Aerospace and Hollywood: How Computer Animation Went from Space to Cineplex

What do people think about when they think of Southern California? Hollywood is probably high on the list, with beaches and freeways close on its heels. Aerospace may not top the list, but it should. Aerospace was the dominant industry in Southern California for much of the twentieth century; only after the end of the Cold War did Hollywood pass aerospace as the main employer in the region. What did it mean to have these two major industries, aerospace and entertainment, in such proximity? At first glance they seem to have little in common: one appears technological, the other creative; one the child of government demand, the other of commercial appeal. But the two share an intertwined history, one that shaped Southern California—and the rest of our world—in surprising ways.

Movie-making and aerospace grew up together in Los Angeles starting in the 1910s, and both industries reached national and even global dominance by midcentury. The contact between these two global industries in and around the area produced sparks from the beginning. Flying fascinated early Hollywood filmmakers, who went on to make many movies about brash young pilots; Marilyn Monroe got her start working in an aircraft factory; and Howard Hughes embodied a still more obvious overlap between aviation and Hollywood.[1] The connections extended beyond the industries' abstract parallels—as "dream factories" devoted to realizing whatever could be imagined, populated with technophiles, futurists, and entrepreneurs—to the specific technologies that brought those dreams to life. The connection between the technologies of motion pictures and those of aircraft- and spacecraft-building may not seem obvious, but their little-known interaction in the field of computer animation turned out to be vastly influential. One cannot set foot in a cineplex these days without experiencing CGI, or computer-generated images. Most moviegoers or gamers are unaware that many CGI techniques were

invented by makers of spacecraft, not movies. Though Hollywood takes the lead today on high-tech CGI developments, the initial inspiration flowed in the other direction, from aerospace to entertainment.

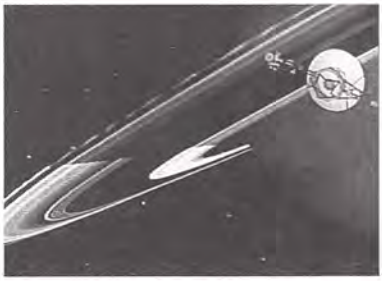
JPL and Hollywood

The Jet Propulsion Laboratory in Pasadena is an offshoot of Caltech supported by NASA. JPL is not an aerospace corporation, but it is certainly part of Southern California's space enterprise. It emerged out of Caltech—which had developed as a center for aeronautical engineering in the 1920s, with close ties to local aircraft firms—and it was formally incorporated during World War II for work on jet-assisted takeoff for airplanes and, later, rocket engines and spacecraft. In addition to its connections to aviation and space, JPL had links to show business from its earliest days. Two of the lab's founders, Frank Malina and Jack Parsons, tried to sell a script about their rocket group to MGM to raise money for research, and Parsons later lost his life in an explosion while working on pyrotechnic special effects for Hollywood.[2] It took a while, but JPL would find better ways to provide special effects for the film industry.

Hollywood has a periodic fascination with space exploration, often inspired by recent developments in aerospace. One such vogue dates to the late 1970s, when the first *Star Trek* movie featured a mysterious, nearly sentient object known as V'Ger—a knowing nod to the Voyager spacecraft built by JPL. In the late 1990s, the discovery of a Martian meteorite with possible life forms, the impact of the Shoemaker-Levy 9 comet on Jupiter, and the landing of *Mars Pathfinder* were followed by such blockbusters as *Deep Impact* and *Armageddon*, which featured meteors on a collision course with Earth, and *Mission to Mars* and *Red Planet*, in which humans encounter mysterious life forms on Mars, not to mention several installments of the *Star Wars* saga. This "merging of entertainment and realities," as JPL's executive council called it, at times even obscured the origin of some ideas. A proposal to fire a 500-kilogram projectile into comet Tempel 1 and observe the resultant crater was dubbed Deep Impact, and JPL's project manager had to explain that the mission's name had been selected prior to the release of the movie.[3]

The Origins of Animation

More substantial connections between JPL and the movie business developed through the lab's technical program. In the late 1970s, a few JPL programmers were working on simple wireframe animations to simulate spacecraft trajectories. The lab's Bob Holzman then created a computer-



Screenshots from James Blinn's animations simulating the Voyager spacecraft flights past Saturn. Courtesy NASA/JPL-Caltech.

graphics group and invested in a powerful computer system to run graphics programs. At the time, the Voyager spacecraft were on their way to the outer planets, and Charley Kohlhase, a Voyager mission designer, was looking for more complex renderings. He heard about a young programmer from the University of Utah named James Blinn, who had just come to Caltech to work with computer guru Ivan Sutherland, himself recently relocated from Utah. The Utah graphics program had flourished after receiving funding from the Defense Advanced Research Projects Agency (DARPA) to design flight simulators. Blinn had finished his PhD in computer science in 1978 and was making a name as an up-and-comer in computer graphics. JPL hired him into the computer-graphics group, and he went to work generating three-dimensional animations to simulate the Voyager flights past Jupiter and Saturn, using data from Kohlhase and the mission design team. The results surpassed expectations. The clips took the viewer on a ride behind the Voyager craft, swooping past the planets and their rings and moons against the backdrop of interstellar space. Television news editors and viewers loved them, and the clips became a staple of the celebratory news coverage of the Voyager flights.[4]

Audiences today, jaded by years of CGI wizardry in movies and video games, may not appreciate the technical advance that Blinn's animation represented. For example, he pioneered a technique called bump mapping for adding craters and other surface features digitally to the smooth spheres of planets and moons. His method adjusted those features' appearance from frame to frame as the viewing perspective changed, allowed them to rotate with the planet or moon at the correct speed, and also showed the terminator—the line of shadow—gradually moving across the sphere. Though the spacecraft itself was a simpler collection of polygons, modeling its movements—such as the rotation of the camera on

its extended arm—required another complex algorithm called hierarchical forward kinematics articulation.[5]

Blinn was a stickler for detail, to the point of calculating the correct location of the planets and the six thousand brightest stars in the background of each frame. And he did all this from scratch; he could not turn to off-the-shelf software packages for algorithms, so he coded it himself. Blinn's colleagues regarded him with something bordering on awe. Sutherland, himself no slouch, said at the time, "There are only a dozen great people in computer graphics, and Jim Blinn is six of them."[6]

There is a reason why these developments in computer animation happened at JPL instead of Hollywood. The Blinn sequences required mind-boggling computations, first in plain celestial mechanics to get the objects and light in the right place, then in the algorithms to render the objects as three-dimensional, textured color images. A three-minute clip had over four thousand frames, each one needing all of these calculations. At the time, the main places with the computing power to run such programs were government labs and universities. Blinn made the Voyager movies on JPL's PDP-11/55 computer, at the time probably the highest performing of the PDP-11 line from Digital Equipment Corporation (DEC) and also what he had used at Utah.[7] Blinn said of this hardware, "Someday artists and graphic designers may be able to own a system like this, but right now the $300,000 price tag is a bit high."[8] In addition to getting their numbers through the processing bottleneck, programmers had to wait for many minutes for their screens to refresh with each new image, even with the most advanced frame buffers. In order to create a moving picture, they then had to take a picture of the screen with a camera and string the images together on film. Because of these hardware requirements, Blinn did not think his programs would be widely useful; only a couple other places in the world had the hardware needed to run them.[9]

Blinn showed what was possible, and this inspired commercial firms to invest in computers to pursue these techniques themselves. Even so, some graphics houses hesitated to take the hardware plunge. For example, the firm Digital Productions raised eyebrows throughout the industry when it splurged on a Cray supercomputer in the early 1980s, and the expense did indeed drive the company out of business.[10] The computing bottlenecks began easing a few years later. The emergence of affordable graphics workstations and then the increasing power of personal computers, the development of faster monitors, and the incorporation of video cards into motherboards—all allowed smaller graphics firms to run their programs in-house.[11]

Blinn soon found an even broader audience for his techniques. In between the Voyager encounters in 1979 and 1981, he made contact with Carl Sagan, who was beginning work on his *Cosmos* television series for PBS. Sagan, who had many connections at JPL, heard about Blinn, and PBS hired him to provide special graphics sequences. One sequence showed a single-celled organism evolving into a fish, then a frog, through a dinosaur to a mammal and, finally, a woman—an early example of morphing techniques later used in the film *Terminator 2* (1991) and the music video for Michael Jackson's "Black and White" (1992). Another sequence simulated a DNA double helix twisting and turning as it replicated. The complex DNA sequences required an hour of computer calculations per frame, and since the filmmakers lacked access to computing power on that scale, JPL let Blinn use the lab's computers to crunch the numbers.[12]

Cosmos aired in 1980 and reached—not quite "billions and billions"—but about half a billion viewers worldwide. Together with the Voyager animations, it brought Blinn's techniques to a wide audience. Hollywood took note. JPL's proximity came in handy, since people from the movie business could just drop by the lab to see Blinn's codes in action. Soon he was giving a steady stream of demonstrations to high-end producers, lower-level animators, and special-effects people—from *Star Trek*'s Gene Roddenberry to Ward Kimball, one of Disney's "Nine Old Men." Blinn himself started getting attention from the movie business, and in 1980 he accepted an offer to help George Lucas establish a special-effects studio for the first *Star Wars* sequels. At the Lucas studio, Blinn joined forces with Ed Catmull, another Utah grad, and Alvy Ray Smith—or rather, rejoined them, since Catmull and Smith had stopped off at JPL on their way to Skywalker Ranch and worked briefly with Blinn on the *Cosmos* sequences. Blinn worked part time at Lucasfilm for about a year, spending two days a week at JPL, but he missed the real space business and returned to JPL full time to produce the Voyager Saturn sequences; he especially wanted a chance to show Voyager crossing Saturn's rings.[13]

Blinn continued to influence work at Lucasfilm despite his departure. Smith's team soon developed a video clip that persuaded George Lucas of the potential of computer graphics. The so-called Genesis shot for *Star Trek II: The Wrath of Khan* showed the view from a spacecraft flying past a dead, moon-like planet that is then transformed by a fiery cataclysm into an Earth-like environment. The shot has had a substantial effect on the graphics community and is viewed as a landmark in the business. In creating it, Smith declared, he "was still under the influence of Blinn's *Voyager* flybys of the planets at the Jet Propulsion Laboratory." Blinn, after all,

had just finished working with the group, and his planetary flyby sequences had accustomed viewers to the perspective from a spacecraft.[14] Catmull and Smith went on to cofound Pixar, where their efforts on *Toy Story* and other computer-animated features would win them Academy Awards and further popularize computer graphics in film; today Catmull is the president of Pixar Animation Studios and Walt Disney Animation Studios.

Blinn's influence was thus inspirational as well as direct and technical. He did not cash in himself by setting up his own business or licensing software. Instead, he published his techniques in a series of seminal articles covering bump mapping, light reflection, the rendering of clouds and dusty surfaces, and blobby modeling (also known as "Blinn's blobs," a technique he developed for the *Cosmos* DNA sequence that enabled later effects like the dinosaurs in *Jurassic Park*). His disinterest in commercial possibilities reflected his own priorities, especially his commitment to working for the space program, and also his sense, at least at the outset, that few places could afford the sophisticated hardware needed to run his programs.[15]

Blinn's free dissemination of his algorithms and ideas was also characteristic of the computing community of the 1970s, which heaped scorn on a twenty-year-old Bill Gates for criticizing the free sharing of software; the computer counterculture itself reflected a characteristic California influence.[16] SIGGRAPH, the computer graphics society, manifested this communal, countercultural ethos, one reinforced by the academic background of many its members. Blinn was a star attraction at the annual SIGGRAPH meetings: his talks would have been popular even without the ingenuity of his ideas or his generosity in sharing them, since he delivered them with a lively, comic wit, and had a striking physical presence, with his six-foot-five frame, long beard, and ponytail.[17]

The communal SIGGRAPH ethic that Blinn exemplified changed in the 1980s, as graphics firms sprang up to serve Hollywood's growing interest, and a more proprietary attitude emerged in the graphics community. Commercial firms began happily packaging Blinn's techniques in software sold to movie studios, as their managers freely admit.[18] Several of these firms, not surprisingly, sprang up in Southern California, including Wavefront Technologies, Information International, Inc., and Digital Productions, whose founders, Gary Demos and John Whitney, were from Caltech. Graphics programmers today recognize Blinn's influence every time they use the "Blinn" button in Maya, the popular software for three-dimensional animation behind most CGI-driven feature films.

Blinn taught not only at Caltech, which he and Alan Barr and Jim Kajiya had made into a hotbed for new techniques, but also at Art Center College of Design, where his courses included an intensive introduction to computer graphics for a contingent from Disney's animation studios. SIGGRAPH members continued to look forward to learning about Blinn's latest techniques, which he developed in the 1980s for two popular series of educational videos, *The Mechanical Universe* and *Project Mathematics!* Blinn left JPL around 1987, staying at Caltech for a few years but eventually joining Microsoft (and hence rejoining Alvy Ray Smith) as a graphics fellow.[19]

A parallel but separate path for the influence of aerospace on Hollywood emerged in JPL's Image Processing Laboratory during roughly the same period. In the early 1960s, JPL engineers had pioneered the use of digital image processing, first to clean up pictures returned from the Ranger missions to the Moon and, later, to adjust other planetary spacecraft images. The first techniques corrected distortion and removed signal noise, such as a particular frequency superimposed on an image by vibration of the camera, and they grew to encompass algorithms for contrast enhancement, cartographic projection, motion compensation, and so on—in short, many of the techniques now available through such photo-editing programs as Adobe Photoshop.[20] By the mid-1970s, JPL had perhaps the most advanced image-processing capability in the country.

Although Blinn was not part of the Image Processing group, his computer animations for Voyager and *Cosmos* used similar techniques, such as reconstructing viewing geometries and surface reflectance. Like Blinn, the image processing effort depended on the advanced computing capabilities at JPL.[21] It had also produced its own motion pictures by combining still photos, such as those from the Ranger and Mariner spacecraft. Around the time of Blinn's work on Voyager, Kevin Hussey was doing some crude three-dimensional animation for atmospheric scientists, including a model of smog distribution in the Los Angeles Basin. Hussey heard about Blinn's work and approached him for help, but had no money to hire him. So Hussey used in-house code written by Michael Kobrick in the Image Processing Laboratory and tweaked by a young programmer named Bob Mortensen. The result, in 1987, was *L.A. the Movie*, which used topographic data from the Landsat satellite program to simulate a three-dimensional view from an aircraft swooping through the Los Angeles Basin.[22]

By that time, Hussey's group had grown from two to fourteen and had formally organized as the Digital Image Animation Laboratory (DIAL),

alongside and overlapping the original Image Processing Laboratory. DIAL intersected Hollywood through its work on digital color correction, starting with a CBS program on the *Mona Lisa* and then working on old *Star Trek* backgrounds. The group helped William Shatner with a shot that zoomed from the galaxy down to Yosemite Valley for *Star Trek V: The Final Frontier* (1989), and it digitally erased telephone wires from the Egyptian skyline for *Raiders of the Lost Ark* (1981). It also did some work morphing images for Whitney/Demos Productions, a commercial graphics firm created by the former heads of Digital Productions, using a technique created to produce a continuous animation of ocean circulation from satellite images taken twelve hours apart. Movie producers again beat a path to JPL for demonstrations of VICAR (Video Image Communication and Retrieval) and other JPL digital-processing software.[23] In the 1990s, Disney would hire away Hussey and several others from DIAL to help build its own digital animation studio.

By then, Hollywood was committing vastly greater resources to computer animation, and the increasing availability of computing power had nourished a proliferation of graphics firms. Trying to keep up, DIAL turned to funding outside NASA, and by the 1990s, IMAX was its biggest sponsor.[24] But Hollywood was already outstripping JPL's capabilities, and influence began to run mostly in the opposite direction, from Hollywood to JPL. It is not a coincidence that in 1995, the entertainment industry passed aerospace as the main employer in California. A *Business Week* cover story in 1994, "The Entertainment Economy," declared that "the entertainment industry is now the driving force for new technology, as defense used to be."[25] In the 1920s Douglas rented a vacant movie studio to build airplanes; now the movie studios were leasing abandoned aircraft factories.

For the last several years, programmers from Hollywood studios have been coming to JPL, bringing with them the latest techniques, including those from video games. JPL is applying these not only in its outreach efforts—for instance, to create online games for kids related to planetary exploration—but also to help mission managers visualize what their spacecraft are doing in space, by transforming raw telemetry into real-time animations.[26] This return flow from Hollywood to JPL has closed the loop connecting aerospace to show business, and popular interest to technical capability.

Conclusion

In 2007 the Entertainment Economy Institute published a study on Hollywood's benefits to other local industries; the report highlighted the flow

of animation talent from movie studios to local businesses, including aerospace.[27] The study failed to note that thirty years earlier, the initial stream ran the other way, from aerospace to Hollywood. Blinn's work at JPL in particular inspired the flowering of CGI in movies in two ways: first, by showing *what* could be done, with images that inspired movie studios to try a new approach; and second, by showing *how* to do it, publishing the algorithms that could then be taken up by studio animators.

These developments invite an analogy to the creation of the Internet, which was created by DARPA long before the dot-com craze of the 1990s.[28] DARPA also funded Utah's graphics program for flight simulation, the very program that launched Jim Blinn's career. DARPA also underwrote the development of early ray-tracing techniques by a company called MAGI (Mathematical Applications Group, Inc.) to model nuclear radiation effects for the military. New York–based MAGI, along with Information International, Inc. in Culver City, later developed graphics for the pioneering movie *Tron*, which Hollywood has recently revisited in a sequel capitalizing on CGI. For both computer graphics and the Internet, the government created a new technology and demonstrated its possibilities, and then the private sector adopted it and ran with it. The government's early role is not surprising, given the substantial long-term investment in computing capability required and the uncertain returns.

This investment flowed disproportionately to Southern California, given the substantial defense economy there. Then geographical proximity aided the transfer of ideas, techniques, and people from one industrial sector to the other. The intersection of aerospace and Hollywood made Southern California a unique incubator for computer graphics. The regional aerospace presence may have dwindled (though it has not disappeared), but it has left a substantial legacy in the thriving field of CGI, which literally and figuratively animates so many of Hollywood's current products. If Hollywood is a dream factory, it was the talent and resources of the aerospace industry that supplied some of the parts.

Notes

Citations to material from the JPL archives follow the form: (JPL collection number, box/folder). All interviews are by the author unless otherwise noted.

1 Shawna Kelly, *Aviators in Early Hollywood* (Charleston, S.C.: Arcadia Publishing, 2008); George J. Marrett, *Howard Hughes: Aviator* (Annapolis, Md.: Naval Institute Press, 2004).

2 George Pendle, *Strange Angel: The Otherworldly Life of Rocket Scientist John Whiteside Parsons* (New York: Harcourt, 2005); Mike Davis, *City of Quartz: Excavating the Future in Los Angeles* (New York: Verso, 1990), 54–62.

3 Gael Squibb, notes on JPL Executive Council retreat, 11 March 1999 (JPL 259, 64/758); James Graf quoted in Matthew Fordahl, "Deep Impact," AP newswire, 9 July 1999; Andrew Murr and Jeff Giles, "The Red Planet Takes a Bow," *Newsweek* (6 December 1999), 61.

4 Charley Kohlhase interview, 2 July 2002; James Blinn interview, 20 July 2007.

5 Kohlhase interview; Blinn interview; Zareh Gorjian interview, 28 June 2007.

6 Natalie Angier, "It Was Love at First Byte," *Discover*, March 1981.

7 James F. Blinn, "The Jupiter and Saturn Fly-By Animations," 1980, http://www2.jpl.nasa.gov/saturn/anim4.html. *Tron* (1982) was created on a PDP-10 known as the Super Foonly F-1, the fastest version of that computer, owned by Information International, Inc. (Triple-I) in Culver City. There is a connection here, too, to JPL: one *Tron* character was a Solar Sailor, and JPL at the time had a popular proposal known as the "Solar Sail" spacecraft; it was to visit Halley's comet, powered by solar radiation pressure.

8 Angier, "First Byte."

9 Blinn interview.

10 John Grower interview, 17 July 2007; Blinn interview.

11 Grower interview; William B. Green interview, 12 February 2002; Gorjian interview, 28 June 2007.

12 Angier, "First Byte." On the use of JPL computers, see C. Kohlhase to F. J. Colella and W. E. Porter, 18 August 1978 (JPL 142, 24/417).

13 Blinn interview; Angier, "First Byte"; David Salisbury, "Computer Art Takes Off into Space," *Christian Science Monitor*, 20 July 1979.

14 Angier, "First Byte"; Salisbury, "Computer Art"; Alvy Ray Smith, "George Lucas Discovers Computer Graphics," *IEEE Annals of the History of Computing* 20, no. 2 (1998): 48–49, and "The Genesis Demo: Instant Evolution with Computer Graphics," *American Cinematographer* 63, no. 10 (October 1982): 1038–39, 1048–50. On the effect of the "Genesis" shot, see Grower interview and Blinn interview. Blinn, Smith, and Kajiya all later worked for Microsoft.

15 Blinn, "Texture and Reflection in Computer Generated Images," *Communications for the Association of Computer Machinery* (*CACM*) 19, no. 10 (October 1976): 542–47; "Models of Light Reflection for Computer Synthesized Pictures," *SIGGRAPH 77* (1977): 192–98; "Simulation of Wrinkled Surfaces," *SIGGRAPH 78* (1978): 286–92; "A Generalization of Algebraic Surface Drawing" [on blobby modeling], *ACM Transactions on Graphics* 1, no. 3 (July 1982): 235–56; "Light Reflection Functions for the Simulation of Clouds and Dusty Surfaces," *SIGGRAPH 82* (1982): 21–29; Blinn interview. On "Blinn's blobs," see Grower interview.

16 Paul Ceruzzi, *A History of Modern Computing* (Cambridge, Mass.: MIT Press, 1998), 235–36; Martin Campbell-Kelly and William Aspray, *Computer: A History of the Information Machine* (New York: Basic Books, 1996), 243. On California and computing, see Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism* (Chicago: University of Chicago Press, 2006).

17 Grower interview.

18 Ibid.

19 Kohlhase interview.

20 Caltech/JPL Conference on Image Processing Technology, *Proceedings*, 3–5 November 1976 (JPL SP-43–30).

21 Green interview. On shared techniques, see Kenneth R. Castleman, *Digital Image Processing* (Englewood Cliffs, N.J.: Prentice-Hall, 1979), 371–77.

22 Kevin Hussey, phone interview, 11 September 2006; Green interview; Kevin Hussey, Bob Mortensen, and Jeff Hall, *L.A. the Movie*, 1987 (JPL audiovisual collection).

23 Hussey interview. For the history of Whitney/Demos, see Gary Demos, "My Personal History in the Early Explorations of Computer Graphics," *Visual Computer* 21, no. 12 (2005): 961–78.

24 James A. Evans memo, "The Reimbursable Program," 28 February 1995 (JPL 259, 50/553).

25 Michael J. Mandel and Mark Landler, "The Entertainment Economy," *Business Week* 14 March 1994, 60.

26 Gorjian interview; Hussey interview.

27 Richard Verrier, "Animators Expanding Their Lines of Work," *Los Angeles Times*, 7 May 2007. For example, the Department of Defense funds USC's Institute for Creative Technologies in order to apply computer graphics and virtual-reality techniques from video games to military training and simulation.

28 DARPA was initially known as the Advanced Research Projects Agency, or ARPA.

Blue Sky Metropolis

The Aerospace Century in Southern California

Edited by Peter J. Westwick

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