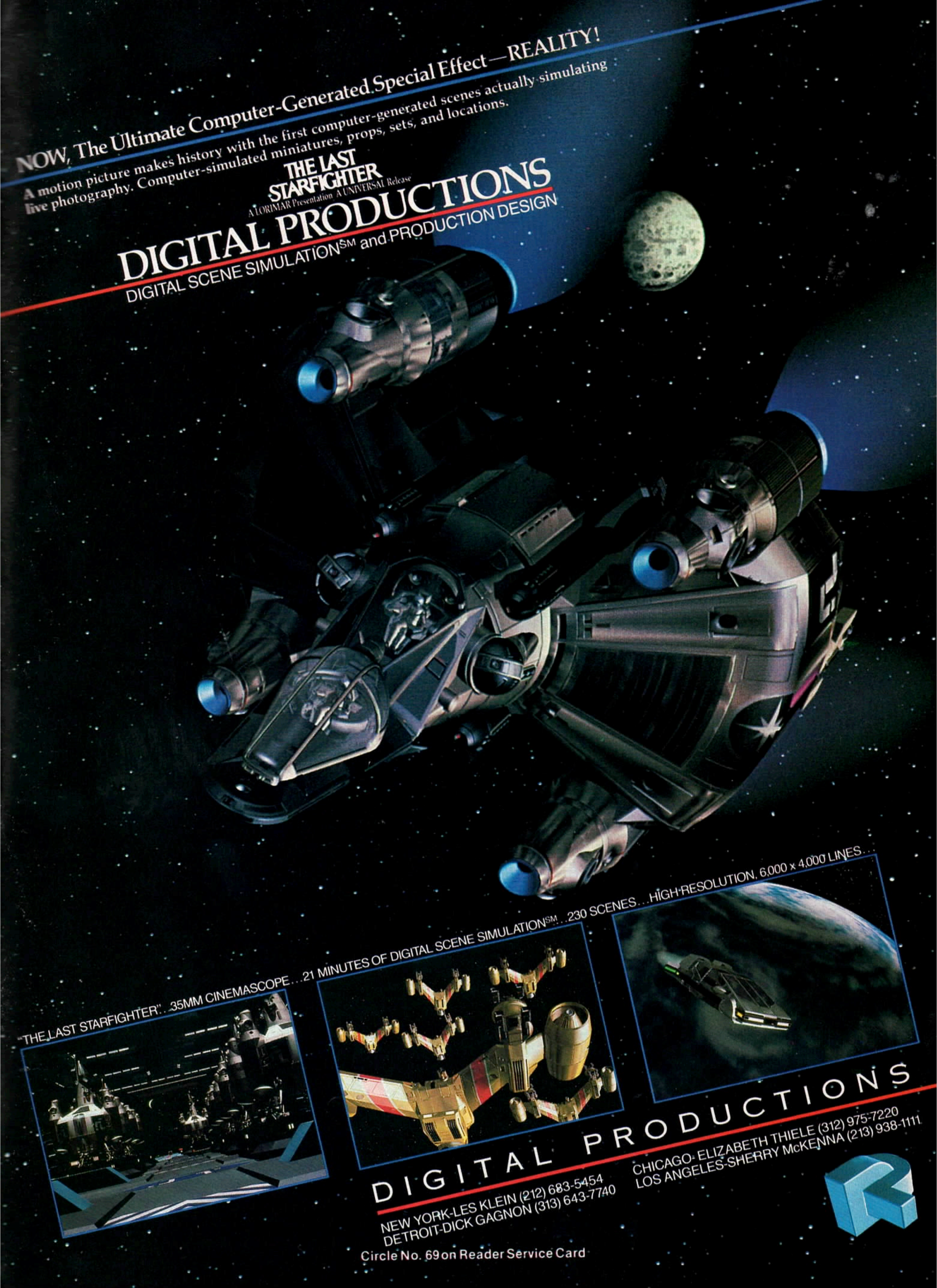
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