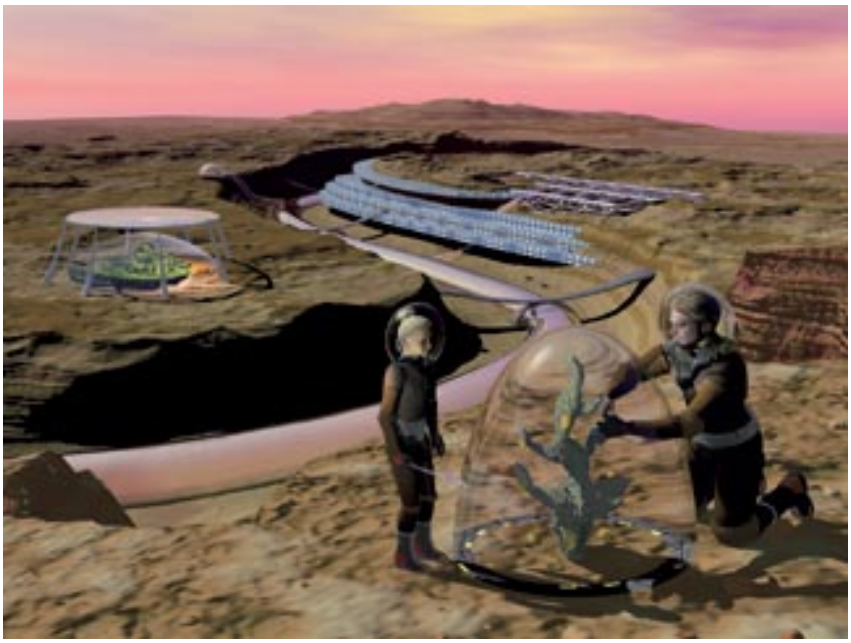
Rocket Science and Art: Travels with Charley

by Douglas L. Smith

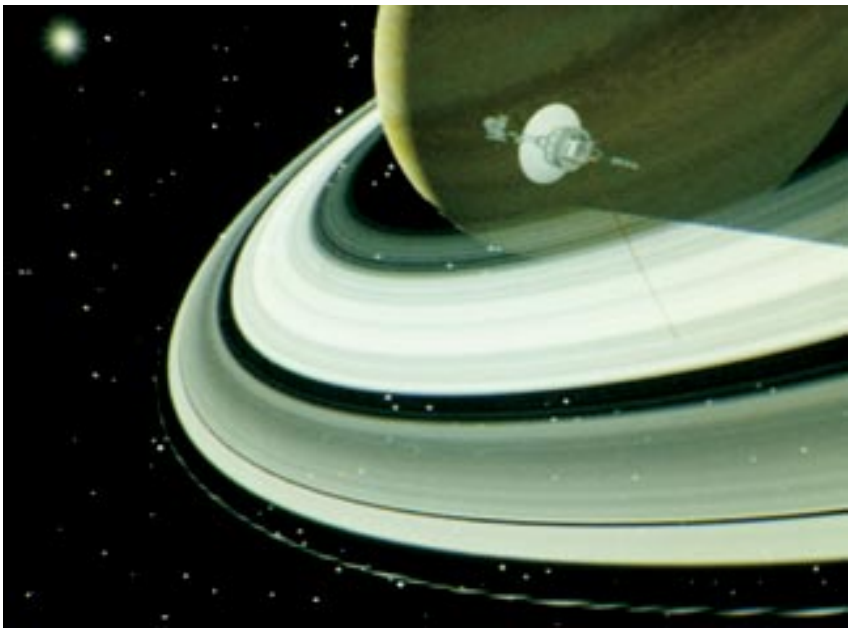
Charley Kohlhase's artistic career has run from nature photography through digital image manipulation to the creation of virtual worlds. *Yucca*, far left, is an unaltered close-up of the plant's bracts, or leaflike structures. *Between Two Worlds*, left, is a late-afternoon shot of Los Angeles's Griffith Observatory. The image was digitized and changed to sepia, and a reddish tint was added to the sky. A poster-sized version of the original, color image will be on permanent display at the observatory when it reopens in 2005. And *Canyon City, Mars*, below, is a 3-D landscape. An animation seen from the point of view of someone flying through the scene is available at http://mars.jpl.nasa.gov/spotlight/charleyKohlhase.html.



Charley Kohlhase joined JPL in May 1959 as a junior engineer in the trajectory-design group. He recalls one of his first assignments: "I was nearly 25 in the spring of 1960, and I was to give a presentation to a dozen colleagues on the possibility of sending a spacecraft to Mars, when in walked Drs. William Pickering [JPL's director] and Wernher von Braun, the latter radiating brain waves … had it not been for my youth, my heart would have given out at that moment. I arose on wobbly legs, stumbled to the board, and watched my life pass in front of me. I can still see the two broken pieces of chalk on the blackboard rail. With a shaky hand, I drew two sun-centered circles and the Hohmann transfer ellipse—one end tangent to Earth's orbit at departure and the other tangent to Mars's orbit at arrival—trying desperately to keep my chalk strokes clean and even. The next 30 minutes passed in a daze."

Kohlhase survived this first brush with greatness and went on to rise through the ranks. He led the trajectory, navigation, and mission design teams for Mariners 6 and 7 to Mars in the '60s. He did that *and* the overall system design for the Viking Mars orbiters/landers in the '70s, ensuring that all the components meshed. He then served as mission design manager for the Voyagers' Grand Tour of Jupiter, Saturn, Uranus, and Neptune. (See http://www.planetary.org/voyager25/stories-charlie-kohlhase.html.) And his last job before "retirement" in 1998 was science and mission design manager for Cassini–Huygens, scheduled to arrive at Saturn in July 2004.

Trajectory design and mission design go hand in hand, and the Grand Tour is a classic example. A flyby uses rocket science from the 1600s—Kepler and Newton have given you a group of curves, called conic sections because you can make them by slicing into a cone at various angles, to work with. You depart Earth on a hyperbola, segue into an ellipse around the sun, and approach your destination on another hyperbola. Then you can whiz



A frame from the groundbreaking 1981 animation of Voyager 2's flyby of Saturn. Saturn's atmosphere and ring system, including the narrow, braided F ring, were rendered as photorealistically as possible, incorporating the discoveries made by Voyager 1. All the stars, including the sun, have their correct positions and brightnesses. This summer is the 25th anniversary of the Voyagers' launches; by now, an estimated one billion people around the world have seen these animations.

on by, or you can settle into orbit—another ellipse, or possibly a circle. All you need is enough fuel to leap from one conic to the next, which can be quite a lot. Getting to a distant planet in a vehicle light enough to launch requires assembling many conics into a clever, roundabout route that gets gravity assists—the so-called "slingshot effect"—from passing close by other planets. "In the case of Voyager's assist by Jupiter," says Kohlhase, "the spacecraft gained 35,700 mph relative to the sun, while mighty Jupiter was slowed by only one foot per trillion years—hardly enough to affect Earth's weather, unless you chat with those picky chaos-theory folks."

The Grand Tour was the most ambitious carom shot ever conceived. "Multiplying the total number of possible launch days by the total number of different arrival dates at each of the four planets gave us some 10,000 possibilities to consider," which Kohlhase and his team winnowed to a set of 110. "The moon Io was top priority at Jupiter, and Titan top priority at Saturn. The game was to ensure that these primary targets were always encountered safely and at the best possible geometry, while picking up as many of the other moons as possible and staying close to the gravity-assist corridor to avoid expending propellant we'd need for subsequent flight-path corrections. We sought good communications with Earth, acceptable navigation sensitivity to errors, good viewing and lighting angles for the cameras, and adequate time spacing for each spacecraft to execute its assorted activities. We made sure that the later-arriving Voyager 2 could pick up important observations that might be missed by Voyager 1, while still enhancing the combined science if both craft were successful. And if Voyager 1 captured the Titan observations at Saturn, then the later-arriving Voyager 2 would be directed to Uranus and Neptune, focusing on the mysteries of those remote worlds—with a close dive over the Neptune 'polar crown' to fly past the large moon Triton a final plum."

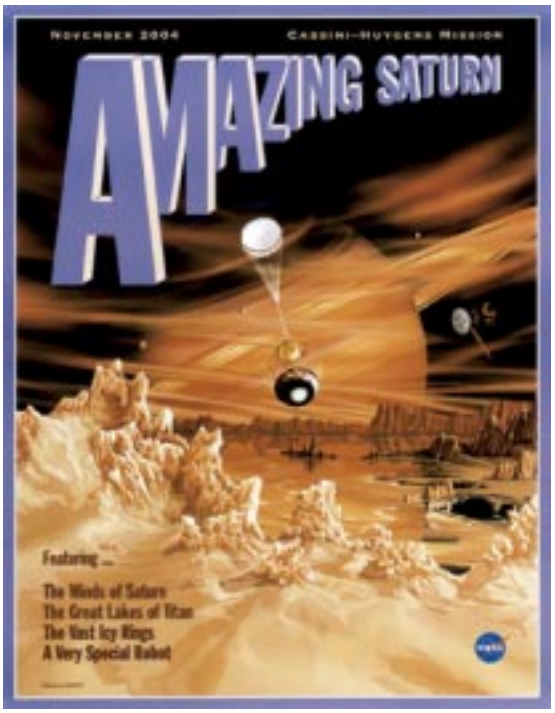
All the grunt work—tracking the planets and moons in their orbits, and plotting the spacecraft's path—was done by computer, of course, but in those days graphic displays were in their infancy and Kohlhase's visual intuition (he had wanted to major in architecture, but couldn't afford the five-year program and settled for physics instead) was given free rein. "I solved problems by combining the equations of rocketry with the 'look' of the orbits around other planets, the gravity and thrust vector diagrams, the way the spacecraft's subsystems interacted, and the multipath, branch-tree diagrams essential in assessing countless mission outcomes and their probabilities … I lived and breathed this job, often awaking in the wee hours with answers to problems my brain had been processing while asleep. I got so I could hear a problem stated and 'see' the answer, often within seconds."

Kohlhase wanted the public to share the movies of the flybys he saw in his mind's eye, so he recruited computer-graphics pioneer James Blinn, then a freshly minted PhD from the University of Utah. Blinn created the modeling and effects software—which originally ran on the microscopic brain of a DEC PDP-11/55—and Kohlhase composed each scene and supplied the commands the spacecraft would be seen to execute. The computerized spacecraft, "built" from more than 6,000 polygons whose vertices were derived from the real one's blueprints, was moved along its proper trajectory in small increments, and "key frames" where actions began or ended were adjusted as needed. Then the full animation would be run in "wire-frame" mode—drawing the polygons but not filling them in—to iron out any final kinks before adding color. (Wire-frame animation was as good as it got before Blinn arrived.) Blinn and Kohlhase later reunited to do several computer-graphic special-effect sequences for PBS's *Cosmos*. In fact, *Cosmos* creator Carl Sagan nominated the work for an Emmy of its own, says Kohlhase, but there wasn't a category for it back then.

This was long before NASA began formal outreach programs. "It just came naturally with being a mission designer," Kohlhase says. "I knew where the trajectory lay, and how the planets were lit, and I could draw clean diagrams whose perspective looked right. So I was always working with graphic artists to make these nice pictures for the folks at NASA HQ and various publications, and the artwork eventually became the animations."

Kohlhase was also the science and mission design manager for Cassini. This was to be the last of the giants, with four gravity assists en route, followed by 45 close passes by Titan during the four-year primary mission to guide the spacecraft's tour of the Saturnian system. But his official duties now included outreach, and more and more of his time was going into creating art for science.

Courtesy of Entertaining Solutions



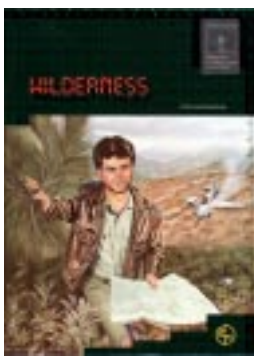
Along with the usual brochures, educators' guides, and Web sites, Cassini's outreach program under Kohlhase produced some more exotic products. At left is a postcard (later a wildy popular poster) Kohlhase patterned after the classic sci-fi magazine *Amazing Stories*. Craig Attebery did the artwork. And above is a development still from *2004—A Light Knight's Odyssey*, showing Dave the photon, voiced by John Travolta (right); and Milton, a prospector on Saturn's moon Mimas, voiced by Robert Picardo. The video is still a work in progress.

Below is a 12- by 20-foot mural designed by Kohlhase and executed by eight East L.A. artists, aged 8 to 17, of the Academia de Arte Yepes. Saturn, a Roman god of agriculture (hence the scythe) lifts the veil of mystery from the Saturnian system as the spacecraft arrives. And spacecraft team members have been signing their handiwork for decades, but the advent of digital media has allowed the general public to join in. In the photo at right, Kohlhase (left) and Richard Spehalski, Cassini's program manager, hold a DVD containing 616,420 signatures from 81 countries. Kohlhase's design for the disk includes the flags of the 28 countries that sent the most signatures as well as six wing feathers from a golden eagle, symbolizing both the attributes of the bird and the power of the pen. (See *Air&Space*, February/March 1999, for the full story.)

Kohlhase has hiked the back country from Patagonia to the Yukon, taking pictures as he went. ***Far North***, above, shot at 4:30 a.m. on a summer's morn in southeast Alaska, appeared in the 1994 ***Photographers' Forum*** "Best of Photography" annual. And less than an hour's drive from Pasadena, the view ***From Baldy Saddle***, left, often affords spectacular sunsets when haze from the L.A. basin infiltrates between the ridges to give a layered, painterly look.

An avid photographer, Kohlhase is never without a camera no matter how close to home he is. The ***Droplet***, at left, encases a mountain mahogany bud he found a block away.

This first-hand experience of nature's beauty confirmed Kohlhase as a staunch environmentalist. *Centurions*, above, showing hard-working oil pumps oblivious to the approaching storm, has been acquired by the World Meteorological Organization to dramatize fossil fuels' contribution to global climate change. *Siblings*, right, captures barn owl fledglings in the Eaton Canyon area of Pasadena. This nest had been used by alternating pairs of barn owls and great horned owls for many years until bulldozers returned to grade land for houses above nearby Kinneloa Mesa. The owls haven't been back since.

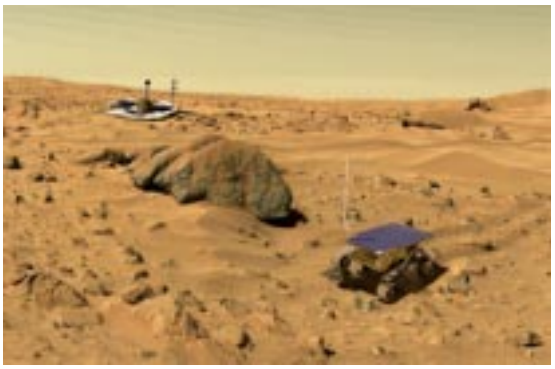


One outreach project remains in limbo—a 40-minute edutainment video following a photon named Dave as he leaves the sun, is absorbed and reemitted by Saturn's moon Iapetus, enters Cassini's Visual and Infrared Mapping Spectrometer, and gets encoded onto a radio wave for the journey back to Earth, where he winds up being reprocessed into an image on a young girl's computer. The sound track to *2004—A Light Knight's Odyssey* is finished. It stars the voices of John Travolta as Dave, and features, among others, Anne Archer, Sarah Michelle Geller, Samuel L. Jackson, James Earl Jones, and David Warner as the Void of Space. But the animation ran into financial problems, and the producer, Harry "Doc" Kloor, is trying to raise the funds to complete it.

In his spare time (such as it was), Kohlhase unwound by exploring the wild places of our own planet. "I logged 15,000 miles on one pair of Italian hiking boots over a 15-year period," he recalls. This became the inspiration for *Wilderness*, a pioneering computer game in which you were the sole survivor of a light-plane crash in the middle of nowhere. You got a topographic map and a few supplies salvaged from the wreck, and had to figure out where you were and find your way to a ranger station up to 90 miles away—the distance from Pasadena to Palm Springs. Assuming, of course, that you were clever enough to hike there in a straight line, as the game generated a landscape twice the size of Delaware.

Kohlhase and Wesley Huntress, then at JPL and now at the Carnegie Institution of Washington, invested some 3,000 hours in the game's creation over a two-year period. Kohlhase did the mission design, as it were, constructing the logic trees that drove the action (Is a bull moose seen? Do you ignore it? Does it charge? Are you hurt?) and writing the equations and procedures that modeled them. Huntress did the program design, scene graphics, and algorithm coding from the resulting four-inch-thick notebook. The game covered everything from jungle to scrub in all weathers, and even kept track of the motion of the sun and stars for navigational use. The duo drew on a U.S. Air Force survival manual, a medical doctor, a natural-history and wildlife expert, and the world's leading authority on toxic plants, among others, and *Wilderness* won high praise for its realism. It didn't make them rich, but it did win *Family Computing* magazine's Critic's Choice award for "text/graphics adventure" games in 1985 (yes, some games were text-only back then), and was rated among the top 10 educational programs by *Science '86*. Perhaps most telling, *Boy's Life* said that it "tests the cunning of even the most woods-wise outdoorsman." Says Kohlhase, "Even now, 17 years later, there's no comparable game on the market. We're considering a modern version, if any multimedia developers are interested."

Kohlhase got bitten by the shutter bug as a teenager, when he used to "borrow" his dad's darkroom



As computer technology grew to permit digital manipulation of photographs, Kohlhase kept up. The above view of Pathfinder on Mars was created in 1995—two years before the landing. The rover is a life-sized mockup at JPL. The lander is a six-inch toy Kohlhase shot in his back yard, using an old shirt for the deflated airbags. He Photoshopped them into a Viking image of a rock named Big Joe, adding the rover tracks and shadows. It's no wonder some people believe that the Apollo moon landings were shot on a sound stage in Burbank . . . *Dawn Patrol*, above right, is a more recent composite in which the Pacific Design Center has been turned on its side and the roof of a merry-go-round becomes a flying saucer. The other vehicles were computer-generated, and Kohlhase put himself in the driver's seat of the foreground one by way of signing the piece.

to develop and print his own work. He graduated to Kodachrome in college, and spent many years honing his technique on his innumerable hikes. Now he's a big fan of the new digital cameras, which give him a fast track to final prints without the darkroom chemicals.

Meanwhile, the collaborations with Blinn and Huntress led naturally to experimenting with Photoshop and the like as they came into being. "For someone who cannot draw or paint like the masters, computers are a godsend. Photoshop allows you to perform digital magic on any image you wish, and 3-D modeling and rendering programs let you create any scene you can imagine."

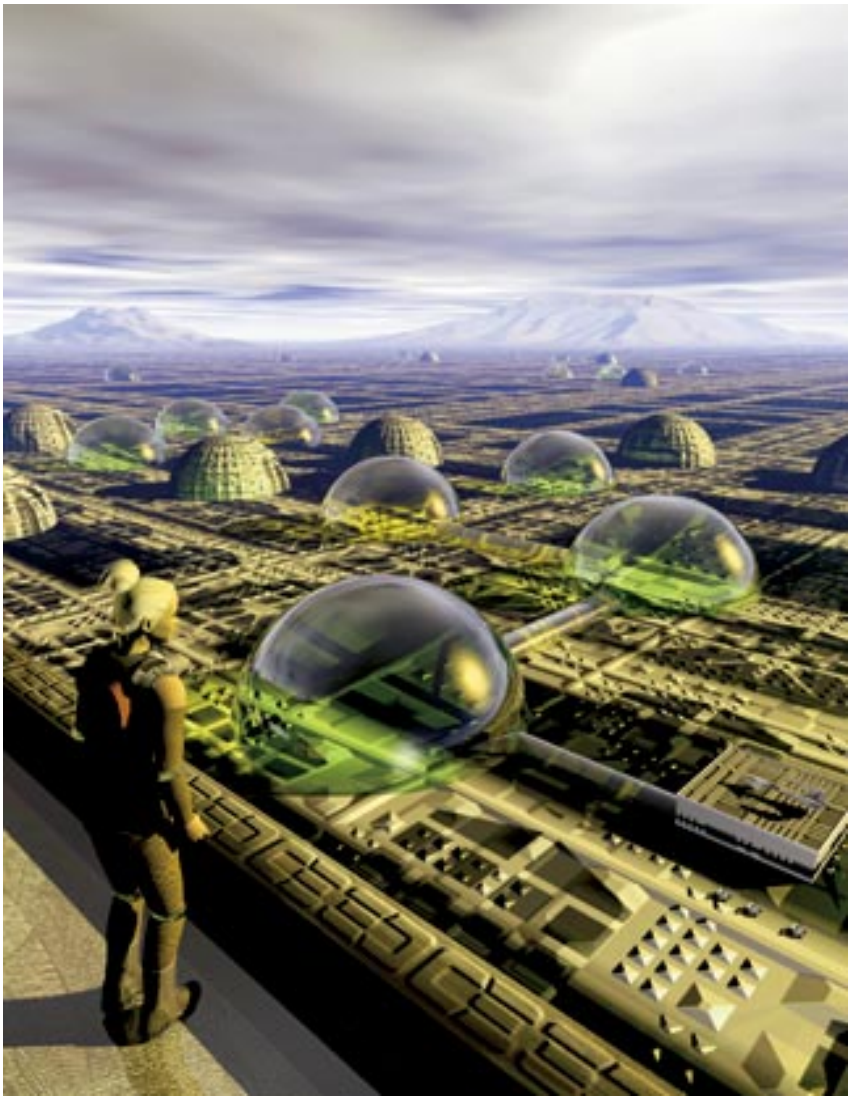
Kohlhase foresees artists using computers to create scenes beyond imagining through directed evolution. "Imagine taking the equations that govern the behavior of subatomic particles, atoms, molecules, DNA, cells, organisms, colonies, ecosystems, planetary systems, star systems, and galaxies. Immersed within this unfolding drama, you could guide its course at any scale and snap pictures with a virtual camera or save those 3-D models having irresistible appeal. Gulliver and the travelers of Jules Verne could not have beheld such sights." It's already beginning—for example, Eric Heller's images of an electron "gas" flowing in two dimensions over a bumpy surface are being sold as fine art. And Karl Sims has written software that generates three-dimensional animated abstractions that evolve as viewers in an art gallery select the most aesthetically pleasing ones and allow them to interbreed. Tom Ray has re-created Sim's software for the PC, so now anyone can grow their own.

Since science and art are both creative endeavors, and many people have a foot in both worlds, it's logical to ask what drives this creativity. Kohlhase did just that in 1999, when he came out of retirement to create the "Artists, Scientists, Engineers and Astronauts" portion of the "Mars Millennium Project" Web site, now the NASA/NEA/JPL

***Renee*, above, uses Photoshop's filters to achieve effects previously limited to 1970s album covers.**

Eventually, of course, you don't need a camera at all. *Steel Sunflower*, right, was output directly from a 3-D modeling program. This is one of a series of "virtual sculptures" in brass and steel Kohlhase began in the mid-1990s—cutting-edge stuff at the time—and one of nine of his works selected by Joe Ruggiero (of *This Old House* and HGTV fame) for display at the Pacific Design Center's IdeaHouse in 1999–2000.

***Overlook 2135*, below, was the cover art for the December 2001 issue of *Creation Engine*. The image was rendered in a 3-D graphics package called Bryce, which is known for its realistic handling of landscapes and light. Kohlhase got bonus points for incorporating the magazine's CE logo into this cargo-storage facility at the nexus of several space-shipping lanes—note the top of the perimeter wall.**



"Imagine Mars" Web site (http://mmp.planetary.org). The site describes itself as "a national arts, science and technology initiative that challenges young people to imagine and design a livable Mars community of the future," and Kohlhase persuaded 72 people from 21 disciplines to contribute short essays on the essentials—cultural as well as technical—such a community would need. Each respondent answered three questions, of which only the last concerned Mars. The first two were, "How were you motivated to choose your particular field?" and, "What can you share about your creative process?"

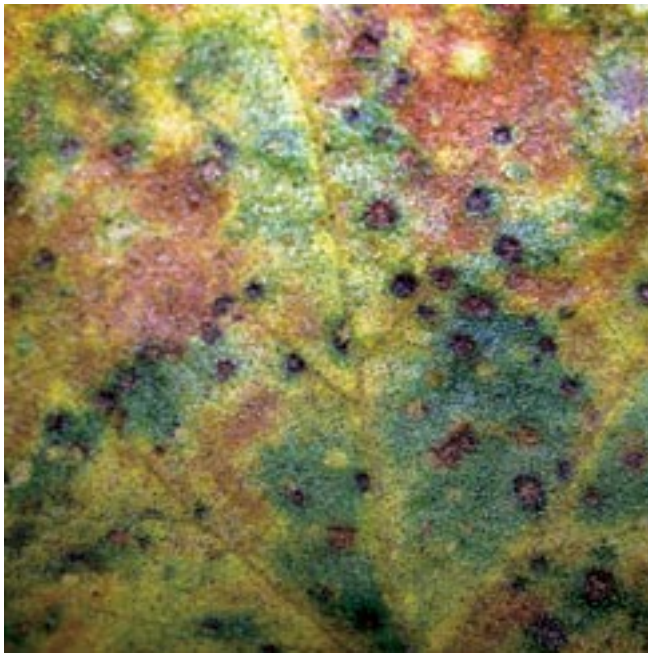
Regardless of the chosen field, several common threads emerged. The two key attributes to unleashing creativity were preparation through education—a thorough grounding in the tools of the trade, be they math and physics for an astronomer, or countless hours of practice for a pianist—followed by the ability to stop and look at the "big picture" from all angles before plunging into the problem at hand. Of secondary importance was a cluster of four traits. One was relaxing after each bout of intensive concentration—the subconscious mind, unfettered, continues to work on the problem, and the solution will bubble to the surface unbidden during a jog through the park, or perhaps in the shower the next morning. (However, scientists were nearly twice as likely to say this as artists.) Another was bouncing ideas off colleagues inside or outside one's field—but not surprisingly, scientists were three times more likely to say this. The final two might really be one item that would thus rank as a third key attribute: "being happy in one's chosen field" and "being passionate about the work and jumping in with 'all burners on.'" To creative people, work is really play, and one's most productive periods occur when playful and self-disciplined states coexist and one effortlessly shifts between them as needed. At these times, says Kohlhase, people feel deeply alive, engaged, and oblivious to the passage of

Serendipity and creativity favor the prepared—a shortcut under the Santa Monica pier during a walk on the beach resulted in the above image, which took all of 30 seconds to compose and shoot. Kohlhase has no idea what the two red boats were doing there.

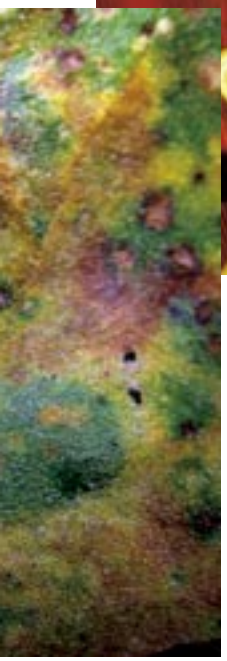
time. "The creative individual is playing with the balance of many forces—playfully energetic but good at relaxing, passionate yet objective, rebelliously independent but disciplined, and constantly moving between reality and fantasy. He or she is usually involved in more than one field, and aware of the great beauty of the natural world."

When asked what motivated their career choice, the most popular answer was the childhood influence of a parent, teacher, or friend who nurtured a talent or sparked an interest—anything from singing to watching an ant farm. Other reasons included storytelling in all its forms (including reading); exposure to the beauty of the natural world; and, for the scientists, innate curiosity and the thrill of the space age. Which was certainly true of young Charley—he built model airplanes and dreamed of flying, and his granny read him adventure stories. "I used to lie in the cool grass and gaze at the stars, but I would never have predicted this bounty. And I still get to watch my old Voyager companions try to reach the heliopause, while my newer Cassini–Huygens teammates seek the remote kingdoms of Saturn." □

Charles Kohlhase earned degrees in physics from Georgia Tech and in engineering from UCLA. He is a planetary mission designer, artist, author, educator, and environmentalist. Called JPL's premiere builder of missions by Spaceflight *magazine, he has received international acclaim for his 40-year body of work on Mariner, Viking, Voyager, and Cassini. He has recently returned to JPL part time to help with what he calls the "stunning queue" of upcoming Mars missions and as a technical advisor to the Kepler project to find Earth-sized planets orbiting other stars. This article was inspired by a Michelin seminar he gave on May 6, 2002.*



Kohlhase built the radio-controlled, quarter-scale model of a circa-1911 Bleriot at left from seven different kinds of wood. It took him 300 hours, so he's never had the nerve to fly it. (Over the years, he's crashed several models and lost a few more—including one that turned up five years later in a field 20 miles away.)



Nature is art, and reality is abstraction. It all depends on the scale of the view. ***Presentation***, at left, is an array of oil and vinegar bottles at the farmers' market in Pasadena's Victory Park. ***Nature as Art***, above left, is a half-inch portion of a tiny leaf. ***Red Runner***, above top, is an exploration of the dimension of time instead of space—Kohlhase was shooting a long-exposure night scene in Amsterdam's red-light district when he was ambushed by the hookers' enforcer. He fled down the street with the aperture still open. ***Urban Rider #2***, below it, is a piece of the Bonaventure Hotel in downtown Los Angeles—a geometric fugue of light, glass, and steel. And ***Palette on Glass***, right, is a snippet of a 35-millimeter slide of a swath of coastal wildflowers near Big Sur, California, digitally enhanced with Photoshop's watercolor filter. For more images, see http://artshow.com/kohlhase.