PROFILE DAN DURDA

Cave Diving on Asteroids

Planetary scientist Dan Durda flies high, dives deep, and wants to be one of the first to touch the surface of an object beyond the moon

BOULDER, COLORADO—Twilight is stunning from the rear cockpit of an F-18 jet, Dan Durda says. A vivid ribbon of red and violet lingers after sunset. The zodiacal light—sunlight reflected from dust in our solar system—arcs above the horizon, brighter than the Milky Way. Stars and planets glow without twinkling in the coal-black sky. Topping it off are the brilliant blue afterburners that propel Durda through the stratosphere, 15 kilometers high.

These flights aren't just military joyrides. Rather, they are the most enjoyable part of Durda's wide-ranging research in planetary science. With help from NASA test pilots, he scours the twilight sky for asteroids that orbit closer to the sun than Mercury. No one knows whether such "vulcanoids"—named for a planet once thought to dwell there—exist, but he wants to be the first to spot one.

Durda would happily spend all his time exploring nature at Mach 0.9. "Dan is one of those people where it's very hard to say what he does for a living," observes planetary scientist Erik Asphaug of the University of California, Santa Cruz. At age 36, Durda is best known for creating painstaking models that have helped reveal how collisions shape the evolution of the asteroid belt, from the largest objects to the tiniest grains of interplanetary dust. He loves plumbing the depths of water-filled caves, and he is an accomplished space artist. He is a pilot himself and aspires to join NASA's astronaut corps.

Indeed, Durda's overarching goal is to float along an asteroid's surface on the first human mission beyond the moon. "Dan would be spectacular," says S. Alan Stern, director of the department of space studies here at the Southwest Research Institute (SwRI) and Durda's colleague on the vulcanoid search. Although government officials have been "stuck in Earth orbit for 30 years," Stern says, Durda's future "is unlimited."

Cosmos and the space shuttle

Durda's office at SwRI overlooks the jagged foothills of the Rockies. A plaque commemorating an asteroid named after him (6141 Durda) sits on a heater under the window. A spectacularly patriotic print of an F-16 jet that once hung in the hallway now decorates his wall after some SwRI staff members teased him that it was jingoistic. Rows of Post-it notes march across a computer table, marked with numerals precisely 2 millimeters high.

Many aspects of his life are as precisely laid out as those numbers. "I absolutely am at my best and most satisfied when I have to think through a detailed plan before I start going through the operation," says Durda, who has receding sandy brown hair, squarish wire-rimmed glasses, and a neat mustache. It's easy to imagine his 1.7-meter, 63.4-kilogram (5′7″, 140-pound) body wriggling through submerged channels. "For years I was stabilized at 132 pounds," he says. "But last year I learned that for the F-18 ejection seat, you have to be 140 pounds, minimum. Otherwise, it can break your back." Despite his hummingbird metabolism, he went to the gym and gained 3.6 kg of muscle mass.

As long as he can remember, Durda has battled gravity. He and his childhood buddies in suburban Detroit made black-powder grenades from the cartridges of BB guns, lit them under rocks, and measured how high the rocks flew. After his parents moved to rural Alger, Michigan, Durda attended high school next to a cow field. Despite the bucolic setting, the veteran corps of teachers in Alger "had maxed out a beautiful science curriculum," he recalls. "Astronomy, entomology, botany, water ecology—I took them all." He dreamed of floating under the sea as a marine biologist, but that changed in 10th grade once he heard the late Carl Sagan expound on the wonders of the universe. "In the fall of 1980, a PBS series called *Cosmos* came out, and boom, that was it."

Durda's fascination with the space program took deep root in graduate school at the University of Florida, Gainesville, where he met fellow student Dirk Terrell. The two became the "dynamic duo," famed for their eerily synchronous thoughts and their repeated 6-hour car trips—27 in all—to Cape Canaveral to see space-shuttle launches. "We went to the first post-Challenger launch, and we were hooked," says Terrell, an astrophysicist and computer specialist at SwRI. "It was a very emotional experience. It brought tears to my eyes."

"The thing that floored me was the color and intensity of the solid rocket-booster exhaust," Durda says. "It's a deep crimson orange, as bright as the setting sun. And all around us was a sound like someone shaking huge sheets of corrugated metal." After several launches, Durda divined the source: thousands of palm fronds, rattling in unison to the intense bass vibrations.

Terrell and Durda also were captivated by Florida's vast networks of sinkholes and water-filled karst caverns, which they explored in increasingly ambitious dives. "I certainly didn't approve of it," says Durda's adviser at Gainesville, planetary scientist Stan Dermott. "I thought he was doing it to prove to NASA that he could cope with ridiculously dangerous situations."

About a half-dozen people die in Florida's caves each year. But Terrell and Durda—who coordinates the International Underwater Cave Rescue and Recovery team in Arizona and Colorado—say they have never felt at risk because of meticu-

Hot jet. Dan Durda admires this model of an F-18, but he flies in the real thing to hunt for new asteroids close to the sun.

CREDIT: ELLEN JASKOL/GAMMA

lous planning. And deep in the tunnels, Durda says, "It's pure joy. The water in Florida caves is as clear as gin. The entrance of a deep sinkhole glows like a cathedral with shafts of teal and turquoise light. No photograph could capture the beauty of that."

Dust and hot rocks

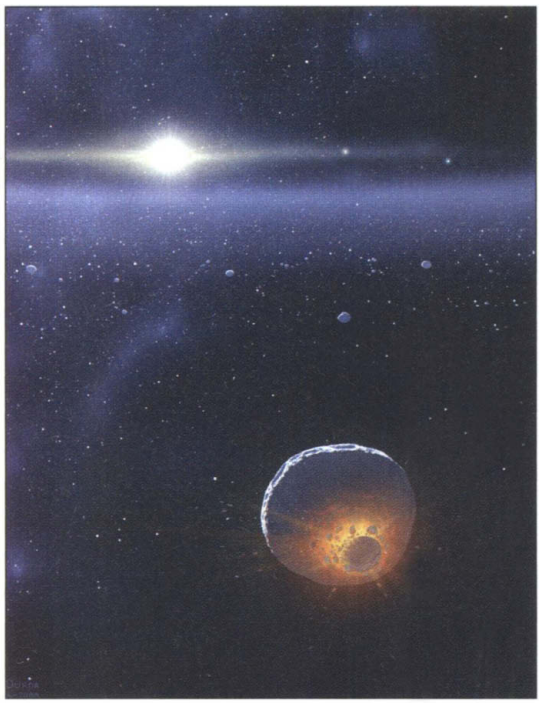
Dermott encouraged Durda to study the evolution of the solar system's minor bodies by taking into account all data about their sizes and bands of dust. Durda made his first mark by building the most detailed models yet of asteroid impacts, collisional histories, and dust formation. He infuses his models with data from experiments in which he blasts projectiles into real meteorites—a facet of Durda's work that, according to Asphaug, sets it apart from the purely theoretical constructs of many colleagues. "It was like holding a dirt clod in your hands," Durda says about one experiment with a Russian meteorite. "It blew into dust, and we didn't even hit it that hard."

In the mid-1990s, Durda worked as a postdoctoral researcher under planetary scientist Richard Greenberg at the University of Arizona, Tucson. Using images from the Galileo space probe, the group dove into detailed studies of Ida, a potato-shaped asteroid. They explained how impacts dredged material from Ida's interior and splashed it across the surface. Incorporating Durda's work on collisions, the model also accounted for Ida's tiny satellite, Dactyl. "It all came together with that team," Durda says. "It was the most satisfying thing I've done."

Geologist David Kring, also at Tucson, urged Durda to scale up his Ida model to the size of Earth and apply it to the sexiest crash of all: the dinosaur-killing asteroid impact 65 million years ago. The blast sprayed trillions of meteors that heated parts of Earth's atmosphere so fiercely that it would have been "like putting your head in an oven on broil," Durda says. In a paper in press at the *Journal of Geophysical Research—Planets*, he and Kring compute where the heat would have been intense enough to ignite wet vegetation. The duo has conducted fieldwork in southern Colorado and elsewhere to expose charcoal deposits left by the resulting fires.

His Arizona years also opened Durda's eyes to the world of space art. "He would come into the gallery, but he never bought anything," says Kim Poor, owner of Novaspace Galleries in Tucson. "He would just look closely at the paintings and leave. It got annoying after a while." But when Poor finally got a peek at Durda's early work, he saw immediately that "it was professional quality."

Durda began painting "rocks and balls," canvases filled with objects floating ethereally in star-speckled skies. As his skills grew, he tackled more intricate spacescapes and dynamic renditions of objects smashing into each other. His painting of Pluto and its moon Charon (*Science*, 26 July, p. 495) has become the iconic image for a proposed mission to Pluto, led by Stern. Most recently, Durda has turned to landscapes that look like earthly vistas. "I make them space art by putting a planet in the sky," he says with a chuckle.



Otherworldly. Durda's art sometimes mirrors his science, as in this painting of a head-on collision between bodies in the outer solar system.

Tucson afforded Durda everything he wanted, save for the chance to soar. "Dan is an addict for airplanes," says Stern. When Stern told Durda in 1998 that SwRI wanted a researcher for the world's only opportunity to do astronomy from high-performance jets, Durda leapt at the offer without even visiting Boulder.

Since then, the pair has carried out increasingly thorough searches for the solar system's hottest asteroids. Many researchers doubt that vulcanoids have survived the sun's heat and other disruptions for nearly 5 billion years. However, some models—including Stern and Durda's—predict that scores of hardy bodies, from 1 to 10 kilometers across, might persist about halfway between Mercury and the sun. The researchers' main tool is a sensitive ultraviolet video camera attached to an 85-millimeter lens that fits in the cockpit.

Soon, Durda and Stern hope to ascend to greater heights—nearly 23 kilometers—in the back of a U-2 airplane. There, the twilight sky will be darker still. "The two of us are on a vulcanoid jihad," Stern says. "We're going to find them if they're there."

Caves near and far

Only one siren could lure Durda from Boulder: the space shuttle itself. "I'd drop everything to go to Houston," he says. "If NASA picked me, I'd be there for life."

During NASA's last selection round 2 years ago, Durda made the top 12% of astronaut hopefuls (playfully called "asho's" by the astronauts). In the next round, set for summer 2003, he hopes to make the final cut. His Tucson colleagues are pulling for him. "He'd be a terrific astronaut," says Greenberg. "He's got intellect and a real level-headed competence, and he's enthusiastic about everything he does." Adds Kring: "I can't think of anyone better prepared in the community."

Meanwhile, Durda keeps launching new ventures on Earth. For instance, he is awaiting word on his request for funding from a new NASA program called Astrobiology Science and Technology for Exploring Planets. He's part of a team led by robotics expert Bill Stone of Stone Aerospace in Gaithersburg, Maryland, that hopes to send an autonomous robot far into Zacotón Cenoté, a deep hydrothermal system near Mexico's gulf coast. The labyrinth claimed the world's top cave diver in 1994.

"Nobody knows what the hell is down there," Stone says. "It screams for robotic exploration." Durda worked with biologists and engineers at SwRI and elsewhere on a robot that could recognize life forms—especially novel ones. He and Stone view the vessel as a prototype for exploring the subsurface of Mars or Europa's dark ocean.

Durda also views the robot as a surrogate for his dreams of reaching space. "Moving around on the surface of an asteroid will require the same skills and techniques you need for cave diving," he says. "Gravity is so low that we will float over the surface, not walk. It will require a lot of care and finesse to avoid stirring up dust."

Durda becomes animated when he thinks of the trailblazing science of such a mission—as well as the role he would play in telling a captivated public all about it. "I'm trying as hard as I can to position myself to be on that first crew," he says. "It's obviously a long shot, but I would do it in a heartbeat."

—ROBERT IRION

ARTWORK: D. DURDA