Science Fact

# Big Smart Objects

Gregory Benford & Larry Niven

My rule is there is nothing so big nor so crazy that one out of a million technological societies may not feel itself driven to do, provided it is physically possible.

—Freeman Dyson,
"The Search for Extraterrestrial
Technology," *Perspectives in Modern Physics*

dialogue has been going on within the science and science fiction communities for centuries now. It may have started with Dante's Divine Comedy, and continued with *Star Maker* by Olaf Stapleton. Freeman Dyson, inspired by Stapleton, calculated limits on a structure's size in outer space, set by the strength of materials. Larry Niven's Ringworld was part of these explorations, and Bob Shaw's Orbitsville. It's a conversation about advanced societies building outrageously big habitats, using plausible science.

Such were called Big Dumb Objects by Peter Nicholls (who quoted British writer Roz Kaveney) in *The Encyclopedia of Science Fiction* as a joke in 1993. There is now a Wikipedia entry on the many such fictions.

The Bowl of Heaven trilogy descends from that tradition, though we prefer to call the Bowl and the Glorian double planet Big Smart Objects, since they must be continuously managed to be stable. Our trilogy is undoubtedly not the last word. We aimed for "amazing vistas, shocks, sensawunda," as our proposal put it, a decade ago. Thinking through the logic of structures, then the structure of plots, takes work.

One of the great problems with world creation is when it becomes an end in itself. When this happens, it can become a rather neurotic attempt to contain a world and to taxonomize a world totally—which is of course impossible. You end up with clunky fiction, walking your characters through all the places you've created, simply because you have created them. This is akin to the age-old heritage of the infodump—*By God, I suffered through all this research and now it's your turn.* It's best to not fill in everything on a map. It's meaningless. Leave things unknown—because there's so damn much of it.

The best reason to do such work is simple: it's fun! We take each other's notions and send

them zipping off on different vectors. We worked best when we could sit, talk, think, build in stacks the ideas that started with the first idea: a vast bowl built to capture and refocus a star's own radiation.

**Plot:** On the way to a distant star, the starship *SunSeeker* comes upon a vast artificial construction that's also heading for their common destination, a planet called Glory. A small star is traveling out ahead of (and pulling along) a large Bowl whose circumference is the size of the orbit of Mercury. The starship comes alongside it.

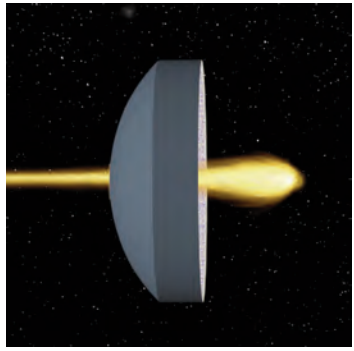

Image by Don Davis

The Bowl is like half of a Dyson Sphere, part of it silvered like a mirrored cooking wok. There is a hole in the bottom larger than Jupiter. A jet from its star passes through the hole, driving the whole system, magnetically controlled. The Bowl is the size of a solar system. The upper rim of the Bowl is a habitable swath of land far larger than the area of Ringworld. It has oceans, deserts, rivers, forests—but no major mountains. Seen full on, it's striking.

Why a Bowl? To manage the star. Why? So the whole system, Bowl *and* star, can move in cohort . . . to explore the galaxy. How? The sunlight reflected back on the star fires off a jet, which pushes the star . . . and the Bowl of Heaven follows like a tethered animal. Tricky, yes—and managed by beings who could and would think of this and make it happen—for millions of years. The Bowl cruises into eternity.

Their ship *SunSeeker* is low on fuel and needs repairs. The Bowl may be their only chance to fix that. But . . . how to get onto it? The rim area seems well defended, so . . . fly up the exhaust! Take the Bowl by surprise. Soaring into a plasma flood, running the rapids.

Of course the crew of *SunSeeker* will explore it. Why not? They sought out the planet Glory to find a new biosphere, and this huge thing is hundreds of millions of times bigger. A bonanza!

It holds millions of adopted species of intelligent and semi-intelligent beings, hundreds of thousands of ecologies. The Bowl is not only a weird, wonderful contraption world; it's a ship traveling the Milky Way. It's been doing so since the time of the dinosaurs.

Humans, being what they are (primates, irritating and pushy), have a natural, omnivore predator's curiosity. The *SunSeeker* crew decide to send a team down to investigate this BSO (Big Smart Object, one that demands control for stability, which Gregory Benford defines in the afterword). The team is led by Cliff Kammath, a biologist, and Beth Marble, a pilot. The rest of the human crew on board the *SunSeeker* remains in orbit around the Bowl, with Captain Redwing in frustrated command—he wants to explore too.

Those ruling this enormous contraption are the Folk, bird aliens. They take some people captive; others escape. There are great views. Great perils. Big risks. Some deaths. Revelations. But the views! Here's one:

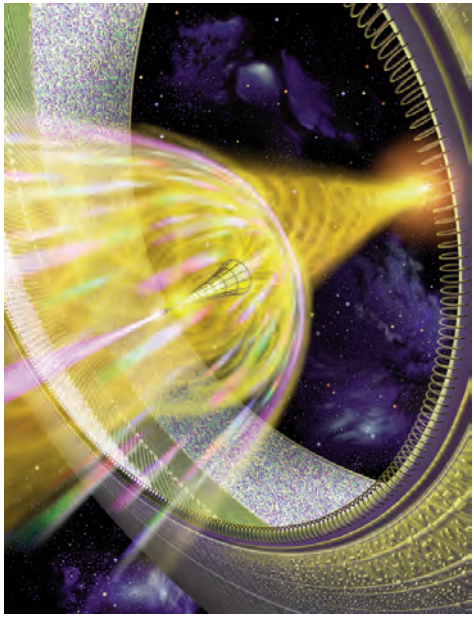

Image by Don Davis

The views are vast, strange and commanding. No stars in the sky, daylight constant, centrifugal gravity from the spinning Bowl slanting at an angle. Strange lands, indeed.

The alien big-birdy Folk hunt the escaped humans across huge distances. Fast transport in a robotic subway-like structure helps, but our heroes seldom get any respite. The Folk are relentless, for they have protected the Bowl against invading species for millions of years. Humans are just another pest. Though ingenious, true. Maybe the Bowl would be better off without them.

Our protagonists meet strangeness squared—the Ice Minds that cling to the outer, cold shell, and are the collective memory of such a long-lived contraption. Stone minds embody hard memory and slow intelligence, with their own wisdoms. Plus the flora and fauna are oddity upon oddity. Like the gasbag creature that's actually a huge battleship, pictured on page 42.

The second novel, *Shipstar*, carries the drama further. There are revelations of the Bowl history, especially since it visited Earth long ago, with impacts on our biology and on human origins. The humans make a deal with the Folk and other smart species—not without conflict and death, however.

The third, concluding novel released in June 2020: *Glorious. SunSeeker* finally voyages on ahead of the slower Bowl, reaching the target star they both sought. From the Glory system come mysterious signals in gravitational waves. How are those vibrations in space-time itself made? Where? And what culture created them?

Turns out, Glory is a double planet. Our solar system has such a pair—Pluto is tide-locked to its large moon Charon, so both eternally face each other. At Glory, these worlds have atmospheres and life, so the natives have made use of their unique dynamics. They have built a Cobweb between worlds, opening a volume far larger than the mere surface of their planets. This colossal building-between-worlds gives them unique resources, populations, technologies. Here's what it looks like, seen from beyond the smaller world:

Image by Don Davis

They can send gravitational wave messages! But . . . to who? And why?

Societies millions of years old have different, strange agendas. Mere humans have trouble understanding this. People die in the attempt. Aliens are . . . alien. Yes.

Exploring this huge construct makes *Glorious* a tour of the possible Big Smart Objects that have played out in science fiction since Dyson spheres debuted in 1960s. It is sad yet somehow appropriate that just as we finished this novel, and were ushering it into print, Dyson died, at the considerable age of 96.

Would aliens build such objects? Could be . . . and humans can be a part of it. After all, we've already made big stories about the ideas. You can't have a future you do not first imagine.

And then . . . adventure on the largest scales ever envisioned.

As a teaser, look to the next column for a Don Davis painting of a skirmish between the Bowl and an incoming small though massive black hole, with a powerful magnetic field of its own. Weaponized black holes! Gravitational effects are apparent in this warfare.

### Physics Writes the Story

We started on *Bowl of Heaven* and realized about half a year later that we couldn't do the story

Image by Don Davis

in a single volume. So we wrote *Bowl of Heaven* and then *Shipstar* to work out the whole bowl society.

But we hadn't gotten to the bowl's destination, which our human characters were headed for, too. So to follow the theme of Big Smart Objects, we followed the logic and designed a wholly new system. The Glorian double planet echoes the flyby of Pluto and Charon that is indeed a natural, mutually tide-locked system (though we had the idea before we learned these things about Pluto and Charon).

At each stage, we tried out ideas on each other, wrote scenes, bounced them between us in the ping-pong of creation. Writing is a solitary craft, but!—uniquely, science fiction encourages

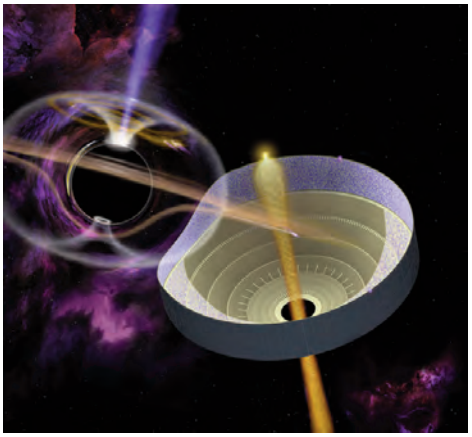

Image by Don Davis

collaboration, echoing its core culture: science itself, in which single-author papers are a decided minority. So our novels come from this ping-pong, making writing fun for and of itself.

Larry likes doing aliens and their odd thoughts, as in his Known Space stories. Gregory likes the designer aspects—how does the Bowl work? And this new place, Glory? More mega-engineering! Plus room for ingenious physics. We don't think any other kind of writing can do this. Which means SF is more fun than, say, mysteries, for the writer(s)—and that plural is key.

In the end, we realized that these novels are a way to think about what truly long-lived societies may be like. We humans have a built-in inclination to go over the horizon, expand, occupy. No other species has occupied every continent and co-opted so much of its energy and land. So too might alien societies.

To get more living room, they might build Big Smart Objects and then move on to other interesting pursuits. The Bowl goes touring the galaxy. The Glorian system ponders deep issues like the stability of the universe itself, and how to avoid disasters that come from mega-engineering hubris. Could this be how the long-lived civilizations think, that the Search for Extraterrestrial Intelligence might find? If so, it's worth thinking now about how to talk to them.

The extraordinary astronomical artist Don Davis helped us envision the gigantic structures and events of this three novel sequence, an invaluable resource. Here is the Bowl, a huge photon-driven engine:

**Why Big?**

We think of such engines as Smart Objects—statically unstable but dynamically stable, as we are when we walk. We fall forward on one leg, then catch ourselves with the other. That takes a lot of fast signal processing and coordination. (We're the only large animal without a tail that's mastered this. Two legs are dangerous without a big brain or a stabilizing tail.) There've been several Big Dumb Objects in SF, but as far as we know, no smart ones.

Our Bowl is a shell more than a hundred million miles across, held to a star by gravity and some electrodynamic forces. The star produces a long jet of hot gas, which is magnetically confined so well it spears through a hole at the crown of the cup-shaped shell. (This plays to one of Benford's research areas, plasma physics on large scales, like galactic-scale jets from the disks around black holes. Later, there emerged jets from ordinary stars. How all these hundreds of jets

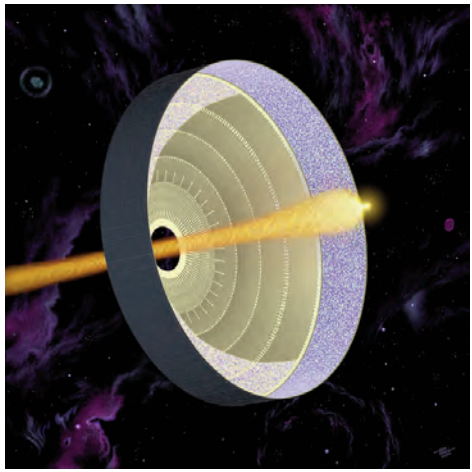

Image by Don Davis

remain stable, jetting through millions of light-years, is an active puzzle.)

To keep balance, this Bowl-made jet propels the entire system forward—literally, a star turned into the engine of a "ship" that is the shell, the Bowl. On the shell's inner face, a sprawling civilization dwells. The novel's structure doesn't resemble Larry's *Ringworld* much because the big problem is dealing with the natives.

The virtue of any Big Object, whether Dumb or Smart, is energy and space. The collected solar energy is immense, and the living space lies beyond comprehension except in numerical terms. While we were planning this, our friend Freeman Dyson remarked,

> I like to use a figure of demerit for habitats, namely the ratio R of total mass to the supply of available energy. The bigger R is, the poorer the habitat. If we calculate R for the Earth, using total incident sunlight as the available energy, the result is about twelve thousand tons per Watt. If we calculate R for a cometary object with optical concentrators, travelling anywhere in the galaxy where a 0 magnitude star is visible, the result is 100 tons per Watt. A cometary object, almost anywhere in the galaxy, is 120 times better than planet Earth as a home for life. The basic problem with planets is that they have too little area and too much mass. Life needs area, not only to collect incident energy but also to dispose of waste heat. In the long run, life will spread to the places where mass can be used most efficiently, far away from planets, to comet clouds or to dust clouds not too far from a friendly star. If the friendly star happens to be our Sun, we have a chance to detect any wandering life-form that may have settled here.

This insight helped *us* think through the Bowl, which has an R of about $10^{10}$ !—ten billion.

The spinning Bowl's local centrifugal gravity avoids entirely the piling up of mass to get a grip on objects, and just uses rotary mechanics. So of course, that shifts the engineering problem to the Bowl structural demands.

Historically, big human-built objects, whether pyramids, cathedrals, or skyscrapers, can always be criticized as criminal wastes of a civilization's resources, particularly when they seem tacky or tasteless.

But not if they extend living spaces and seminatural habitat. This idea goes back to Olaf Stapledon's *Star Maker*: "Not only was every solar system now surrounded by a gauze of light traps, which focused the escaping solar energy for intelligent use, so that the whole galaxy was dimmed, but many stars that were not suited to be suns were disintegrated, and rifled of their prodigious stores of sub-atomic energy." Dyson says this passage gave him the Dyson Sphere idea.

Our smart Bowl craft is going somewhere, not just sitting around, waiting for visitors like a Dyson Sphere or Ringworld—and its tenders live aboard.

We started with the obvious: Where are they going, and why? Answering that question generated the entire frame of the two novels. That's the fun of smart objects—they don't just awe, they intrigue.

Benford's grandfather used to say, as the two of them headed out into the Gulf of Mexico on a shrimping run, *A boat is just looking for a place to sink.* So heading out to design a new, shiny, Big Smart Object, we said, *An artificial world is just looking for a seam to pop.*

You're living just meters away from a high vacuum that's moving fast, because of the Bowl's spin (to supply centrifugal gravity). That makes it easy to launch ships, since they have the rotational velocity with respect to the Bowl or Ringworld . . . but that also means high seam-popping stresses have to be compensated. Living creatures on the sunny side will want to tinker, try new things . . .

"Y'know Fred, I think I can fix this plumbing problem with just a drill-through right here. Uh—oops!"

The vacuum can suck you right through. Suddenly you're moving off on a tangent at a thousand kilometers a second—far larger than the 50 km/sec needed to escape the star. This makes exploring passing nearby stars on flyby missions easy.

But that easy exit is a hazard, indeed. To live on a Big Smart Object, you'd better be pretty smart yourself.

### Stable?

Very smart, it turns out. The Bowl is unstable, because it's not in orbit—just like the Ringworld. Push it inward, it falls into the star. Push it away, as the photon thrust will do, and it'll fall outward, doomed. So how to build something that harvests a star's energy to move it and can be stabilized? We supposed the Bowl's founders made its understory frame with something like *scrith*—a Ringworld term, greyish translucent material with strength on the order of the nuclear

binding energy.

Right, incredible—but not impossible. This is from the same level of physics as held Ringworld from flying apart. It is the only outright physical miracle needed to make Ringworld or the Bowl work mechanically. Rendering Ringworld stable is a simple problem—just counteract small sidewise nudges. Making the Bowl work in dynamic terms is far harder; the big problem is the jet and its magnetic fields. This was Benford's department, since he published many research papers, in *Astrophysical Journal* and the like, on jets from the accretion disks around black holes, some of which are far longer than galaxies. But who manages the jet? Nobody; nature does it for free. And how, since it's larger than worlds? This puzzle is how you get plot moves from the underlying physics.

One way to think of the strength needed to hold the Bowl together is by envisioning what would hold up a tower a hundred thousand kilometers high on Earth. The tallest building we now have is the 829.8 m (2,722 ft) tall Burj Khalifa in Dubai, United Arab Emirates. So for Ringworld or for the Bowl we're imagining a scrith-like substance 100,000 times stronger than the best steel and carbon composites. Even under static conditions, though, buildings have a tendency to buckle under varying stresses. Really bad weather can blow over very strong buildings.

So this is mega-engineering by master engineers indeed. Neutron stars can cope with such stresses, we know, and smart aliens or even ordinary humans might do well too. So: let engineers at Caltech (where Larry was an undergraduate) or Georgia Tech (where Benford nearly went) or MIT (where Benford did a sabbatical) take a crack at it, then wait a century or two—who knows what they might invent? This is a premise and still better, a promise—the essence of modern science fiction.

Our own inner solar system contains enough usable material for a classic Dyson sphere. The planets and vast, cold swarms of ice and rock, like our Kuiper Belt and Oort Clouds—all that, orbiting around another star, can plausibly give enough mass to build the Bowl. For alien minds, this could be a beckoning temptation. Put it together from freely orbiting substructures. Stick it into bigger masses; use molecular glues. Then stabilize such sheet masses into plates that can get nudged inward. This lets the builders lock them together into a shell—for example, from spherical triangles. The work of generations, even for beings with very long lifespans. We humans have done such, as seen in Chartres cathedral, the Great Wall, and much else.

## Jets and Origins

Still: Who did this?—and why? The Bowl was first made for just living beneath constant sunshine. Think of it as an interstellar Florida, warm and mild, with a fantastic night sky. Which keeps moving, over time.

At first the builders may have basked in the glow of their smaller sun, developing and colonizing the Bowl with ambitions to have a huge surface area with room for immense natural expanses.

But then the Bowl natives began dreaming of colonizing the galaxy. They hit on the jet idea, and already had the Knothole as an exit for it. Building the mirror zone took a while, but then the jet allowed them to voyage. It didn't work as well as they thought, and demanded control—which they got by using large magnetic fields.

The system had virtues for space flight, too. Once in space, outside, you're in free fall. The Bowl mass is fairly large, but you exit on the outer hull at high velocity, hundreds of kilometers a second, so the faint gravitational attraction of the Bowl is no issue—or of any passing star. Anyone can scoot around their parent solar system, and it's cleared of all large masses. The Bowl atmosphere serves to burn any meteorites that punch through the monolayer, just like Earth. Plus you get great vistas in view of all, since it's always daytime. Local gravity depends on what part of the Bowl you're living on:

The key idea is that a big fraction of the Bowl is mirrored, directing reflected sunlight onto a small spot on the star, at the foot of the jet. From this spot the enhanced sunlight excites a standing "flare" that makes a magnetically confined and directed jet of plasma. This jet drives the star forward, pulling the Bowl with it through gravitation.

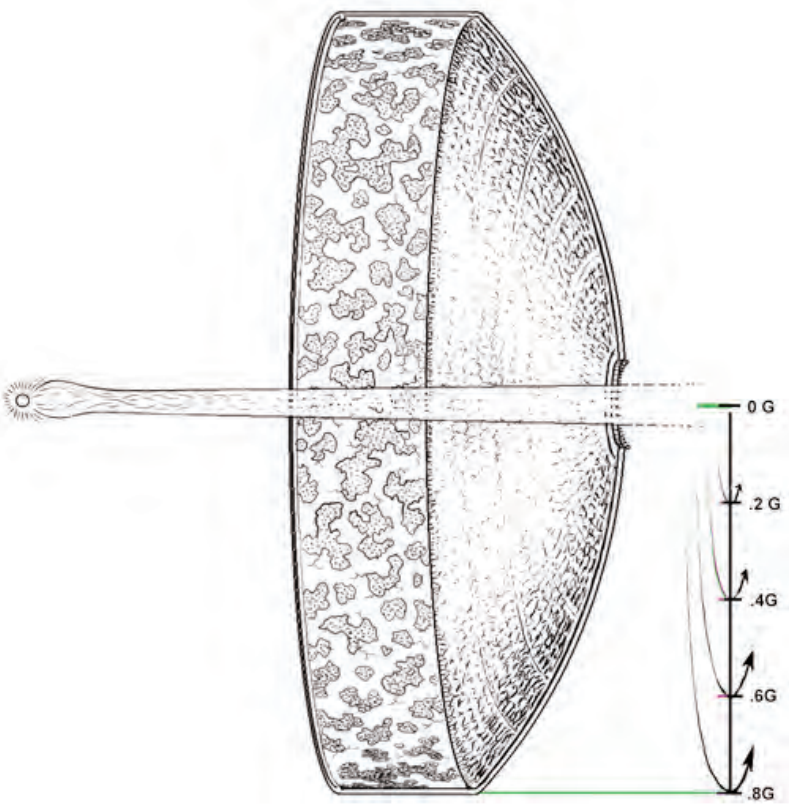


Image by Don Davis

The jet passes through a Knothole at the "bottom" of the Bowl, out into space, as exhaust. Magnetic fields, entrained on the star surface, wrap around the outgoing jet plasma and confine it, so it does not flare out and paint the interior face of the Bowl—where a whole living ecology thrives, immensely larger than Earth's area. So it's a huge moving object, the largest we could envision, since we wanted to write a novel about something beyond Niven's Ringworld.

For plausible stellar parameters, the jet can drive the system roughly a light-year in a few centuries. Slow but inexorable, with steering a delicate problem, the Bowl glides through the interstellar reaches.

The star acts as a shield, stopping random iceteroids that may lie in the Bowl's path. There is friction from the interstellar plasma and dust density acting against the huge solar magnetosphere of the star, essentially a sphere one hundred Astronomical Units in radius.

So the jet can be managed to adjust acceleration, if needed. If the jet becomes unstable, the most plausible destructive mode is the kink, like a twisting firehose—a snarling knot in the flow that moves outward. This could lash sideways and hammer the zones near the Knothole with virulent plasma, a dense solar wind.

The first mode of defense, if the jet seems to be developing a kink, would be to turn the mirrors aside, not illuminating the jet foot. But that might not be enough to prevent a destructive kink. This has happened in the past, we decided, and lives in Bowl legend.

The jet blows off, carrying most of what would be the star's solar wind, trapped in magnetic fields and heading straight along the system axis. The incoming reflected sunlight also heats the star, which struggles to find an equilibrium.

The K2 star we gave the Bowl is now running in a warmer surface regime, heated by the mirrors, thus making its spectrum nearer that of Sol. This explains how the star can have a spectral class somewhat different from that predicted by its mass. It looks oddly colored, more yellow than its mass would indicate.

For that matter, that little sun used to be a little bigger. It's been blowing off a jet for many millions of years. Still, it should last a long time. The Bowl could circle the galaxy itself several times.

The atmosphere is quite deep, more than 200 km. This soaks up solar wind and cosmic rays and makes the Bowl toasty through greenhouse effect. Also, the pressure is higher than Earth normal by about 50%, depending on location in the Bowl. It is also a reservoir to absorb the occasional big, unintended hit to the ecology.

Compress Earth's entire atmosphere down to the density of water, and it would only be thirty feet deep. Everything we're dumping into our air goes into just thirty feet of compressed nitrogen and oxygen, then. The Bowl has much more, over a hundred yards deep in equivalent water. Too much carbon dioxide? It gets more diluted.

This deeper atmosphere explains why in low-grav areas surprisingly large things can fly—big aliens and even humans. We humans Earthside enjoy a partial pressure of 0.21 bars of oxygen, and we can do quite nicely in a two-bar atmosphere of almost pure oxygen (but be careful about fire). The Bowl has a bit less oxygen than we like: 0.18 bar, but the higher pressure compensates. This depresses fire risk, our engineers figure out later.

Starting out, we wrote a background history of where the Builders came from, which we didn't insert into the novel. It lays out a version of what made the Builders do all this.

### Is this Plausible?

Not really. But possible, yes—following the Dyson quote we opened with. It demands the *scrith*, for example, which nobody knows how to make.

And the Bowl is a vast accident waiting to happen. You can't just say *Don't blame me, it's nonlinear.* Somebody has to manage that jet *forever.* The natives get to take part in slow-motion starflight, but they're always in danger. Their society must keep this from being obvious, or they'd all go crazy.

Why risk riding on such a contraption? To tour the galaxy while enjoying a balmy, semitropical, vast landscape.

The Bowl and the humans who overtake it are headed to the same star: Glory, people call it. We took two books to explore the Bowl, *Bowl of Heaven* and *Shipstar.* Both our jaunty people and the Bowl reach their target in *Glorious*—which turns out to be another kind of gigantic

Image by Don Davis

contraption. Here's a look at the Glorian colossus:

### Thinking Ever-Larger

So how to avoid such a narrowing of the tech sublime? Back to our novels: both the Bowl and the Glorian Cobweb between worlds envision using larger scales to manifest greater freedom. Equating expanses with freedom is a very American perspective.

These perspectives animate Big Object fiction such as John Varley's Gaean trilogy, Robert Reed's *Marrow*; George Zebrowski's *Macrolife*—all pointing back to Olaf Stapledon's *Star Maker* (1937) These need not be interstellar contraptions. We could build in our solar system miniature Ringworlds that—rather than encircling their suns and needing artificial arrangements to reproduce the cycle of night and day—are simply tilted to allow half the inner surface of the rotating Ring to receive natural sunlight. So while our Bowl and Glory systems are alien, megaconstructions could loom large in our future in space here.

Perhaps an endearing aspect of megastructure stories is the frequent contrast between the gigantic scale of the artifact and the often trite plots taking place on, in or about it. Conceptually boggling settings become backdrops for mere soap operas that could have happened on Manhattan island. For all that, they retain an archetypal power, no matter what crudenesses they may encompass.

Of course, any artificial means of life support needs maintenance and control. Our houses are machines for living, small scale.

The Glorians are a collection of several strange, smart species who share this overall goal—enormous dwelling areas, with continent-sized countryside inside, and sunlight streaming through immense windows. They've built a long enclosed corridor between worlds, enclosing living volumes a million times that of our mere Earth. The competing forces of gravity—stronger at the two lower anchored ends—and the outward/upward centrifugal force, stronger in the middle, result in the structure under tension, stationary over a single position on each world. In 1979 Arthur C. Clarke's novel *The Fountains of Paradise* dealt with building space elevators made of diamond. Today we dream and calculate how to build such a space elevator from carbon nanotube cables. A space elevator using presently available engineering materials could be constructed between mutually tidally locked worlds, like Pluto and Charon, that gave Benford the idea. What is the driver behind our modern desire for such vast creations?

### The Technological Sublime

Distancing, the pulling back from "reality" in order to see it better, is perhaps the essential gesture of science fiction. Such removed fictions can achieve aesthetic joy, tragic tension, and moral cogency. Going to larger, distant scales also accents our sense of embedded beauty, of the sublime.

We humans get our sense of the sublime in natural wonders— lightning storms, tornadoes, mountains, sunsets, the Grand Canyon. These are big, powerful, and can be tinged with a certain terror. Similar feelings apply to what some term the "technological sublime"—which demands size, scale, purpose—not mere gadgets. Technological sublimity can mute the terror, for we are its creators and masters.

Some feel this sensation played a central role in the formation of Americans' sense of selfhood. From the first canal systems through to the moon landing, Americans have arguably gotten unity from the common feeling of awe, inspired by large-scale applications of technological prowess. Far back, we built big things: the Erie Canal, the first transcontinental railroad, the Brooklyn and Golden Gate bridges, the Empire State Building, Boulder Dam, onward. Size and power, usefully combined. Soon came nuclear weapons' power and spectacle. Then especially space travel, bringing endless vistas—natural, yet both alien and delivered to us by technology. These cultural currents creep into our modern consciousness.

The technological sublime is not a simple concept, or only visual. It can call forth all senses, both rational and emotional. The steam locomotive shook the ground and filled the air with strange smells of steam, smoke, and sparks. The Saturn rocket did much the same thing,

far bigger. The strong contrast between the silence of a distant rocket's liftoff and the sudden thunder a few seconds later is also vital in making that spectacle sublime.

In Norman Mailer's account of the Apollo 11 launch, he admits he came as a skeptic, bent on resisting the event's allure. But when Apollo launched, the ground rumbled, the roar arrived, Mailer found himself saying over and over again, "Oh, my God!" That is the emotional, sensory power of the technological sublime.

Some think this is culturally important. Americans have been divided by region, ethnicity, race, religion and class. The Founding Fathers worried about this. Absent the traditional elements that bind a society together, the technological sublime gave Americans shared, wondrous experiences. This helped a national character coalesce. Big constructions, big landscapes, even a genre—the western. Americans blended their religious instincts with their veneration of technology, until the experience of shared, big creations took on the unifying role of a cultural religion. Launches at Cape Canaveral become less a matter of a big show than a pilgrimage to a shrine where a technological miracle is guaranteed. The congregation celebrates both the event and their beliefs. When *Challenger* failed on launch, it was a national tragedy.

Today we have a sort of consumer sublime. Disneyland and Las Vegas have no use, are solely for entertainment. Their epiphanies have not the power of nature, not the majesty of human reason, but the titillation of passing amusement.

It seems the technological sublime is alive and well, if increasingly rare. What happens when the technological sublime runs dry? Unlike the natural sublime, a non-renewable sublime wears off. Nobody much notices steam engines or Boeing 747s anymore. Consumer sublime, which may signal future ennui, may be how technological innovation ends, not with a bang but a sigh.

Peter Thiel, who helped start Paypal, neatly sums this up in his well-known quip, "We wanted flying cars, instead we got 140 characters." Or on a religious note, Algorithms Who Art in Apps, Hallowed Be Thy Code.

But in science fiction, we can dream large and keep our sublime alive.

We began *Bowl of Heaven* as a single novel, only to discover we could not cover all the ideas we had. So we resigned ourselves to a trilogy and took a decade to write it all.

Our goal in writing these, and perhaps stories to follow, was to show how strange an alien mindset could be, by giving it a real, physical presence, in the Bowl and the even stranger system around Glory.

Also, we wanted to see what it felt like to think of where humanity itself might go, given time, purpose, and the true essential—imagination.