GREGORY BENFORD

Ten Thousand Years Of Solitude

ONE OF THE chores of physics professors everywhere is fielding telephone calls which come into one's department. Sometimes they ask "What was that I saw in the sky last night?" -- to which I reply, "Could you describe it?" This makes for quick work; usually they've seen an aircraft or Venus.

Sometimes calls are from obvious cranks, the sort who earnestly implore you to look over their new theory of the cosmos, or their device for harnessing magnetism as a cure to the world's energy needs. These I accord a firm diplomacy. Any polite pivot that gets one off the line is quite all right. One of the few rules we do follow is that one may not deflect the call to another professor!

In 1989 I got a call which at first seemed normal, from a fellow who said he was from Sandia Laboratories in Albuquerque, New Mexico. Then I sniffed a definite, classic odor of ripe crank.

"Let me get this straight," I said. "The House of Representatives has handed down a requirement on the Department of Energy. They want a panel of experts to consider a nuclear waste repository and assess the risks that somebody might accidentally intrude on it for . . ."

"That's right, for ten thousand years."

I paused. He sounded solid, without the edgy fervor of the garden variety crank. Still . . .

"That's impossible, of course."

"Sure," he said. "I know that. But this is Congress."

We both laughed. I knew he was okay.

So it came to be that a few months later I descended in a wire-cage elevator, clad in hard hat with head lamp and goggles, and carrying on my belt an emergency oxygen pack. I had a numbered brass tag on my wrist, too -- "For identification," the safety officer had said.

"Why?" I had asked.

She looked uncomfortable. "Uh, in case you, uh . . ."

"In case my body can't be identified?"

"Well, we don't expect anything, of course, but you know rules."

We rattled downward for long minutes as I pondered the highest risk here: a flash fire that would overwhelm the air conduits, smothering everyone working in the kilometer-long Waste Isolation Pilot Plant outside Carlsbad, New Mexico.

We clattered to a stop 2150 feet down in the salt flat. The door slid aside and our party of congressionally authorized experts on the next ten thousand years filed out into a bright, broad corridor a full thirty-three feet wide and thirteen feet high. It stretched on like a demonstration of the laws of perspective, with smaller hallways branching off at regular intervals.

Huge machines had carved these rectangular certainties, leaving dirty-gray walls which felt cool and hard (and tasted salty, I couldn't resist). Flood lights brought everything into sharp detail, like a 1950s sf movie--engineers in blue jump suits whining past in golf cans, helmeted workers with fork lifts and clipboards, a neat, professional air.

We climbed into golf carts with WIPP DOE stenciled on them, and sped among the long corridors and roomy alcoves. Someone had quietly inquired into possible claustrophobic tendencies among our party, but there seemed little risk. The place resembles a sort of subterranean, Borgesian, infinite parking garage. It had taken fifteen years to plan and dig, at the mere cost of a billion dollars. Only the government, I mused idly, could afford such parking fees . . .

Nuclear waste is an ever-growing problem. It comes in several kinds --highly radioactive fuel rods from reactors, shavings from nuclear war-head manufacture, and a vast mass of lesser, lightly radioactive debris such as contaminated clothes, plastic liners, pyrex tubes, beakers, drills, pipes, boxes, and casings.

Fifty years into the Nuclear Age, no country has actually begun disposing of its waste in permanent geologic sites. Many methods have been proposed. The most plausible is placing waste in inert areas, such as salt flats. Also promising would be dropping waste to the deep sea bed and letting subduction (the sucking in of the earth's mantle material to lower depths) take it down. Subduction zones have a thick silt the consistency of peanut butter, so that a pointed canister packed with radioactives would slowly work its way down. Even canister leaks seem to prefer to ooze downward, not percolate back up. (A few million years later, fossil wrist watches and lab gear could appear in fresh mountain ranges.) Finally, the highest-tech solution would be launching it into the sun.

All these have good features and bad, but the more active solutions seem politically impossible. Law of the Sea treaties, opposition to launching anything radioactive, and a general, pervasive Not In My Backyard-ism are potent forces.

The only method to survive political scrutiny is the Pilot Project, sitting in steel buildings amid utter desert waste forty-five minutes' drive from Carlsbad. The Department of Energy regards it as an experimental facility, and has fought endless rounds with environmentalists within and without New Mexico. Should they be allowed to fill this site with eight hundred thousand barrels of low-grade nuclear waste -- rags, rubber gloves, wiring, etc.? It is to be packed into ordinary 55-gallon soft-steel drums, which will then be stacked to the ceilings of the wide alcoves which sprout off from the ample halls.

We climbed out of our carts and inspected the chunks of dirty salt carved from the walls by the giant boring machines. Everything looks imposingly solid, especially when one remembers that 2150 feet of rock hang overhead.

But the point of the Pilot Project is that the walls are not firm at all. This Euclidean regularity was designed to flow, ooze, collapse.

We trooped into a circular room with a central shaft of carved salt. Meters placed around the area precisely recorded the temperature as electrical heaters pumped out steady warmth. The air was close, uncomfortable. I blinked, feeling woozy. Were the walls straight? No --they bulged inward. There was nothing wrong with my eyes.

Salt creeps. Warm up rock salt and it steadily fills in any vacancy, free of cracks or seams. This room had begun to close in on the heaters in a mere year. Within fifteen years of heating by radioactive waste left here, the spacious alcoves would wrap a final hard embrace around the steel drums. The steel would pop, disgorging the waste. None would leak out because the dense salt makes perfect seals -- as attested by the lack of ground water penetration anywhere in the immense salt flat, nearly a hundred miles on a side.

"Pilot" is a bureaucrat's way of saying two things at once: "This is but the first," plus "we believe it will work, but . . ." Agencies despise uncertainties, but science is based on doing experiments which can fail.

Often, scientific "failure" teaches you more than success. When Michaelson and Morley searched for signs of the Earth's velocity through the hypothetical ether filling all space, they came up empty-handed. But this result pointed toward Einstein's Special Theory of Relativity, which assumed that such an ether did not exist, and that light had the same velocity no matter how fast one moved, or what direction.

An experiment which gives you a clear answer is not a failure; it can surprise you, though. Failure comes only when an experiment answers no question -- usually because it's been done with ignorance or sloppiness. The true trick in science is to know what question your experiment is truly asking.

Bureaucrats aren't scientists; they fear failure, by which they mean unpredictability. They tread a far more vexing territory: technology. The Pilot Project has been held up because equipment did not work quite right, because there are always uncertainties in geological data, and of course, because environmental impact statements can embrace myriad possibilities.

Ours was the furthest-out anyone in government had ever summoned forth. No high technology project is a child of science alone; politics governs. The pressure on this Pilot Project arose from the fifty years of waste loitering in "temporary" storage on the grounds of nuclear power plants, weapons manufacturers and assorted medical sites -- in "swimming pools" of water which absorb the heat (but can leak), in rusting drums stacked in open trenches or in warehouses built in the 1950s. The long paralysis of all nuclear waste programs is quite probably more dangerous than any other policy, for none of our present methods was ever designed to work for even this long. Already some sites have measured slight waste diffusion into topsoil; we are running out of time.

Of all sites in the USA, the Carlsbad area looked best. Its salt beds laid down in an evaporating ocean 240 million years ago testify to a stable geology, water free. The politics were favorable, too. Southern New Mexico is poor, envying Los Alamos and Albuquerque their techno-prosperity. Dry, scrub desert seems an unlikely place for a future megalopolis to sprout -- ignoring Los Angeles.

So we members of the Expert Judgment Panel split into four groups to separately reach an estimate of the probability that someone might accidentally intrude into the sprawling, embedded facility. We had some intense discussions about big subjects, reflecting the general rule that issues arouse intense emotion in inverse proportion to how much is known about them. Should we be doing more to protect our descendants, perhaps many thousands of years in the future, from today's hazardous materials? How do we even know what future to prepare for?

Usually we envision the future by reviewing the past, seeking longterm trends. This can tell us little about the deep future beyond a thousand years. Going back 225 years, what is now the Eastern United States was in the late English colonial period. At least in the European world, there were some resemblances to the current world -- in fact, some countries have survived this long. For this period, extrapolation is useful in predicting at least the range and direction of what might happen. Going back 1,000 years takes us to the middle of the Middle Ages in Europe. Virtually no political institutions from this era survive, although the continuity of the Catholic Church suggests that religious institutions may enjoy longer lifetimes. Most history beyond 1,000 years is hazy, especially on a regional scale. Prior to the Norman invasion in 1066, English history is sketchy. Beyond 3000 years lie vast unknowns, nine thousand years exceeds the span of present human history. The probability of radical shifts in worldview and politics means that we cannot anticipate and warn future generations based on an understanding of the past, even when we anticipate the use of modem information storage capabilities. There are three types of future hazards. The best are those we can identify and reduce or eliminate, such as DDT and other chemicals. More ominous are those we know little or nothing about, such as some additive or emission -- for example, radioactivity wasn't thought to be harmful a century ago. Finally, there are hazards we know pose deep-future hazards but which we do not wish to ban -- long-lived nuclear waste, toxic chemicals essential to industry.

Instead, we decide to continue producing it and then shove it away in some dark comer, with warnings for the unwary and unaware. Ancient civilizations did this without a thought; Rome did not label its vast trash heaps, ripe with lead and disease. Working on the panel was intriguing but frustrating. We used scenarios to help fix specific possibilities firmly in the mind, allowing us to pick assumptions and work out their implications using common sense in a direct, story-telling way. Like extrapolating from the past, scenarios reduce infinite permutations to a manageable, if broad, group of possibilities. Watching the social scientists particularly grapple with the wealth of possibility open to them, I came to realize how rare are the instincts and training of science fiction readers. We do think differently.

Scenarios, as detailed stories, consider the physical as well as the social environment. They must also be bounded within some range of assumptions, or else the game becomes like tennis with the net down; not doing this negates the usefulness of scenarios in the first place.

Our initial assumptions were:

* • The repository will be closed after the proposed period of operation (25 years).

* • Only inadvertent intrusions were allowed; war, sabotage, terrorism, and similar activities are not addressed.

* • Active control will be maintained of the site during the "loading" and for a century after closure.

* • After active control, only passive measures will remain to warm potential intruders--no guards.

* • The radioactive materials will decay at currently projected rates, so the threat will be small in ten thousand years.

* • No fantastic (although possible within 10,000 years) events will occur, such as extraterrestrial visits, big asteroid impacts, or anti-gravity.

Modern geology can yield firm predictions because ten millennia is little on the time scale of major changes in arid regions like New Mexico. By contrast, myriad societal changes could affect hazards, as readers of science fiction know well.

Our four-man panel (no women accepted the Sandia Lab invitations) worked out three basic story-lines for life around the Pilot Project, based on the role of technology. There could be a steady rise in technology (Mole-Miner Scenario), a rise and fall (Seesaw Scenario), or altered political control of technology (The Free State of Chihuahua Scenario). Envisioning these, arguing them through, was remarkably like writing for Fantasy & Science Fiction.

The Mole Miner Scenario: If technology continues to advance, many problems disappear. As Arthur C.

Clarke has remarked, "Any sufficiently advanced technology is indistinguishable from magic." A magically advanced technology is no worry, for holders of such lore scarcely need fear deep future hazards from present-day activities. Indeed, they may regard it as a valuable unnatural resource. Remember that the great pyramids, the grandest markers humanity has erected, were scavenged for their marble skins.

The societies which must concern us are advanced enough to intrude, yet not so far beyond us that the radioactive threat is trivial. Even though we here assume technology improves, its progress may be slow and geographically uneven--remember that while Europe slept through its "dark ages" China discovered gunpowder and paper. It is quite possible that advanced techniques could blunder in, yet not be able to patch the leaks.

As an example, consider the evolution of mining exploration. Vertical or slant drilling is only a few centuries old. Its high present cost comes from equipment expenses and labor. An attractive alternative may arise with the development of artificial intelligences. A "smart mole" could be delivered to a desired depth through a conventional bored hole. The mole would have carefully designed expert systems for guidance and analysis, enough intelligence to assess results on its own, and motivation to labor ceaselessly in the cause of its masters -- resource discovery.

The mole moves laterally through rock, perhaps fed by an external energy source (trailing cables), or an internal power plant. Speed is unnecessary here, so its tunneling rate can be quite low -- perhaps a meter per day. It samples strata and moves along a self-correcting path to optimize its chances of finding the desired resource. Instead of a drill bit, it may use electron beams to chip away at the rock ahead of it. It will be able to "see" at least a short distance into solid rock with acoustic pulses, which then reflect from nearby masses and tell the mole what lies in its neighborhood. CAT-scan-like unraveling of the echoes could yield a detailed picture. Communication with its surface masters can be through seismological sensors to send messages -- bursts of acoustic pulses of precise design which will tell surface listeners what the mole has found.

The details of the mole are unimportant. It represents the possibility of intrusion not from above, but from the sides or even below the Pilot Project. No surface markers will warn it off. Once intrusion occurs, isotopes could then escape along its already evacuated tunnel, out to the original bore hole, and into ground water.

This is the sort of technological trick sf so often explores. I contributed most of this story, while the social scientists considered less optimistic ones.

The Seesaw Scenario. Many events could bring about a devastating and long-lasting world recession: famine, disease, population explosion, nuclear war, hoarding of remaining fossil fuels, global warming, ozone depletion. Then the rigors of institutional memory and maintenance would diminish, fade, and evaporate. Warning markers -- and what they signify -- could crumble into unintelligible rubble. Later, perhaps centuries later, society could rebuild in areas especially suitable to agriculture and sedentary life. A tilt in the weather has brought moisture to what used to be southeastern New Mexico. Explorers would again probe the earth's crust for things they need. The political instabilities in the region during the dimly remembered Late Oil Age had kept some of the oil from being pumped out. A quest for better power sources for the irrigation systems of this reborn civilization then leads to the rediscovery of petroleum as an energy source. A search of old texts shows that much oil drilling had been done in the Texas region. Since all the oil was known to have been removed from that region, explorers turn westward to New Mexico. In the spring of 5623 A.D. an oil exploration team comes upon the remains of an imposing artifact in Southeastern New Mexico. "Perhaps they left it here to tell us that there is oil down below."

"Maybe there is danger. We should consult the scholars to see if they know anything about this."

"Ah, you know these old artifacts -- all rusted junk. Let's drill and see if there's oil. . . ."

This strongly recalls Walter Miller's classic A Canticle for Leibowitz -- our "Expert Judgment" recreating the genre, in clunkier prose.

The Free State of Chihuahua: The year is 2583, just after a century of political upheaval in the former American Southwest. After endless wrangling caused by regional interests and perceived inequities in political representation, the United States has fragmented into a cluster of smaller nation states. Similar processes have affected the stability of Mexico, traditionally plagued by tensions between the relatively affluent North and the centralized political control of the South. Its northern provinces have formed the Free State of Chihuahua.

Political uncertainty in the Free State leads to a large-scale exodus of Anglo-Saxons, as well as many long-established Hispanic families, from the former U.S. territories. They are escorted by forces loyal to one or the other of the new countries, who practice a scorched earth policy, destroying most of the technological infrastructure, especially installations of potential military value, on the northern side of the former U.S./Mexico border.

The Free State lacks foreign exchange and has a poor credit rating. Because it is limited in available natural resources, its people evolve into a scavenger society, recovering, repairing and reusing all available technical artifacts from earlier times. While making excavations at the former site of Sandia Laboratory, Free State "resource archaeologists" (fancy-named scavengers) discover references to the ancient Pilot Project site, including photographs of waste barrels filled with abandoned tools, cables and clothing. They find fragmentary maps locating the site, but no references to radioactivity. In any case, social knowledge of radiation is limited, due to the development of non-nuclear energy sources during the 21st century -- the Age of Ecology now long past.

Arriving at the site, Free State resource archaeologists find the remains of markers which locate the site but do not transmit unambiguously the message that there is danger. They decide to enter. Later, the site is intentionally mined by people unaware of the potential hazard. They breach the site. Ground water gushes up the drill, driven by the long-sealed heat of radioactive decay. This scenario reminds us that no nation has survived for more than a few centuries. Large states tend to fragment into smaller, more culturally coherent ones. For example, the Austro-Hungarian Empire is today divided amongst at least nine smaller countries, and something similar seems to be underway in the ex-Soviet Union only seven decades after its inception. Union with northern Mexico is not critical to the scenario --one can visualize a variety of ways for political control to change. As political control alters, the possibilities of inadvertent intrusion rise.

Gabriel Marquez's One Hundred Years of Solitude alerted many of us to the subtle cultural differences between North and South America. Trying to store waste for ten thousand years of solitude reminds us, in turn, that cultural and geographical boundaries make no difference over such eras.

For example, an unspoken constraint on the U.S. program is that the waste must be stored within the country. Why not find better spots elsewhere? Mexico has many salt flats larger than the Carlsbad one.

One of the ethical philosophers on the sixteen-man Expert Judgment panel found this abhorrent. "Risk," he pronounced, "is not morally transferrable."

But of course it is. Anyone who works in a coal mine or lives near a heavily traveled highway incurs extra risk for some gain. How much risk to accept is a personal decision. The ethical pivot is that people should know the dangers they undertake.

But the Pilot Project points to a deeper problem. Over ten thousand years, no continuity of kinship or culture respects borders. Mexicans are the same as, say, New Yorkers--populations shift, societies alter. Risks resolutely kept in New Mexico are the same as risks piled up in Mexico City, for the people diffuse over these passing perimeters within a few centuries. The idea of nationality fades. We really are all in this together, in the long run.

Of course, the above scenarios don't exhaust the possibilities; they only sketch out the conceptual ground. We also considered a "USA Forever" yarn which assumed government could indeed keep continuous control. It yielded a smaller risk, but we thought it had much smaller probability of coming true.

Such stories are fine, but how could we use them to predict quantitative probabilities? Congress wanted a number, not a short story anthology.

We believed two elements of these scenarios most directly affect the likelihood of inadvertent intrusion: political control of the site region, and the pattern of future technological development. How could we use this intuition?

Here we used a "probability tree," which links chains of events in a numerical way akin to the simple estimates I discussed in "Calculating the Future," (F&SF, September 1993). After much wrangling, we settled on a ballpark estimate of less than 10% chance the site would suffer intrusion.

The major risk came from the seesaw scenario of technological decline and rebuilding. For this we estimated the probability of drilling intrusion. The neighborhood (approximately 400 square miles) suffered roughly one drilling per year over the last century. Assuming random drilling, the buried waste's area of about half a square mile should then have a probability of about 0.001 per year of drilled intrusion. If over 10,000 years such eras occur a hundredth of the time -- -i.e., a century in all -- then there is a one percent total probability. Adding in other scenarios gives a final sum of a few percent.

Do I believe this? Of course not, in its details. When we wrote up our result, and found that the other three teams of four each had gotten the same few percent result, I reassured the head of the program that we could even guarantee the answer. "If there's an intrusion, I'll pay back ten times my consulting fee . . . ten thousand years from now."

Then I learned that since we finished our report first, the other teams knew our answer before they finished theirs -- bad technique. A convergence of opinion is common in all prognosticating, and "experts" like us were not immune to it.

I had further worries. Physics has dominated our century, but biology may well rule the next. The implications of the Human Genome Project and rapid progress in biotechnology remind us of a more general truth: The most difficult realization about the future is that it can be qualitatively different than the present and past. This implies that an irreducible unknown in all our estimates arises from our very worldview itself, which is inevitably ethnocentric and timebound. Are we being too arrogant when we assume we can accurately anticipate far future hazards or protection mechanisms? Probably -- but we have no choice. Waste of all sorts stacks up and we must do our best to offset its long term effects.

The Department of Energy was happy with our estimate. They and Congress could tolerate risks up to about ten percent. At present, the Pilot Project staff is gearing up for a trial run to further study the salt creep, how it seals, etc.

Personally, I believe the Pilot Project will be filled, and that's only the beginning. Storing all our accumulated nuclear waste, not just the low-radioactivity debris the Pilot Project is designed for, would take about ten more such vaults.

What's the point, politically or practically, in dispersing the sites? The only other site for disposal, Yucca Mountain in Nevada, is under heavy technical and political pressure. All our waste for a century could go into that single salt flat near Carlsbad.

Confining the area both lowers costs, reduces total risk, and localizes damage if it occurs. It's also politically astute. The locals want the work and the opponents in northern New Mexico have nearly run out of legal delays. They seemed to operate out of a Not In My Back Yard psychology, with no alternatives. Part of the problem with waste of all sorts is that fears have been blown so high, few really perceive the rather minute level of risk. That was why Congressional fretting over ten thousand years from now seemed so bizarre to the panel, who actually knew something about real risks.

During our deliberations, television stations sent their cameras and environmentalists demonstrated. I asked one of the placard-carrying men where he was from. "Santa Fe," he answered. I was surprised; he lives many hundreds of miles from the site.

"They might bring some of that waste through my town, though," he said. He was right. Spills during transport are a real, if remote, possibility. I wanted to talk to him further about sentiment in Santa Fe, which leads opposition to the site, but I couldn't tolerate his company any longer. He was puffing steadily on a Marlboro.

He could well claim that smoking was his choice, his risk -- and unless he spoke out, he had no control whatever over nuclear waste. But then, there is always secondhand smoke. And the waste was generated by the federal government, an obligation settled upon all of us.

Neither Congress nor the Department of Energy has pondered the long-term issue of disposal in one site yet, but I think it is obviously coming. The waste must go somewhere.

If we halted all nuclear power and weapons production tomorrow, we would still have a vast pile of medical contamination to care for. Nobody, I believe, wants to do away with cancer diagnostics and treatments, which produce great volumes of mildly radioactive waste.

Suppose I'm right. This leads directly to the next question: How do we warn the future about the dangerous package we've sent down the timeline? A whole new panel pondered that question. I'll report on it next time.

Comments (and objections!) to this column are welcome. Please send them to Gregory Benford, Physics Department, Univ. Calif., Irvine, CA 92717.

A Conversation with Gregory Benford

Interview with Stephen Davis

I read a brief bio of you that mentioned you were involved in trying to bring the WorldCon to Dallas in the late fifties. You would have been, what, seventeen or eighteen at the time?

Yeah. Seventeen or eighteen, exactly.

Do you remember why Dallas lost the bid?

Well, it lost a few years later because, I think, Chicago had a better bid, and also because the Dallas Futurian Society fell apart. I went off to university, and other people went off, and we were kind of the people holding it together and the rest of the people just dissolved. Our big peak was the Southwestern Con, which was held in July of 1958, two months before the WorldCon. That was the first Con ever put on in Texas. I have the weird distinction of having been the instigator of the first Con in Texas and the first Con in Germany.

Oh!

The German convention was in fact in '56.

Were you a fan of science fiction before you knew you wanted to make a career in science?

Yes. I started reading SF when I was probably nine or eight.

Who were the authors you were reading then? I'm assuming Asimov, Bradbury...

Well, actually my first discovery was Heinlein, and then later Bradbury and Clarke, and then Asimov.

So, you were attracted to the guys who were writing -- well, I want to say in the "hard sf" mode, but I imagine that wasn't as popular as it became later.

Oh, yeah. That's certainly the case. But remember, hard SF -- there was something like it then, but there wasn't nearly the feeling of specialization. I mean, the field was not nearly so self-aware then.

I guess it was a little more pulp-driven in the fifties.

Definitely. But hard SF emerged as an ideology only in the very late fifties, early sixties, to some extent in response to the New Wave. I mean it was the kind of thing people had been doing, but not naming.

Do you think your interest in science fiction is what drove you toward a career in science?

Oh, sure. That's true of a very large number of scientists. I've checked, and I'd say fifty percent of those I've asked read it vociferously.

Now that you've managed to have success both as a physicist and a novelist, if you had to make a choice, would you rather have the world remember you as a physicist or as a science fiction writer?

I think as a writer, because scientists generally have little of themselves carried forward in their work. Most people don't, when they talk about DNA, think about Watson and Crick anymore. And it's because of the application of science to the larger world that it does not contain the stolistic idiosyncrasy of the arts, generally. So, scientific immortality is of a different kind.

So it doesn't even do you any good if you have a process named after you? Will we be talking about Dyson spheres long after we've forgotten who Dyson is?

Quite possibly so. Look at say, Hobson's Choice. Who was Hobson? He was a guy who ran a stable in Cambridge. His choice was that he had one horse, and he'd tell you that you could have any horse you want... just choose one.

[Laughter] Sounds like Ford's Choice: you can have any color car you want, as long as it's black.

That's right, but people have forgotten who Hobson was, though we still have Hobson's Choice.

Is there one particular award or achievement in science or science fiction that you're especially proud of?

I'm proud of receiving two Nebulas, and in the sciences, winning the Lord Foundation.

I wanted to ask you about that. What is involved in that prize?

Well, the Lord Foundation gives a set of awards, I think every three years. I got the one for contributions to science, generally. It's very nice. They bring you to Pittsburgh. They have this huge, formal dinner out in the middle of the Carnegie Museum. They give you a painting of yourself. There's a wonderful reception and some cash, and they take such good care of you. They fly you out first class and give you a limousine and driver for as long as you want. We stayed for five days. I mean we went out and saw the Robert Frost home, Falling Waters, and it was just a great time. I had never been to Pittsburgh.

OK, now this is kind of a naïve question, I'm sure, but keep in mind that I had to go through*all* the sciences as a college freshman before I found one I could pass courses in: Has physics reached the point where, even if we don't know all the answers, we at least know all the questions?

No. We don't even know the right questions, I think, for many of the major issues. I don't think our way of seeing the universe is the last way. The fact is there are some questions that are so hard to solve, especially concerning origins of the universe. Looking at the problem of the origin of life, for example, suggests that we're asking the question the wrong way.

Do you see an area of physics that offers the most potential for a break-through or discovery that would alter the way we live or think about the universe?

Uhm... wow. [Laughter] I would say that the physics of information. Everything such as... where does information go when it falls into a black hole? We really just don't have a clue. We don't know what happens to all the physically conserved things that fall into a black hole and don't come out. What law of conservation is obeyed in all this we don't know.

Let me move on to your latest book,**Cosm** . Through some strange quirk the book I read immediately before**Cosm** was a non-fiction work by someone whose name I can't remember at the moment. I think it was called**The Last Three Minutes** .

Oh. Paul Davies.

The author mentions false and true vacuums and as I understood it, the idea was that we might be living in a bubble of false vacuum, and that if a particle from our bubble bridges across to the true vacuum, everything in our universe comes to an end. Now, you've put a little bit of a different twist on this in**Cosm** , and I wondered if you could explain your use of the theory.

Well, basically, instead of our living in a false vacuum, I say that this experiment at Brookhaven, upcoming in seven more years, has a small possibility of creating essentially a whole new universe in its own separated out space-time and leaving behind just a narrow bridge. None of this is my idea. These are calculations that a number of physicists have published in the literature, and it caught my attention in the early '90s. And I simply take this and say, if it's true, what would follow: What are the huge philosophical issues? What is your moral posture if you have created a universe? Are you responsible for all the good and evil that occurs in it? What does good and evil mean? How can you tell? You can't even see individual people in this universe, if they exist.

Do you think that Alicia Butterworth's discovery, what she christens the Cosm, is just a flight of fancy, or is it the sort of thing you wholly expect to be reading about in*Scientific American* someday?

Well, I think in terms of theory, I'll certainly be reading about it, because the theory is too interesting to leave alone. Now, whether we actually produce one or not is up for grabs. That's the reason people worry about this. I think the chances are small, because you're trying to produce an incredibly dense mass energy. But we don't know quantum mechanically what the probability is that we can, as we say, tunnel through to that state.

After I'd finished reading**Cosm** , I re-read an essay by Oscar Wilde called "The Decay of Lying," and in that essay Wilde states that "there is such a thing as robbing a story of its reality by trying to make it too true." Now, you're a physicist at the University of California, Irvine, writing about a physicist at the University of California, Irvine. Do you find that looking into a mirror, so to speak, as you write, is more of a help or a hindrance to you in creating your novel's reality?

Well, it's a great deal of help, actually, because all kinds of local details come readily to hand. However, Alicia Butterworth is really not me. Some reviewers seem to have been confused about this.

I thought Max Jalon was probably you, actually.

Well, more like me. But, I deliberately portrayed [Alicia Butterworth] as being a really bothered personality, someone who's irritable, with an odd set of opinions, that are not necessarily my opinions. One in particular kept trying to attribute her views to me.

I think even I did that in my review, and I realize there's a danger and a fallacy in attributing things that characters say or do to the actions or views of the author, but one of the reasons why that might be the case is that many of the characters seem kind of amoral, in the sense that there doesn't seem to be a lot of positive images in the book. That was one of my questions for you: Is the novel's reality your own world-view, or is it more "through a glass darkly"? And I think you just answered it.

Do you believe the universe is the result of intelligent design and forethought, the serendipitous by-product of an alien science experiment, or simply a completely random, if fortuitous, event?

I think the first of the choices. The fact that the universe has law in it implies that there is an ordering principle.

So you're not inclined to Max Jalon's view at the end of the book?

No, though it's fun.

That was one thing that confused me that I mentioned in my review. In that particular section, I couldn't tell if you were being very dead-pan or giving the reader something that Max Jalon is just having some fun with.

Both. I mean, he supposes it, and at that point, I wanted the readers to catch on to the idea. Whether that's amusing or not is a matter of taste.

I had two more questions to ask. One of these is that there are a lot of negative things voiced in the book. What are some things you look at positively, and do you think Alicia would look positively on the same things?

Well, there's always students, and reaching people in a new way. It's the tendency of universities to become not just bureaucracies, but top-down structures, that I dislike. The students are a good antidote to that.

I imagine over the last month you've been asked a lot of questions about **Cosm** at signings and readings. Is there one question you wish someone had asked you that nobody has?

No one has asked me why I chose to use a black protagonist, and the answer was, I wanted someone who was different, and who actually violated the conventions. Her opinions don't fit any rule.

Actually, I found the black protagonist refreshing, because it let you do some things that I think if your protagonist had been white, you would have had people picketing outside your office. I especially found her comments about Maya Angelou to be refreshing and possibly truer than even she intended.

Oh, indeed. There, actually, I agree with Alicia. I've always thought Maya Angelou was a dreadful poet. Now the *Washington Post* review called me out on exactly that issue. Called it "mean-spirited" to regard Maya Angelou as being anything but a wonderful poet, but in fact, she's dreadful.

Do you think that may be the reason -- not the Maya Angelou part -- why no one has asked you that question; because to ask it is to indicate that maybe the questioner is somehow not quite "with it"?

Sure. I think you're undoubtedly right about that. People are uncomfortable about it. I'm not uncomfortable about racial issues. I grew up among blacks....

Where did you grow up?

Southern Alabama.

I guess you're like me, then. I haven't managed to pick up a southern accent, yet.

I can change my accent any time you want. [Dr. Benford says this in a Southern drawl.]

[Laughing] And sometimes when you're in the South, that's very useful. Well, listen, I want to thank you for your time this evening. I know you've probably got some things you need to do.

Yes.

It sounds a little like you found something to eat.

Yes, actually I'm eating some almonds. By the way, I missed your review. Where did you say it was up?

It's the SF Site atwww.sfsite.com . And you'll probably discover I'm a little out-spoken, but I mentioned I thought the book was well-structured and it's one of the few things I've seen recently that I read in a couple sittings. I actually put some stuff off to get through it.

Well, great. That's the kind of response I want. My actual name for this book is a scientific suspense novel. This one isn't really a thriller. That's why I was surprised when we got a really good movie deal for it about four weeks ago from FOX.

So, major release type movie, not made-for-TV type movie?

No. A feature-length film.

My suspicion is they would love it, because I can't remember a lot of scenes where they're going to have to do a lot of special effects.

There are now.

Oh, really?

They had me write in the treatment a whole new third act, so now there's a whole new ending where things get much worse.

That was one thing. I thought it was a little bit of a cop-out when you left that enormous sphere at the end.

That's exactly what they said. "This is a second ticking bomb you can use."

Well, I'm definitely looking forward to that. I'm trying to figure out who they will cast as Alicia Butterworth.

Uh, Angela Bassett. Well, that's who they've been talking about. In fact, I just got done with a conference call to Dustin Hoffman's people as a possibility for Max. Well, I'm trying not to worry about it. On to the next project.

What is the next project?

I'm doing a novel for Avon, the working title of which is**Eater** .

[At this point, realizing that it was dinner time on the West coast, I let Dr. Benford go.]

Steve is faculty member in the English department at Piedmont Technical College in Greenwood, S.C. He holds a master's in English Literature from Clemson University. He was voted by his high school class as *Most Likely to Become a Young Curmudgeon* .

Window on a Universe

As a science fiction writer, Gregory Benford is in a unique position. His work as a research physicist and physics professor at the University of California at Irvine doubles as research for his novels, which are notable for the clarity of their explanation of cutting-edge physics and for their precision of detail. His latest novel, *Cosm* , recounts a young physicist's accidental creation of a wormhole--an object in space-time that allows her to watch, as through a miniature window, the entire life cycle of a new universe. Benford, who has embarked on what for him is a rare book tour, recently spoke with Amazon.com's Barrie Trinkle and Bonnie Bouman, who began by asking him whether science or science fiction was his first love.

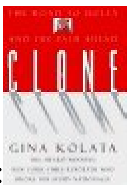
Gregory Benford:Both. (laughs) I was always fascinated by science, in part because I read science fiction. Science fiction is the literature of the voiceless minority in our culture that actually drives the future. And yet this [scientific] culture really is a separate culture. It has no poet laureates, no balladeers--it's largely unknown to the public, because scientists don't write about themselves. And the outsiders can't really understand the tribal ways. Like Margaret Mead in Samoa: she thought she got it right, but there was a lot she got wrong. 

And if that was possible in Samoa, it's certainly possible in the scientific community, which has a lot of rather subtle shrugs and grunts--methods of communicating that most people don't understand.

Amazon.com:You explore the misunderstanding of science and scientists in *Cosm* .

Benford:Yes. It's really about the clash between the individual experience of science and the increasing public experience of science, now that there is so much attention from the media at every stage. If you hit on something important in science, it ceases to be your experience. It becomes a communal experience in fast forward.

Amazon.com:Did you have any real-life scientific event in mind?

Benford: 

What really helped determined the structure of this book was Dolly the sheep. I'm a bug about this because I am a twin, therefore a clone. The hysterics on TV were astounding. Look at the know-nothing lawyers like Bill Clinton pronouncing on issues of human reproduction. Where does the

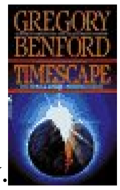
Constitution say that the federal government should even be discussing this matter? Cloning is a method nature uses in reproduction--one-third of one percent of all humans are clones. In fact, twins are better than laboratory clones. Artificial clones don't share the same womb as the progenitor and won't grow up at the same time. So they are very much less a carbon copy than identical twins, like me. My twin brother, Jim, is also a physicist and we are very close. I find it astonishing that the policy makers are so ignorant that they don't even know that they need to know anything technical about something to open their mouths about it. And it amazes me that the culture doesn't have any critical filter--doesn't say, hey, this politician made a statement about this profound technical biological issue, but doesn't know the difference between Levis jeans and human genes. It's like asking Cher about foreign policy!

Amazon.com:Isn't the brouhaha simply a natural part of the cycle of knowledge? Any new practical scientific breakthrough is suspicious at first, just as test-tube babies were two decades ago.

Benford:That's true, but knowing that doesn't prevent people from indulging in the idiot wind that blows through this culture at hurricane force sometimes. Dolly was the biggest scientific story of last year, but opinion and emotion swamped the nature of the story itself. That kind of public emotion is what I addressed in this book.

Amazon.com:Why did you choose to set*Cosm* seven years in the future?

Benford:Because the experiment Alicia Butterworth does will actually be done then. The machine opens in two years, but they are going to slap gold together for about five years and then uranium is slated for around 2005. Everything in the book is as close to the way it will be as it can possibly get. The room numbers at Caltech are the right room numbers, and so forth. It's to serve my own sense of verisimilitude.

In the afterword I note the deviations from the real world, but there are very few. 

I'm really writing a series of what I call scientific suspense novels.*Artifact* , a novel about Greek archeology I published over a decade ago, is a scientific suspense novel.*Timescape* and*Cosm* are, as well. They're less science fictional than stuff like*Jurassic Park* . When are they ever going to have a Jurassic Park? Well, I can tell you when*this* experiment is going to be done--in 2005!

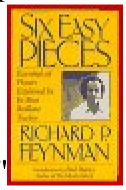
Amazon.com:Speaking of Alicia, it's interesting that you created a protagonist who is rather on the outside looking in.

Benford:Yes--well, I have always been on the outside myself.

Amazon.com:In what way?

Benford:Well, I*am* from Alabama. My father was a career military officer in Japan, and that was where I stumbled upon science fiction, the standard estranged literature. I lived on the outpost of the American empire, in Japan and then in Germany, and that was a shaping experience. I went to the University of Oklahoma, not to an Ivy League school. I had to change my accent when I entered the academic world. I chose a black woman as the lead character because I wanted to do something different. Alicia can be irritating, she can be a bit odd, and she's allowed to, because she's a black woman. She's figured that out, and she uses it, which isn't good for her character. She is not a swell person, as you probably noticed. She says acerbic things, and she doesn't get along with people. But creative scientists are not like bank clerks. Society hardly gives them any latitude. Artists are expected to be strange, but scientists are expected to be like ordinary office workers--and they aren't.

Amazon.com:I loved the way you satirized that in the anecdote about the scientist who wanted to get married so he wouldn't have to have a social life. That rang very true.

Benford:Yes, and I even dropped in that old joke about the scientist who impulsively goes home with a gorgeous woman he meets in a bookstore, and then when he explains to his angry wife where he's been the last few hours, she says, "You're lying! You were in the lab!" 

I love writing about the social quirks of scientists. It's a mirror of the cultural problem. Scientists don't know how to speak to the public. The posthumous annunciation ofFeynman is all about that. He was a charismatic figure--the best public speaker I ever saw, better than any politician--and now that he's dead, all his books are back in print. We're looking for that kind of identifiable scientific figure, because the guy in the lab is not making it in the popular culture. And we have lost all our advocates. Carl is dead. Isaac is dead. Who have we got?

Amazon.com:No more PR people.

Benford:We desperately need someone.

Amazon.com:It's interesting that*Cosm* has been picked up by Book-of-the-Month Club, which indicates that they see it as something that breaks out of genre.

Benford:I think so. Or perhaps that they've finally gotten rid of their reflex reaction to science fiction.

Amazon.com:It's a book that works on a lot of literary levels. There's the scientific suspense: what is this object, what is it going to do next? Then there's the commentary on the whole academic and political circus that surrounds it. And finally, there's a very convincing, non-cloying romance between two scientists whose work is everything to them.

Benford:Thank you. I worked a long time to try to write a*short* book with all of those things in it. There's a transaction between the guy and the gal and there's some physics and there's some plot advancement, all of it in one scene. It's not like most conventional literary novels, where one scene only does one job.*Cold Mountain* is a very well written book but it's mostly a sentence level book. Great paintings are not made up of beautiful brush strokes, but of aesthetic concepts. Brush strokes are necessary but not sufficient. That's true in novels, too.

Amazon.com:Do you ever imagine yourself turning to mainstream fiction?

Benford:My territory is the scientific subculture, and it's unexplored. Why should I try to do a novel of suburban romance, which everyone is doing, when I can write about a subculture that is more important to society? I think I'll stick to what I know. The conventional literary world has never understood the strength of the American genres. This is the culture that produced Broadway musicals, the hardboiled detective novel, ragtime, jazz, rock and roll, modern science fiction, modern fantasy, romance novels. That's what we are good at. The literary world thinks that isn't important, but history will not echo that judgment. The literary world doesn't understand American cultural vitality--it keeps producing these nostalgic novels about Americans. That's a deep problem in the literary world; it's the reason that the literary novel has itself become a genre. It has its own cover designs and marketing strategies, its own clearly defined audience--it's a genre, folks!

Amazon.com:What are you working on now?

Benford:I've finished my next book,*Deep Time* , which is nonfiction. After that I have a novel--the working title is*Ultimata* . It's a bit hard to explain, but it's about a black hole in our solar system. It's set in the near present. I've got a lot of work done on it, but I still have to figure out the characters. Although I never figure them out completely until I actually write them.

Amazon.com:Would you call it a companion to*Cosm* , the way*Cosm* is to*Timescape* ?

Benford:That's right. It's another scientific suspense novel. This time I try to explicate the astronomical community, which I've worked in. They're ripe for interpretation because they're so different. The most actively creative parts of their lives are spent on mountaintops at night. The contrast between the human scale and scientific scale is at its most extreme in astronomy. Even now a mission to the outer solar system takes one entire scientific career. To formulate an idea, get it funded, build the spacecraft, launch it, get it there, get the results, and get it back is a career. We have reached the actual limit of the involvement of a single person. So the astronomical scale has a profound unspoken impact on astronomers.

Amazon.com:Do your colleagues look forward to appearing in your novels?

Benford:(laughs) I don't think so, but the reaction to*Cosm* has been positive by the people who are portrayed in it; there must be a dozen real people in there under their own names.Faulkner said that "Ode on a Grecian Urn" is worth any number of grandmothers-- in other words, art is more important than people's likes and dislikes. Of course, that's a classic example of artistic arrogance.

Amazon.com:How do you organize your mental energies between science, writing, and personal life?

Benford:I stay home and write on weekends. During the evenings I do the thinking, note-taking, things like that.

Amazon.com:You don't usually do book tours--is that because you've got a day job, so to speak?

Benford:Well, yes, but I've just never cared much about them. This one is different, more organized. If you go on National Public Radio's book review show, you have to go to Madison, Wisconsin. And that's effective. I hadn't really realized that until this trip. Tours used to be just a bunch of book signings, which are nice enough, but you just meet people you've already sold the book to. Other than getting your book on*Oprah!* ® how do you reach a larger audience? Publishers really don't know. Well, now the smart bunnies try to get on Amazon.com.

Amazon.com:There's always Hollywood.

Benford:I've done a bunch of pitches in Hollywood in the last couple of weeks. I've met several directors who thought*Cosm* was a movie plot. I never realized that, but then, who would have thought*My Dinner with Andre* was a movie plot? So I was pitching it to these guys who were very heavy hitters, and they say they couldn't make it for less than $80 million.

Amazon.com:Gee, all they really need is some lab equipment and a big steel bowling ball.

Benford:But they don't want to save money! They want a big special effects finish, so they would redesign the whole back end of the story. The secret reason they're interested is that Lucas has the deep space epic locked up for the next three years, and no one wants to go up against him. So they're looking for special effects plots set on Earth in the near future, not the far future--just right out of his ballpark.

An Introduction to Gregory Benford

by Peter Nicholls

Greg Benford is the sort of man you can (and do) meet anywhere. I was not at all surprised in 1997 to run into him unexpectedly while he was holding forth on the deck of the *Queen Mary* . As he talked with typical animation, in my mind's eye I saw the Greg Benford I had originally met almost a quarter of a century ago--I think it was 1976--and mentally superimposed the past image over the present one. Astonishingly, he had hardly changed at all from the youngish man I'd met while he was working in Cambridge, UK.

It's true the greying beard is a rather pepper-and-salt affair now, but he hasn't become overweight, and still looks youthful though he's in his late fifties-born 30 January 1941--and still holds a glass of something alcoholic as he gestures, while he talks nineteen to the dozen. His conversation is knowledgeable, argumentative and good-humoured. He's a good man to talk to (though he doesn't suffer fools gladly), and a good friend of mine, though I suppose we've only got together twenty or so times in three decades. In appearance, he looks intellectual but tough. He looks as if he might have been a sportsman once, maybe a football player, but he probably wasn't. (Footnote: Greg told me when he read the above that he gave up quarterbacking in Junior High, getting tired of being knocked down, but has suffered around ten broken bones from surfing, baseball etc.)

Most famously, of course, he has combined two complementary careers, academic physicist and science-fiction writer. (He must be the only writer in the world to have published both novels and scientific papers on the galactic centre: one of the novels is *Furious Gulf* , 1994, and one of the papers is "An Electrodynamic Model of the Galactic Center", *Astrophysical Journal* , October 15th, 1988, pp 735-42.) But he was already active in science fiction long before either of these careers took off.

Benford has been a Californian for several decades now, but his childhood was in the Deep South, in Alabama, plus years spent in Japan and Germany because his army-officer father was posted there. Benford has a Texas connection too. An interview tells us "I have the weird distinction of having been an instigator of the first Con in Texas and the first Con in Germany." The Texas con was the Southwestern Con, July 1958. The German convention was even earlier, WetzCon (for Wetzlar, Hesse) in 1956. Not bad going for a teenager.

Like so many other sf writers, Benford began life in the science-fiction world as a fan, and rather a notable one. He was, for example, co-founder in 1955 of the celebrated fanzine *Void* with his identical twin James, at the age of fourteen; subsequent co-editors included Ted White and Terry Carr. (Carr's experience here stood him in good stead; he went on to win a 1959 Hugo for his later fanzine *Fanac* , co-edited with Ron Ellik, and later became a distinguished writer also, and editor of the Ace Specials.) By now Benford was moving westward, and he did his undergraduate degree in physics at the University of Oklahoma, graduating in 1963.

Professional writing came quite a bit later than fan writing. His first published story was "Stand-In", 1965, written while he was a PhD student at the University of California, San Diego. It won second prize in an amateur writing contest held by the *Magazine of Fantasy and Science Fiction* , but he wrote little more before 1969.

Much of his early work, and some later, was written in collaboration. These stories and novels included some written with his brother Jim, with his sister-in-law Hilary, and most importantly with Gordon Eklund. There were later novels in which he collaborated with William Rotsler, and subsequently with David Brin.

His earlier novels were usually based on stories previously published, sometimes by reworking three or four of them and putting them together in mosaic style. In another writer this could be laziness, or a mean-minded attempt to wring every possible last nickel from previously published work. With Greg, I think the motivation is quite different. He gets dissatisfied, he wants to work out the implications of ideas more rigorously and deeply. Like a terrier with a bone, he shakes an idea and tosses it about and buries it, then digs it up again to worry it still further. Or, as Greg put it another way in an interview, "Ideas come to me in a lapidary way, layering over the years."

For example, his first novel was*Deeper than the Darkness* , published by Ace Books in 1970. It was based on a 1969 story, one of his earliest, and also called "Deeper than the Darkness". When he looked back on the book-length version later on he was dissatisfied, thought it "dreadful"; it was "hastily written". So he expanded and rewrote it into a more sophisticated version,*The Stars in Shroud* , 1978.

But I've just re-read the original novel, having remembered that it excited me at the time. Sure, there are infelicities, and the ending is ill-plotted and rushed, but it's still pretty good. It's obvious why I liked it: it came out in the middle of the rather phoney debate between "hard sf" on the one hand, and "New Wave sf" on the other, and with extraordinary dexterity it reconciles the warring factions. It's about both inner and outer space. It sees value in and uses the soft sciences sociology and psychology, but it also includes tachyons, gravity waves, and some rather nifty orbital calculations. The story is indescribable and rather ugly--telling the effects of an alien "plague" weapon on a human race, scattered through the galaxy, whose dominant mode of living is a form of collectivism based on oriental philosophies. The plague takes the form of its victims suffering acute agoraphobia, and burrowing into shit-lined tunnels where they lie cocooned, straight from the collective into stinking isolation, and ultimately die. It is a memorably telling image.

Before leaving this novel, I should refer Australian readers to the following: "…my father a truly rare specimen: one of the last pure Americans, born of the descendants of the few who had survived the Riot War. That placed me far down in the caste lots, even below Australians."

Deeper than the Darknessforeshadows Benford's later work in many respects: a love of anarchic individualism which is interpreted by some as a version of right-wing Californian libertarianism (though I'm pretty sure Greg wouldn't go along with that); a melding of psychological studies (linguistics, the nature of intelligence, the nature of sentience, the function of emotions) with hard physics (Benford's real-world specialty is plasma studies, especially as they relate to astrophysics, but he has worked in other areas of astrophysics as well); an extraordinary breadth of theme. He works on a broader canvas than almost any of his hard sf colleagues and with more colours on his palette.

Benford became well known quite quickly. After a couple of previous award nominations, he quickly won a Nebula in 1974 for a fine novelette he wrote with Gordon Eklund, "If the Stars are Gods". This was one of the four pieces that were woven together to make the collaborative novel of the same title,*If the Stars are Gods* (1977). This first-contact story tells of aliens in our solar system, who regard our Sun as a sentient being, and treat it as a god. It is one of the most interesting 1970s stories that use religious themes in sf. (It was around this stage of his career that I first met Greg, when he was a Visiting Professor at Cambridge University, in 1976.)

Benford won his second Nebula, this time for best novel, for the 1980 novel *Timescape* . It remains his best-known work, and has deservedly become a classic, but I think it has had an unfortunate side effect in somehow shadowing his subsequent career. Perhaps readers expected more of the same, which Greg was not really prepared to give them. *Timescape* is the definitive time-travel-through-tachyons story, and is set in the world of scientific research, a world that Greg of course knows intimately, and he makes vivid use of his insider knowledge. The plot involves a vital, panicky message sent by future scientists to present-day ones via tachyonic coding. The book was so powerful that one publishing house, Tor Books, named an entire sf line the Timescape line. Few novels become logos.

I had vaguely assumed that Benford had won Hugos as well as Nebulas, and it was only while researching this introduction that I found I was wrong. He has never won a Hugo in any category. Benford's absence is arguably the major omission in the list of Hugo winners over the last three decades. Among his fellow hard sf writers who have won Hugos in the same period are Poul Anderson, Greg Bear, David Brin, Arthur C. Clarke, Larry Niven, Kim Stanley Robinson, Charles Sheffield, John Varley and Vernor Vinge. Naming no names, Benford surely writes as well as the best of these, and better than several of them. (Surprisingly few Hugo awards have gone to sf writers who use hard science, despite the mundane stereotype of the sf fan--the man or woman who votes for the Hugos--as typically a technonerd. This is, it occurs to me, a very significant datum.)

As it happens I recently re-read the classic works of many of the above writers including Benford (not Robinson and Vinge, but with the addition of James Blish from the USA, and Bob Shaw and Paul McAuley from the UK). I was researching hard sf, which I love, despite the reputation sf encyclopedia editors have for being New-Wave lit-loving aesthetes, who wouldn't know a Lagrange Point from a Punctuation Point.

I have to say that the results, perhaps because I'm getting old, were disappointing. Only three of the writers seemed as good or better on re-reading, and few of their books managed to renew the original sense of wonder I'd had when I first encountered them. The writers that most successfully survived this cranky, subjective examination were Larry Niven (a veteran), Paul J. McAuley (a younger writer) and Gregory Benford (two years younger than me). Re-reading Benford, I kept finding neat nuances and implications that I'd somehow missed first time through. It was an exciting voyage through Benford's weird but stimulating mind.

The Benford series I had just read again is the enormous Galactic Center series of six connected novels. It consists of, as a kind of prologue, *In the Ocean of Night* (1977), followed by the series proper: *Across the Sea of Suns* (1984), *Great Sky River* (1987), *Tides of Light* (1989), *Furious Gulf* (1994) and *Sailing Bright Eternity* (1995). It would take thousands of words to describe the cosmic sweep of these novels properly; they consist of a swirling sea of characters and ideas, bubbling with manic energy, serving as venue for a heady narrative of conflict between organic (mostly human) intelligences, and machine intelligences. But it goes a lot further than that. The nature of sentience and the nature of the universe are only two of the series' ambitious themes. Benford must be the pre-eminent inventor of aliens working in sf today, and he really thinks them through. They do not just come from the standard alien template. Go and read the books. You may, like me, find them even better the second time.

This series makes utterly clear that to call Greg Benford a hard sf writer is only to tell half the story. For one thing, he has read a great deal, and a lot of what he writes has resonant allusions to other writers. (Notably to William Faulkner. I always enjoy Benford's public controversies-there have been quite a few of them. But the Faulkner-homage scenario was the most enjoyable yet, with Greg receiving what looked like a knock-out uppercut from ace critic Gary Wolfe, only to bounce back off the canvas and bruise Wolfe with a series of well-judged left hooks.)

As he foreshadowed in *Deeper than the Darkness* , Benford has continued (particularly in the Galactic Center series) to balance outer space against inner space, biology against physics, history against information theory. If you think this sounds daunting, well, yes it is a bit. But it's entertaining, too, every now and then to read books that rigorously exercise the mind, rather than feeding it the usual fast-food snacks. This quality of Greg's writing, together with his sporadic willingness to take experimental risks with ordinary English-language prose, means that he has never been able to seduce what I call the *Star Wars* audience. But then, where would movies like *Star Wars* get their ideas from if it were not for the pioneer work of the Asimovs and Clarkes and Benfords and Bears? (No offence meant to movie fans here-I'm one myself.) No, Benford's secret, and from a certain point of view his failure, is that he writes for grown-ups.

This is a brief introduction, not a critical essay, so I'll not discuss *all* Greg's books, though I must at least mention a few. There are two good collections of short stories, the first being *In Alien Flesh* (1986) and the second being *Matter's End* (Bantam 1994, but the UK edition of 1996, Gollancz, has extra stories added.) Many stories, however, remain uncollected. There was much sometimes heated discussion of Benford's authorized sequel to Arthur C. Clarke's *Against the Fall of Night* , entitled *Beyond the Fall of Night* (1991), and of his recent contribution to Asimov's Foundation sequence, *Foundation's Fear* (1997), when they appeared. I haven't yet read his most recent novel, which is *Cosm* (1998), but it has had some great reviews.

It is a mystery to me how Greg finds the time for all this stuff. He does not generally seem stressed or tense when you meet him, and his relaxation can almost reach the point of leglessness, so to speak. He and I on one occasion in the 1980s got embarrassingly drunk, though this-for Greg at least-is atypical.

However, he obviously works very hard. In 1971 he became Assistant Professor at University of California, Irvine. He became Associate Professor there in 1973, and has held this position ever since. This research post is a real and demanding job, not just a sinecure like Asimov's post at Boston University mainly was. He has also been an advisor both to NASA and to the Citizens' Advisory Council on National Space Policy. And he was rewarded for all this in 1995 with a Lord Foundation award, which is a seriously heavy distinction given to not many scientists.

He has published around 150 scientific papers, which is a lot, and in addition has produced many popular science articles for *Amazing* (1969-76, and some much later), *Vertex* (1973-75) and in the nineties for *Isaac Asimov's Science Fiction Magazine* . (However, quite a few of the more recent Benford columns--these have attitude, being simultaneously levelheaded and deliberately polemical--have been more about literary criticism than popular science.) It is perhaps odd, given this rich publishing history, that not until the end of 1998 did Benford's first non-fiction book appear. It is *Deep Time: How Humanity Communicates Across Millennia* .

Greg Benford is arguably the premier hard sf writer of our time-though Greg Bear, Greg Egan, Paul J. McAuley and Kim Stanley Robinson in their different ways are up there too--and he is amusing and interesting in person, too. Also approachable and friendly. Don't be frightened to talk to him. Chances are he will talk right back, and if he doesn't, well, no damage has been done. He will not be the sort of guest of honour that spends most of the time lurking in his or her hotel room. I like him a lot, and I think you will too.

GREGORY BENFORD

ANTARCTICA AND MARS

Recently I was mulling over my favorite authors, and it struck me that often a writer's essential flavor can be summed up by one of his book titles. Charles Dickens, Great Expectations. William Faulkner, The Sound and the Fury. Hemingway, In Our Time.

At least it's an amusing game. I picked The Stars My Destination for Alfred Bester, Star Maker for Olaf Stapledon, Childhood's End for Arthur C. Clarke. Ursula K. LeGuin, The Word for World is Forest. Poul Anderson, Time and Stars.

Then I thought of that ceaseless advocate of the space program, Robert Heinlein. Surely his mood and attitude is captured by The Moon is a Harsh Mistress. Space as gritty, huge, hard, real.

Which depressed me a bit, for today the space program's spirit is anything but that. A diffuse unreality pervades NASA. Similarly, James Gunn's definitive treatment of the radio search for intelligent life, The Listeners-- not a bad title choice for his essential theme, since Gunn is one of our best social critics -- now seems quite optimistic, since Congress recently killed the program (though the Planetary Society plans to carry on, using public donations). Were all these hopeful outlooks in sf simply naive?

I reflected back on my own involvement with space, from the freckled kid reading Willy Ley and Arthur Clarke describing how rockets worked, to a consultant for NASA and the Planetary Society. Somehow a lot of the zip has gone out of space for a lot of us, and for the public, too. Why?

We went wrong just after Apollo, I think. James Fletcher was NASA Administrator from 1971 to 1977, when the Shuttle was being proposed, designed and checked out -- or rather, not checked out. He convinced Congress that this nifty little reusable rocket-cum-space-plane gadget would get magically cheaper and cheaper to fly, eventually delivering payloads to orbit for a few hundred dollars a pound.

The cost now is over $5000 a pound, and still climbing as missions get delayed and services shrink. A twenty-fold increase, allowing for inflation. The Nixon administration bequeathed to us an econo-ride Shuttle (and Jimmy Carter signed the appropriations bill for it). They also axed the remaining Apollo missions and the 1970s version of the space station, though they weren't vital. Their killing the long-range research for a Mars mission had great effects, however, because we now have no infrastructure developed for large deep space missions.

Then came the Challenger disaster, with Fletcher in charge again. In the Challenger commission report he allowed as how "Congress has provided excellent oversight and generous funding and in no way that I know of contributed to the accident." Except, of course, for consistent under-funding and pressure to attain goals set by people with little or no technical competence.

The shuttle is a spaceship designed by a committee of lawyers. "The fault was not with any single person or group but was NASA's fault," Fletcher went on, "and I include myself as a member of the NASA team." As Joe Haldeman sardonically remarked, "Most people would say he was more than just a member."

And we can't even buy shuttles in quantity. The Fletcher-Nixon vision saw a flight a week. That got scaled down to twenty-four a year, then twelve. In 1989 there were nine, in 1990 six, with that abysmal prospect, a flight every few months, apparently settling in as the normal routine.

Unmanned exploration was once the virtually unblemished, high-minded face of space. Now our failures accumulate. The wrong lens curvature of the Hubble telescope. The big antenna which won't deploy aboard Galileo as it limps toward Jupiter, years late; we could have sent it directly, on a Proton booster the Soviets offered us at bargain rates, but politics of the late 1980s ruled that out. The Titans that explode with billion-dollar packages aboard, the satellites which go awry.

And the Mars Observer, lost to unknown error or just bad luck. My personal guess at the time was that while a small chip manufacturer is now getting blamed, there is an interesting coincidence that we lost contact after the thruster tanks were being pressurized. Tanks have exploded on missions before-- remember Apollo 13 -- and in both cases they had been engineered to three times the expected design limits. The review panel fingered the same plausible culprit, but basically we will never know.

The repair of the Hubble Telescope lifted spirits a bit, but face facts: it was a repair job we should not have had to do at all. The Hubble mission was overloaded with tasks, and NASA ejected to do them all with One Big Shot -- a poor strategy when you're pushing the envelope in several different directions.

It wasn't always so. Both Voyager spacecraft -- remember them? --returned a very interesting bonus in mid-1993 -- a burst of low frequency electromagnetic radiation. We believe these emissions came from beyond the spacecraft, about a hundred astronomical units from the sun lan A.U. is the distance from the sun to your house). A big flare eruption on the sun had propagated past the spacecraft and the emissions came at a time when the fast-streaming particles, going about 100 km/sec, struck something about twenty or thirty A.U. further out. What?

Plasma physicists identified the emissions as probably waves radiated by those particles as they ploughed into the shock wave which separates our solar neighborhood from the true deep-space plasma that ranges between the stars. Thus the Voyagers may have sensed the boundary of our little solar comfort zone. Within a decade or so they will cross that standing transition, where the plasma density drops and true inter-stellar space begins, a "wall" more meaningful than the orbital radius of Pluto.

Voyager was a miracle. We caught the big brass ring on that one, beginning when an orbital specialist noted in 1963 that a Grand Tour could be won by looping a probe past several of the outer planets. The window for this orbital high wire act opens every 175 years, but the last time, when Thomas Jefferson was President, we missed the chance. In 1972, when astronauts still trod the moon, we decided to go for the launch window in 1977.

I don't think NASA could do that today. Hell, it couldn't even decide to not do it that quickly. In just five years during the 1970s NASA invented and developed nuclear-power batteries which are still running, sixteen years after launch. It assembled fail-safe computers, and electronics that withstood the proton sleet of Jupiter, where a human would die of an hour's exposure. Built to give us Jupiter and Saturn, they still forge outward after gliding past Uranus and Neptune as well.

Voyager is a legacy of the 1960s, a child of the hustling Space Age that wanted to do everything it could (and a few things it couldn't, like building a true space plane). The Voyagers keep sailing on just as they were, dutifully sending back reports to a society that has changed profoundly.

Nothing follows them. Sure, Galileo is bound for Jupiter, due to arrive in 1995, but there it stops. NASA passed up the Halley's comet mission, while other nations went. Nothing will go to Saturn for many years. The proposed Cassini probe which does finally reach Saturn, probably sometime in the next millennium, will drop a vessel named Huygens onto Titan, the second largest moon in the solar system and to me the most interesting place of all.

Titan has a surface pressure not much different from that in your living room. It is far colder, but its thick atmosphere holds the organic chemicals we know existed on the early Earth. Has some slow, cold chemistry been at work there, conjuring up life forms utterly different from our own? Impossible to say, for our only closeup look showed only the featureless upper cloud deck of a methane atmosphere.

The stretching out of missions is getting worse. Galileo was planned to get to Jupiter in 1985. Though cooperation between the US and the Russians keeps getting talked about, it still has not materialized in solid ways. The recent agreements to combine our operations with the Mir station are a good sign, and probably will work out. But it's still only a beginning.

Gorbachev in 1987-88 sounded much like Khrushchev, talking up space. George Bush in 1989 resembled Kennedy, setting a goal: a manned Mars landing by the 50th anniversary of the Apollo landing, 2019. Both leaders sounded the charge. Both countries yawned and changed the subject. Shortly afterward, they changed the leaders, too.

What's different? The game has changed. It isn't national rivalry any more, and probably won't be for quite a while.

Brace Murray, former director of the Jet Propulsion Lab and professor at CalTech, pointed out to me many of these curious analogies and features of the Space Age, but his most striking analogy reached even further back.

Once we had a distant, hostile goal, and men threw themselves at it, too: Antarctica. Early in this century, Scott and Amundsen raced for the south pole with whole nations cheering them on. The Edwardian Englishman who tried to impose his own methods died. The savvy Norwegian who adapted to the hostile continent came through smoothly.

Others tried to follow. Shackleton made some progress, and then national rivalry became far more serious: World War I swallowed up the exploratory energies. Admiral Byrd and others made headway between the wars, but true, methodical Antarctic exploration did not resume in earnest until the International Geophysical Year, 1957.

The wars gave the International Geophysical Year teams cheap, reliable air and sea transport technology. (Scientists don't like to talk about it much, but modem war bequeaths science a feast of intriguing gadgets.) Military services were happy to assist, exercising their capabilities. International though the spirit was, national and territorial claims did not vanish; Argentina and Chile still mutter over their rights to turf. Indeed, perhaps the major reason nobody disturbs the present high-minded international air is that no serious resources seem to be at stake. Discover a rich field for mining or pumping and all bets are off.

Scott-Amundsen: Apollo. Shackleton and Byrd: Voyager and Galileo. The World Wars, in this analogy, are like our rising concern with domestic problems -- not soaring nationalism, luckily, but at least a deflection of those energies to local concerns.

Bruce Murray pointed out, in a speech published in Space Policy, Feb. 1991, that a science fictional alternate world scenario can perhaps illuminate our predicament. Think what our world would be like, he said, if the two-term limit on the presidency had not been enacted in the late 1940s. Franklin Roosevelt's four terms had provoked that change in the Constitution. The first president it applied to was Dwight Eisenhower. I remember how popular he was even in 1960. I'm pretty sure he could have beaten Kennedy; good grief, Nixon almost did.

Eisenhower would have presided over the whole early Space Age, 195764. He called space programs "pie in the sky," refused to fund research at a fast clip, and warned us against the "military-industrial complex".

In a parallel world with Eisenhower in office until 1964, we would have had no brave setting of the Apollo goal, no race to the moon. "It was that close," Bruce said.

He thinks that by 1990 we would probably have seen some US-USSR muscle-flexing in near Earth orbit and probably a few unmanned probes would have studied the moon. No Grand Tour trajectory for Voyager, probably no Mariner to Mars or any of the rest of it. George Bush's 1989 speech might have been a stalwart call for a manned moon landing before the turn of the millennium.

Not impossible. I can scarcely argue that such a plausible, sensible space program was unlikely. After all, I had once written a story in which Robert Taft got the nomination in 1952, not Eisenhower. (And Taft's private choice for the vice presidency was one Senator McCarthy of Wisconsin...)

The plausibility of this imaginary history tells us that we have been very lucky. We lived through dramatic times, Sputnik-Apollo-Voyager, which quite probably will be seen as like Columbus-Magellan-Drake. Maybe we are now getting back to normal. And normal means, alas, dull.

The trick in using analogies and scenarios is knowing when to stop. How does our predicament differ from the past? We must play to those differences if we are to steer a better course than Destiny would give us.

Large space projects have fed off nationalism. Kennedy sold fears of Soviet technology, with an attractive patina of worry over our science education. This worked well -- and I directly benefited, being a senior in high school in 1959, from the special science courses rushed into the schools; in fact, I might well not be a scientist today, were it not for the sudden spotlight cast on lowly high school physics courses.

Gerard K. O'Neill tried to hook up his giant solar power collecting satellites to the energy "crisis" of the 1970s, but of course the price of oil fell well before any such gargantuan project could get under way.)I never really believed in the O'Neill designs or strategy, and spent an entire dinner in a pricey restaurant trying to argue him out of the approach. He was sure that eventually energy prices would prove him right. When he died in 1992 he was still rather wistfully pushing the project.}

The paranoia road is necessarily short. Fears abate. Enemies topple. So it's time to face "Space as a Place" -- a terrain to be studied and used in its own right, not as a sideshow battleground for earthly concerns.

We must also face the fact that we've done the easy things. Putting a pressurized Huygens probe on Titan, amid chilly winds and with many more light-minutes of delay in getting radio orders through, will be a much tougher job than was landing Viking on Mars.

There are some signs of intelligent management. In January 1994 NASA launched Clementine, a bargain basement mission. It rose on a Titan IIG rocket, recycled after spending 25 years in an Arkansas ICBM silo. It is a light, low-cost probe, using land testing) sensors developed by the Ballistic Missile

Defense Organization, the heir to the Strategic Defense Initiative, a.k.a. "Star Wars." Clementine is state of the art with powerful laser-ranging device which can map our moon completely for the first time, then leave the moon and fly by an asteroid to within 100 kilometers, 1620 Geographos, about the time you read this.

Contrasting with the billion dollar Mars Observer, Clementine cost a mere 75 million. Plans for a second mission which will rendezvous with an asteroid and study it come in at about 30 million dollars. A small team put Clementinc together in two years. Such savings point to the hard-nosed, realistic program we need.

Space must be made cheaper. Even Space Station Freedom, an orbiting pork barrel, is proving to be more than the congress can swallow. The present NASA Administrator, Daniel Goldin, has negotiated with Russia to combine Freedom and Mir, their already orbiting station.

The reality of the mid-1990s seems to be that a go-it-alone station is not going to get funded by congress. A three-step plan appeals: first, send shuttle flights to the existing Mir for early experiments. Second, fly up US add-ons, so we get our own gear running. Third, collaborate on Mir II, a much fancier station, somewhere a decade or so hence. The trouble here is that shuttles can carry only light payloads into the high-latitude Mir orbit. We can't get by with this "workhorse" any longer. This opens the door to a new, better workhorse vehicle to come.

I suspect this is how matters will work out. US-Russian joint ventures contain the ominously large station costs, letting the rest of the space program go on with long-range plans that have some fiscal plausibility. Symbolizing the end of the Cold War, collaboration will also provide jobs for Russian engineers who might otherwise be working on North Korean or Libyan missile projects.

It would also lessen the load on the Shuttle. This is a time bomb in the belly of NASA, for its own internal studies show that the odds are about one in seventy-eight of a major accident, every time it flies. I served on a study group assessing the Shuttle in the 1970s, and we calculated the odds rather higher -- about four percent, or one flight in twenty-five. Regrettably, Challenger was right on the money. Then NASA became obsessed with hand-tuning every bolt on the craft, and now the odds are better.

But they will never be good. Rockets are not safe, period. The Titan failure rate is about three percent, and the Russian Protons do about the same. No rocket has ever done better over the long haul.

The schoolteachers-in-shuttles agenda, sold to the public for so long, came out of wanting to project the Eisenhower perspective-- a go-slow Space Age, elbows tucked in, chin down, making no mistakes. How can we counter that?

First, appeal to the frontier. Young people, not just Americans, want to believe in an expansive sense of the future. More than consumerism and the Beavis & Butthead worldview. Our time needs heroes rather desperately. Notice how the media seize on the merest sign of character, such as Attorney General Janet Reno's accepting some blame for the errors of her underlings.

Political leaders are tuned to sense this better than scientists. That's why the emphasis on manned space, which scientists like James Van Allen deplore because, after all, it is pricey and returns little for research folk to study. Man-in-space is a political event.

Actually, the general risk of rocketry plays to this. Danger equals drama. It would be a breath of fresh air if the President would simply tell the public that every launch is much more like a test pilot run, with casualties expected. No schoolteachers riding a bus into orbit. Instead, gutsy men and women on a wing and a prayer. As in The Right Stuff, "No Buck Rogers, no bucks."

We'll probably have a shuttle blowup before this decade is out, a fiery finish with grieving widows, and we might as well be prepared. Indeed, the deeper lesson we should drive home is that space will never be safe. Adventures aren't.

Second, we should have a clear set of cost-conscious reasons for every single project. Here the Antarctica analogy helps.

There are still solid national reasons for space. Nobody thought that there were good scientific uses to Antarctica when Scott and Amundsen raced across it. We didn't see that chilly clime as a laboratory peculiarly sensitive to the whole planetary system.

Now the "ozone hole" is a major diagnostic of our planetary health, an early indicator of the depletion which is hard to measure globally, but gives itself away among the frozen crystals floating high above the poles.

The space analogy to this is "comparative planetology." We can learn basic information about how our system works by seeing the variants played out on Mars, Venus and elsewhere. These places can teach us much about the sensitivity of planets to the sun, to chemical components in their atmospheres, and much else. Clearly there is some connection between solar activity and climate, but we know little of how it works, much less how to make predictions. Mankind arose during the last great inter-glacial time, and another may be coming. What should we do about it.?

The Martian polar caps contain layers going back to the Ice Ages of Earth. Was the main cause external to both planet s-- the sun? Or is there something more complicated going on, involving the atmospheres as primary players?

These questions are best answered by robots. They send back reams of data, grist for the scientists' mill -- for people like me, who explore the solar system in their mind's eye. What about manned flight?

An old siren song might work here: leadership in aerospace. Control of how to get into orbit. Further, dominance of the technologies which might be useful in future conflicts. This certainly means communication and surveillance satellites, but it probably implies some space station capability as well. Certainly, even big robotic expeditions to other worlds will take some assembly in orbit.

I doubt that robots can do that, though the answer is not obvious. Politically, the manned solution to orbital assembly might be preferred simply because the public will find it far more interesting than watching a cousin of R2D2 fitting pipes together in zero g.

Most space advocates have regrouped around a clear, seemingly inevitable goal: Mars. Mostly, I suspect, for its romance, mystery and the classic: because it's there. Of all manned projects-- the space station, a moon base, even power satellites--it promises the least, Alan Steele argues, in economic or technological spinoff benefits. Probably true. But it's also the one goal which can quicken the pulse of the multitude.

I don't think anything on the space menu can satisfy a public longing for action with meaning nearly as well as Mars. It will be expensive and dangerous and we can all go, via TV.

But to even propose such a thing, as George Bush did, pushes quite a few problems to the top of any space agenda. Current blue-sky planning for Mars exploration assumes that we will use liquid rockets and take about a year each way. This means problems of human deterioration in zero g become major. calcium leaches from bones, muscles atrophy. Should we do studies of people inside spinning cans, to see if centrifugal effects will duplicate gravity in the physiological sense?

Maybe. Or perhaps we should look beyond chemical rockets. To fast ships which can get a small payload, of people plus a few weeks' rations, to Mars within a month. Their supplies could be pre-positioned, waiting in orbit at Mars. Nobody needs to leave until all their support gear is in place and working.

Of course, space station research in rotating living quarters has more human involvement, so it might be politically preferred. But the other major problem of a Mars expedition, really high reliability of all that gear, is best served by sending backup systems along long, slow, cheap orbits.

This underscores another need: really big rockets for getting considerable masses into Earth orbit. Or else, much better ways to do it --laser-driven systems, say.

All these are policy decisions, but they must be made in light of what humanity as a whole wants to see in space. Drama. People. Mystery. Wonder.

Perhaps manned presence should be seen now as intrinsically international, because we desperately need goals as big as the human prospect. The world needs lofty aims. Space buffs love their iconography -- the drama of liftoff, of horizons brimming with the unknown, of Voyagers serenely gliding above alien landscapes. As well, they have an answer to those who say that these are simply the distractions of a high culture, perched atop a seething, oppressed mass.

The industrial nations have about twenty percent of the world's population. The bulk of humanity labors long and hard for little. Not because the advanced nations steal their wealth -- that same twenty percent produces two thirds of the world's output, including agriculture -- but because most of the world has never learned the many social and intellectual abilities which produce wealth.

We will probably have no real peace in the world until most of humanity is somewhat prosperous, or at least has solid hope of becoming so. But if they pursue the agenda of the industrial nations, the strain on raw resources will be vast. So, too, will be the pollution from more mining, metal smelting, fossil fuel burning, irrigation and the like. The planet simply can't support it, not with present technology.

The energy and mass needed for uplifting humanity must come from elsewhere -- space. And it is quite foolish, in the long run, for us to do messy, polluting things in this thin shell of vulnerable air and water which gave birth to us all.

We're fouling our nest. But a smart bird learns to fly.

Gregory Benford
Joe Haldeman

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[The material below is an edited version of a discussion held at MIT on October 15, 1997.]

What Happens to the Body in Cyberspace

Jenkins: Both of your selections tonight picked up on a theme that was very common last time: what happens to the body in cyberspace or what happens to the body in a world where we can shape information in new ways. What are your current assumptions about the relationships between bodies and information?

I was here at MIT for a day-long program on wearable computers, watching all the many ways people were thinking of adhering computers to clothes or to various portions of their anatomy so that you can carry them around. At first glance, it seemed improbable. I can remember when fifteen years ago people started turning up with these rather awkwardly large boxes and they were wearing headphones and I said: "Who wants to walk around listening to radio?" [laughter]

Yes, yes, I was really right on the cutting edge there. So Sony Walkman has become one of the most popular pieces of consumer electronics ever. I must say that it still occurs for me that if I go for a run on the beach I would rather hear the waves than what passes for music these days, or at least popular music, but so what, I am out of it. But I was fascinated today by the very idea of wearable (i.e. portable) computers, the idea that they don't actually have to be carried around like a fanny pack, that they can be woven into your clothes. If you want to really get sophisticated about it, you can weave electronic capacities into your clothes. There were people wearing jackets which were musical instruments we played, actually, at the reception afterwards. You go up and hit these various commands that are right here on the jacket and it plays melodies, it plays whatever you want to play; you are a walking piano. It's got a power pack and a processor and so on. But you can go far beyond that. You can imagine clothes that in fact do what clothes really do. Clothes don't just keep you warm, they are actual signals. This actually doesn't occur to people very often on the east coast where everybody seems to wear things that are dark. I don't know why since it's dark here already. We from the west coast wear color and we have more color anyway.

Haldeman: It effects the brain.

Benford: ...and it effects the brain, right. Yes, it does. The ineffable lightness of being. And I thought of a stunt you could do: you assemble a coat and trousers made out of light pipes; they take the information coming from your back, pipe it around, computer process it and emit it in this direction. And vice versa in the other direction. You split the light pipe, half goes this way, the other half goes the other way. To someone on that side, you appear to be not there; instead they are looking at the building behind you; you have become invisible. Now if that's not alteration of the body, what is? Well, it's a kind of invisibility. Of course, you can try for a partial effect. Say, you only do it for a hole about this large. You walk down the streets; you seem to have a large hole blown through you. You look like a victim from a war that hasn't happened yet. Nice effects, you know, people are not going to forget seeing you today which is the part of the thrust of some clothes I've seen. You know, the insulting T-shirts. What's that supposed to do: it is supposed to make you remember that person. You won't necessarily like that person, but you'll remember that person.

Well, there are all kinds of social ways of expressing the body. Then, I began to think about really sophisticated computers. In a couple of generations, people looking back may think of us as people who lived in a dumb world. Once you have augmented your customary moving self, you have made your clothes smart. Then they would be able to respond to what is smart, what is interactive, in the environment. I mean this building is a dumb building . You walk into the building and it doesn't respond to your presence at all. But many buildings in a sense should; for example if you walk into a bank, it would be handy for the bank to know whether you are armed, or whether you belong there at all or what you want to do there. Exit the receptionist. You walk into the building; the building tells you what you need to know about what's in the building and it interrogates you and so forth. But all parts of the landscape, all parts of the artificial world that we have created can in some sense be smart and interact with you. You walk into a hotel suite and say "I hate this color, turn everything in the room mauve, I hate this yellow," and BAM! it does that.

This is like being Bill Gates. Bill Gates does have these big screens in the house that he is building which produce very high resolution pictures such as the Madonna or any old landscape that you want; you can have it show a real time image of waves breaking in Mawai, if you want. You are looking out of the window at a sea scape on the other side of the planet. Rooms, buildings can react to you in that way and they become smart in the sense that they become an interactive part of your environment. So the world divides, then, into smart and dumb. And your body has smart and dumb processes to the extent that there are these three spheres: there's a social world (clothes have social functions,) there's the physical world (we all have physical functions), and there is the digital world. The fact that these can all overlap simultaneously in some shared space means that the entire concept of your body has changed.

Your concept of your body has already changed in ways that you really don't register anymore. Someone three thousand years ago would have found it very mysterious that we have things on our faces, in front of our eyes. Why? Or that we have odd pieces of metal stuck into our teeh; or my left shoulder, which I've stupidly broken twice, once playing softball and once surfing, is now made of metal. All of these things are augmentations, changes that we accept as natural. The next change, then, would probably be a smartening of the body. We would then have a division between smart and dumb interactions with the world. And the world would be divided between smart and dumb in the same way that human culture divides the world into artificial and natural. Chimpanzees almost certainly do not have the classification of cultural and natural, and certainly, they don't have it in the way that we have it. Soon enough, our division would be between smart and dumb ways in which the body reacts to the world. And that will be as profound a change as anything that I can think of. And we can't really even glimpse what that would necessarily imply. It is very hard to get outside of your cultural perception but if computerization keeps on going for a couple of more decades at its current rate, all these things will become readily possible and I don't think we can quite understand how big a movement it will make.

Haldeman: Yes, it's interesting to talk along those lines. I am looking forward to a time in the very near future when the idea of the computer as a separate instrument is curiously quaint; when doors and tables and microphones have computers inside them and they just sense what you want and go ahead and do them. [Beeper phone beeps in audience] In fact, pockets would have little computers in them that would tell you that somebody is waiting for you. One thing about the modification of the body is to make the body smarter. Some thing that I haven't seen investigated in science fiction and I am going to patent it right now so that Greg can't write about it. Our intelligence is actually not limited to the brain but spread all through the nervous system. A person who plays a musical instrument does not figure out which way to move his fingers everytime he moves his fingers. In fact, you go much faster than you could possibly think. After a certain amount of practice, you not only can memorize a piece very fast but you can improvise faster than you can actually do any cognitive work.

I find that fascinating and it's not something that is happening in your brain; it's happening somewhere between your spinal column and your fingers. What happens if you can actually modify that; what happens, if you can speed that up; what happens if you can actually do some time sharing between some part of your brain and that little autonomic stuff. I don't know, but it would be interesting, I think that we may see a revolution in the arts, for instance, to make a really conservative prediction: a kind of music so fast and so subtle that we couldn't even understand it now. But when everybody can do it, when everybody who cares can do it, that may become a dominant form of music.

We may be able to augment our eye sight so that the visual arts become..oh, I don't know...we could use up a lot more of the spectrum. Not a LOT more, we can't see radiowaves without having eyes this big, and you don't want to look at something that's in gamma rays for too long, it might hurt the other parts of the spectrum. But our visual acuity could increase by an order of magnitude and we could actually increase the visual spectrum by an octave or two and have things that are tremendously complex and moving paintings that you and I would just see as a piece of blank canvas, or a monochrome. I am fascinated by the stuff that we saw over at the wearable computers, a lot of the things that were interesting were just concept clothing; that is, nobody has figured out how to wire them yet, but the one that I really liked is the one that I read about in science fiction story a couple of years ago about a reporter who goes to cover a war and she's wearing everything she needs, she's got a camera in her hand and she's modemed fairly well. She speaks into her jaw and a computer a thousand miles away writes up her stories and projects them onto a little a screen in front of one eye so that she can edit it, and there was a gal wearing one of those things on a pedestal at the Media Lab show and it was functional. She had a little camera, not a great camera but a little camera on her palm and like a three by four inch screen in front of her eyes that showed what she was looking at. She had her left hand wired with five contacts where she could type by tapping different combinations of fingers into a little computer output that was onto one breast. I could use on outfit like that!

After the first hundred thousand dollar one comes then comes the ten thousand dollar one and then finally it reaches Radio Shack. If you want to really spend money, you can get one that nobody can tell you are wearing. It's all heads up and its lens is built into your nail. We'll see that really soon because as a culture we are addicted to the preservation of information about our activities. This way, you can get real time the whole boring vacation, nail your relatives and say alright this is going to take about twenty hours. Yeah ó this world does need editors; it already needs editors and think how horrible it is going to be in the next century.

Question: You mentioned before smart clothing that changes while you walk, while you're moving around the room. You meet somebody from across the room and your sweeter changes to match theirs and flashes. What does that change in the nature of communication?

Benford: Yes, sexual signaling is very important in clothes. Of course, the most important sexual signaling is when you take them off. Yeah, there's certainly going to be stuff like that. Remember fifteen years ago when they had clothes that would change color because at places with direct contact with the body they would warm up Those didn't catch on, because of course, it was a random signal. With a smart system, you can interrogate somebody else's system and you can skip the cocktail chat and get right down to the heavy breathing stuff, but the mind boggles. That's one thing that could happen, but you would assume that all people were smart unless, of course, they were wearing dumb clothing. That's yet another hierarchical thing that would start to separate us out in a way.

Haldeman: What happens when a dumb person wears smart clothing?

Benford: They just don't say much I guess.

Haldeman: They'll say you're new in town.

Benford: Well, smart, of course, means just capable of interacting and interrogating about all kinds of stuff.

Suppose you walk into a room and all you have to do is look at somebody and a couple of key touches here and there and you could instantly download his entire web site. So you walk towards a person and you can read his website and you go up to the guy and you know something about him, a lot maybe. You could go off and have a drink, look at the skyline and read the whole website, read his last essay in the*New York Times* Refuse of Books and come back and argue with him about it. The possibilities are endless here. Of course, a lot of reading, I know.

Haldeman: Well, we'll be able to read much faster in the future.

Benford: Oh yes, that's the one thing that hasn't improved. We have all kinds of technology to make us disseminate words faster but nothing, except for the electric light, to make us read faster.

Haldeman: You've never taken that Evelyn Wood speed reading thing?

Benford: No, never had the time.

Haldeman: Too much to read.

Question: Both of your stories dealt with reinterpreting the senses, altering sensory information and subjectively changing reality. What kinds of effects do you see this technology having on people and on society?

Haldeman: Well, in one corner I can see profound changes in recreation, things like synesthesia ó rearranging the input of the senses into something pleasing or strange or even horrifying and strange but therefore entertaining. In terms of actually coping with the real world, the external reality I see an amplification of the senses which would allow a normal person do more subtle work; I mean the obvious things like nanoengineering and so forth. We are already doing things that literally couldn't have been described fifty years ago, couldn't have been thought of. The idea of operating on a nucleus of a cell by moving things around is incredible. It's everyday now, but when I was born nobody was even thinking about it. I got a little calculator, a little computer cost me three hundred bucks and I can write on it in script and it comes out printed as a word processed document.

When I was in graduate school, they put that about a hundred years in the future...and voice recognition and computers was something they said: "Well forget about it; that's science fiction." Hell, I can buy a little program that costs 25 bucks that does voice recognition on my machine. Doesn't do it perfectly, but it does it. We are living in this strange world because these wonders become everyday overnight and there are new wonders that come speeding around the corner all the time. And perhaps guys like us who are a little longer in the tooth than you guys are more actively impressed when these things happen. But I suppose that every now and then it might occur to you that you are living in a strange and rapidly changing world.

Benford: What's hot in the moment and everybody can see it coming is going to be more interesting media technologies. Lots of graphics and interactive this, that and the other. I think these new media are going to amplify our views of the world enormously so that it's worth talking about new media in science fiction and seeing how far we can push it. That's what the story I read was basically saying. Stock brokers now sit in front of a screen and type out stuff and look at stock to place but what it would be like if you went to work and it was more like you were playing tennis but you are still doing the same operation. You were actually bodily engrossed in the activity. You were not just using your hands and your eyes but you are using your whole sensorium. It's the expansion of the human sensorium that I think will give us a radically transformed world for some people anyway in the next century because I don't see any real end in sight yet and the horizons we are looking at are pretty far off. You mustn't think of people eighty years from now having just bigger screens or better keyboards to type on. It can't be like that at all. The keyboard's going to go away. The keyboard itself is a only hundred years old and why would we want to stick with that?

Reimagining the Body

Jenkins: Last time, James Patrick Kelly read a story in which people rather casually decided to neuter themselves, to get rid of their genitals. In much contemporary science fiction, there is a lot of a play with bodily modification. It strikes me though when I read Joe's stories, which often include descriptions of wounds and mutilation, there seems to be a real attachment to the body and a sense of loss when the body gets altered. That seems to be a reality that's often lost when science fiction writers imagine future societies in which we casually toss aside pieces of bodily flesh in order to change who we are. And I am wondering what resistance the body poses to some of the visions of technology that are cropping up in recent science fiction.

Haldeman: Well, we are learning a lot about the immune system and along with that we are going to learn more about radically transforming the internal organs of the body. I myself don't look forward to that sort of future but it's coming. I was signing books the other day and this really beautiful woman about twenty , twenty-one came up and she had more metal in her mouth and on her face than I have in my bicycle. She had all these little bolts in her tongue and lips and everything. She was beautiful but it was a kind of horrible beauty. And what I saw was not the future. What I saw was a fad that didn't have much longer to go, because she had obviously taken it as far as she could. God knows what else she had, I didn't try to visualize that. "I have a pierced pancreas, right through. It's the only one in all of Cambridge." God, doesn't it hurt? I suspect that the first thing we'll do, once we have solved the organ of harvesting organs out of animals like pigs, is to replace our own aging organs. That's going to be real fast; that's like raising a pig for a pork chop; give me a break. And I think that process will go from experimental to routine in no time at all because it will be a method of routine life extension and it will go from very expensive to moderately expensive to covered by group insurance plans real fast. And I suspect that you and I will probably live long enough to have a little piggish heart beating around or something like that. Maybe little piggy hair on my bald head.

When it comes to radical changes I wonder about the people who write these stories. I love James Patrick Kelly's story,*Mister Boy.* That's one of my favorite science fiction stories. People take the strangest forms, like this guy has turned himself into eternal boy. He's like nine- or ten-year old; he's getting older but he's looking like a nine or ten years old boy. His mother is looking like the Statue of Liberty and I guess she's about 25 feet tall and his best friend looks like stegosaurus or something. I wonder about this. I had my body really badly modified by a machine-gun and rockets and rifle grenades. I have had so much surgery, I have so many pieces of metal in my body and I have seen my insides; that's something that most of the people who write about these things have not had the pleasure of seeing. I've seen other people I knew blown to pieces and lying rotting in the sun and that's not something that makes me looking forward to cutting a part of one's body and rearranging it into something that looks like a Mattel toy.

But if it were done painlessly and if it were something that would make you popular and get you the girls or boys, they'd do it.

Benford: Yes, I have the same reservations. In fact I instantly thought of John Varley who is a very interesting and rather strange guy and he wrote stories in the seventies and early eighties in which people change sex back and forth and it is all easy and cosmetic. Those stories really bother me because one thing we really do know about our sense of sexuality and our sense of self is that a lot of is hard wired in, from early experience. And if you just go down and change the genitals and reform the body and stuff, you are not going to affect this big driver up here and that driver is not going to be driving the right equipment. And it is not just going to be so simple that you, bang, become a woman and you see what it is to be a woman and the next week you are going back to being a man; it's just not going to be that easy. It's the mental equivalent of the TV dinner. Looks easy, but it's not satisfying. And I wonder about that brand of science fiction, because I just don't believe it.

You were just talking about how the knowledge lies in the body. Yeah, Ted Williams knew that, right? Hitting a baseball is not up here man, it's disseminated material. And the same thing is true about a lot of things about ourselves. Einstein once said that instead of having visual pictures or mathematical pictures, his sense, when working on a physics problem, is kinesthetic. Einstein felt movement and he felt it in his whole body. If you take away the body, you are not going to have the same Einstein. And I think that it is generally true. This kind of science fiction that treats the body as a series of disposable parts or as the feminists in the seventies used to say the only difference is in the plumbing - it just ain't so. This kind of easy technology is not going to work and the pursuit of it is probably going to get you in a whole mess of trouble.

Haldeman: You can look at the statistics of people who have two sex change operations, who change their sex and try to go back to the other and are imperfect copy of what they were in the first place. Think about how much pain and expense and terror there is involved in the operation. You would think nobody would do it again but a lot of people do. There was an article in the*Esquire*> about it, it was terrifying. I think that idea terrifies me anyhow, but what if it were easy to change the sex, but not the gender, to leave the hardwiring male but make the plumbing female. You would get a kind of weird cocktail of sensations. Cocktail is not a very good word to use. Einstein was talking about this hardwiring but, the same guy in his sixties wanted to get real old so he didn't spend half his time thinking about women. And that's hardwiring because very few women spend half their time thinking about men, at least past the age of sixteen and that's because you have to run the world and all we have to do is make new babies. Just think that we will be obsolete in another fifty years. Parthenogenesis will be the order of the day and people will remember what the world was like when there were men.

Interactive Storytelling

Jenkins: If we go back to the origins of the American science fiction tradition, Hugo Gernsbeck saw science fiction as responding to technological or scientific changes, as part of the public education about science. Of course we know that Hugo Gernsbeck was also very involved in amateur radio and so was very interested in communication technologies. Science fiction became a way to educate a public about the changes which those media technologies were causing in their daily lives. Today, many would say we are in another period of media in transition or rapid change, and I was wondering if you had thought about how creative artists contribute to helping the public understand that process of change.

Haldeman: I feel like an anchor; that's my role. I am basically a conservative artist and I've been looking at the things people have been doing in terms of interactive writing and writing into sort of cartoon worlds that are built on gaming software and some of them are really neat visually, interesting to look at for a few minutes. But I haven't yet seen one that had any actual writing in it, that had interesting stories. I guess it's hard to get someone who's gone through years and years of story telling in a conventional medium to sit down and actually learn how to use the software. I'd be tempted, but I have to make my living writing this stuff and I can't spend a couple of years creating something in a new medium that nobody is going to pay me to enjoy. I guess we just keep letting the engineers work on it and work on it until it's so natural that a writer or a musician or painter can just step in and use it. But, I remain a little skeptical.

I have a friend who's a fine artist and her medium is collage and we talk all the time on email. She lives in London. And when I got PhotoShop, I told her that "This is what you need for collaging because you can set the sucker up and you can make images out of the various elements of the collage and you can turn them into variables and just move them across a field and see what the thing would look like before you paste anything down." She was appalled at the idea of not taking the chance of cutting out the picture and glueing it down. I can sort of agree with her because I am a water-colorist and I know part of the charm of watercolor is the danger because you can't change it when you put it down. If you make a mistake, you just throw it away. With any kind of computer-aided art, you can always back up and if something goes wrong, you can try the state previous to it. This can be pretty neat, but it may be antagonistic to a certain kind of artistic sensibility and it may just require a new kind of artistic sensibility that is more fluid and more tentative.

Benford: You know writing changed that way when we went from chiseling the stuff into stone and it's been a tough transition for some of us but we've done it. You can actually rewrite. So artistic change is inevitably driven by technology and there ain't no way out of that. I wonder if writing can really do much about the new medium. We can write short stories envisioning what might come, but there's so little you can do in the printed page that's truly avant-garde. Almost all of it has been done by somebody and basically almost all of it is a blind alley. What bothers me about interactive fiction is that people really want to be told a story and there's a hierarchical authority position in story-telling: I am telling the story. You are listening. You've even paid money for it. Sorry, too late, you've bought it, it's yours. Of course you don't have to read it. But people want to be told an authoritative story. They wish to be told how something came out and that's part of the suspension of disbelief. If you tell them, "Hey, this is all malleable! You can change all this at every step," it destroys some of the suspension of disbelief that is crucial to caring about the story. You've read a book. You know these people aren't real and yet you are indulging in an extra size of caring about them. This is a page turner; you are going to find out what happens next but you know it didn't happen. And that's an odd little trick that we have because story-telling is very important for us. You are taking a real risk if you tinker with that, and say at every turn "Oh, by the way , this is completely arbitrary, and remember you can change this as much as I can change it." I think that may be fatal to interactive media and that is one of the reasons that I've not done it.

Haldeman: Or maybe interactive media is going to be something as different from reading as say surfing is different from reading; that is just a different way of amusing yourself. There was a fascinating book a few years ago, Arthur Shank's *Tell me a Story* . His convention was that we are hard-wired to be told stories and that almost any kind of heuristic process from algebra to learning how to play ball is done in a sort of a narrative way. Yes, there is always an authority, the person who knows what you have to know. And stories are entertaining because they present what is in essence a hard-wired survival mechanism in a non vital context. You exercise skills that you have to do well in order to succeed but while you are at a movie or reading a book, the outcome is not itself crucial to your development as a surviving or reproducing creature. Of course, we have had, in essence, hypertext stories since the nineteenth century when the Germans did it. If you want Grunwelt to win the fight, go to page 43 and if you want Herman to win the fight, go to page 44 and you keep branching the story like that. It's actually a fairly old trick but the fact that it's a fairly old trick and people don't do it indicates to me that it never has worked too well.

Question: I have a question about interactive fiction. You talked about the narratives being central to interactive fiction. As I see it, interactive fiction allows you to be a world builder rather than a storyteller; that's something that science fiction writers excel at. Science fiction writers have always built interesting worlds and populated them with interesting things. Do you think that's more the role of the storyteller in interactive media?

Haldeman: I tell you, quite seriously, a big difference is that science fiction writers get paid for doing it. If they allow the authority to build the world and tell the story leak out to the reader, then what are they getting paid for? They are essentially just building masters at that point.

Benford: In fact, I just entered into a contract with an Internet firm called Hollyworlds. They are taking a novel of mine called *Great Sky River* and building a game on it that is accessible by the Internet. They deployed the first level of it at Thanksgiving and you can dialup on the Internet and play this game involving all the sociology of this family on a planet where machines are of higher capabilities than humans and human beings are the rats in the walls and you are trying to stay alive. You can play it singly or in groups. You are a member of a family moving across a strange terrain and there are various kinds of creatures. All of the key ideas come from my novel,*Great Sky River* and they just wanted to use the background apparatus. You go in there and you write your own narrative by performing in it. About every month or two, they will add another layer as they develop more of it and it will become a more elaborate quest to find a certain thing and so forth. This is something that has never been done on the net before, at least not with a novel. Specifically it's an advertising vehicle. They are going to sell banner space on the side to Mitsubishi or somebody. I don't care, I just get ten percent, I don't care. I get ten percent of all gross revenues. So that's actually doing what you said and it's interactive not in the sense that you could go in and tinker with the basic mechanics but rather that you can act in that play; you can do things. You can convince all the members of the family you ought to go down in this valley rather than in that valley and you can change its outcome because you've been down there and you got killed, so you do it differently next time. And I suppose that's what you mean. Who knows, maybe it will fly, maybe not. I might even try to play it myself. I'll probably looooooose real big.

Haldeman: They made a board game out of the*Forever War* . They gave me a copy of it and I couldn't figure it out. It was this huge thing and it must have had 250 pieces in it and you had to punch them all out and the manual was so poorly written you had to be a computer jerk to understand it. So I've never played it. It's still sitting there.

Class Issues and Body Augmentation

Question: I was wondering what impact personal augmentation would have on the divisions between social and economic classes in our society and if this is something that we as a society should be worried about.

Haldeman: If there's going to be a financial division in the cyber universe, it is going to be in the nature of filters. I get so much email that I just ignore most of it and yet I still can take care of it in about ninety minutes a day. Ultimately I will have a machine that will discard all of the ones that are obvious crap and then it will feed that to another machine that find out the people I talk to most frequently and stacks them first and then if I have time, I get to the others. That's trivial. Probably there's a program out there now that would do it or hell, I could write one but I don't have time. It takes less time just to click through the mail. Ultimately, digital media is democratizing. I love the sight of these free terminals in public libraries and the ubiquity of net facilities in public schools at least in some school districts. Because it is a key to the universe, I mean you can ultimately download anything if you have the patience and the hunting skills to find it and that hasn't ever been true before. Because the thing that kept the hierarchy going in the medieval world and before that was the lack of information available to the lower classes. Only the upper classes learned how to read, let alone had access to the scrolls and manuscripts that had the information. Now you are born with access to information as a birthright.

Benford: Yes, that's true. But every technology leaves somebody behind and not just the technophobes. There's still people using quill pens, you know somewhere. But it would be a small percentage, I hope. I think that technology will get so cheap that everybody will have the rudiments in the same sense that just about anybody can buy a newspaper now or can suck on the glass tit of the TV. TV sets are so cheap now that everybody has them and in fact they are the number one soporific of modern society. Where I part company with the Internet evangelicals is when they think that it will transform the world. Actually, I think most people will use it for trivial reasons. The rest of us will be watching public television.

Haldeman: or hardcore pornography.

The Responsibilities of the Science Fiction Writer

Question: Does science fiction have a special responsibility to help us understand the consequences of information technology and if so, how can this be accomplished?

Benford: Yes, SF, all fiction, has some responsibility to do some thinking about where the hell we are going it's just that most fiction isn't conditioned to do that. The mystery novel, the western, they typically don't tell us anything about technology, so it's more or less left up to SF. The problem is that cautionary tales are a bit limiting once you catch on to what they are cautioning you about. The best ones can really throw you a zinger or two and I like those kinds. There are so many obvious drawbacks to technology that we try to defend against but it's just a chimpanzee fascination, folks. We are just going to make this stuff. It's too sweet. You see the technical sweetness of the thing and you will build it. I mean, look, we built nuclear weapons and that's got obvious problems. On the other hand, the first half of this century was a slaughter house and the second half has been a golden age because you couldn't stop the nation states from slogging it out with each other by appealing to their higher interests or morality but you could sure scare them. Nobody realized that when we invented that thing. And that's the problem ó technology has huge effects on society. And who would have predicted that (in fact nobody did) nuclear bombs would simply scare the nation system so badly that they never use them, so far. Nobody guessed that.

Haldeman: And nobody got the first moon landing right either. How many hundreds of stories about the first trip to the moon and nobody had it an essentially political act of misplaced or displaced aggression.

The Science of Science Fiction

Question: What role does contemporary scientific research play in your writing?

Haldeman: It does make it harder to write. You can only read so much a day and most of the science that I read is on the general level:*New Scientist, Scientific American.*I can read technical things if I screw my brain really hard. I can read physics reviews letters and I can read the astrophysical journal, but I don't unless I absolutely have to find out something that only they have and medical journals are pretty easy to read if you have a little medical dictionary. But the point is there's so much information. How do you know what's important unless it's within a spitting distance of your own specialty?

The students I have in this August institution (and I used the word institution advisedly); a lot of them don't know much about science outside of their required courses or their major. 40% of us are course 6, and course 6 people don't seem to know an awful lot about physics or chemistry because they don't have to and they have to learn so much else... course six is computer science and electrical engineering. It's where the money is. And I am even worse, because I don't have to learn anything about any science. I can write science fiction about totally bogus stuff so long as I know what not to write about. I wouldn't write bogus stuff about computers because half the people that pick up a science fiction magazine know more about computers than I do, so I just kind of tiptoe around that. I am also very careful about writing in the life sciences, because I know I can't keep up with that; it's going too fast. I can't even speak the language anymore, but I can write fairly straightforward stuff about physics, astronomy and astrophysics while I basically don't try to write about superstring theory. I don't want to write about things that other people can't understand anyhow. I am basically in the communication business, so most of my physics was actually written down before 1960. But if they actually had pulled a rug out of from under Newton and nobody has told me...? Newton still seems to describe the world that I live in.

Benford: Well, that's because you don't drive as fast as I do.

Haldeman: I don't drive. I ride a bicycle.

Benford: I drive a Mercedes 560Sl and it can go 170miles an hour and v/c is still 10(-6) but still you can see the effect. The light gets redder as you run away from it.

Haldeman: Does it make you live longer?

Benford: It will seem longer. Indeed that's a very real problem. I have written about a lot of things like biology which has taken a hell of a lot of work, but luckily, my latest novel is actually about mostly papers written by Alan Guth here in your own physics department. And I got all the information by coming here on a sabbatical four years ago and talking to Alan Guth and taking him to dinner and reading all his papers. That's one way to do it, but it's always a challenge. The problem is that scientific culture is the true bloom of the twentieth century (not that it was that minor in the nineteenth) but it's an astonishingly complex structure and yet it's cultural implications and how it works and how scientists work in a society is largely uninspected in fiction.. And the fictional landscape just doesn't understand what's going on so you have lots of conventional novelists like Philip Roth. They don't have a clue what really happened in the 19th century or the 20th century without looking at the role of science. The science fiction writers are some of the few people who are trying to understand what the true drivers of our times were.

Final Thoughts

Jenkins: Do either of you have any final comments to make before we wind things down?

Benford: I think it's striking that science fiction has captured the larger culture. The most popular films of all time are science fiction. Science fiction metaphors have invaded the ordinary speak of midtown America and yet the kernel of science fiction has not made it through; science fiction expresses a profound disquiet and yet enthusiasms for change. Science fiction is particularly well matched to the American mind. The American mind is not like that of the Europeans or the Asians or something. We have a different mindset, a different culture, and that's why modern science fiction is predominantly American. Even the most popular British writer, Arthur C. Clark, is really more American than the other British sci-fi writers. And yet I have this profound feeling that science fiction is being exported into mainstream culture and it's primary field is not getting through yet, and may never. The only way you can get people buy a science fictional landscape with all the virtues it has, life's interesting new things in it, is by getting them to go there as a part of a club or part of a family as a shared experience. And that's why*Star Trek* was inevitable. And that's why*Star Wars* is about basically Hans and you know, a bunch of other guys, or is it Han, yeah, I am not fan of any of those. But it's basically about three or four people who are close to each other and have this strange relationship and so forth.*Star Trek* is about a bunch of swell folks who go to the stars. You go to these movies and identify with people in there. It's a shared experience. We go to the stars and we are always safely ensconced in some support mechanism. Raw science fiction isn't like this.

The Stars My Destinations about strange people doing strange things, by themselves, somewhere up in the future and that's rather hard for some people to take. So I predict the big popular media breakthroughs in science fiction will probably always be a communal experience of the future in which you can identify with the group. This period in which we are seeing a whole bunch of these new ideas and great technical effects will last decades, but it will finally be over and there will be an era just as there was for the western when nobody wants to make this stuff any more. "Science fiction is over. Let's do some detective stuff." I would like to see our culture really get the true fix of science fiction and I don't know how to do that. I think to some extent it may depend on the audience insisting on something better than what we've been getting in the big sci fi movies. For those of you who like SF, and not sci-fi, what you need to do is proselytize about what is good but not getting through in modern science fiction.

Science fiction has a lot to offer to the culture and particularly this current moment when our culture would have to think hot and heavy about the future because the rate of change is getting faster. Things are accelerating. We are entering a new era in which we truly have to become the stewards of the earth. The greenhouse warming and the ozone layer are just the beginning of large problems that we will confront. The big problems of the next century are going of those kind. And if we come out of it a century from now, it will be because we have finally realized that we have to actually manage the whole planet. Really we do. We can't just believe that if we make nice, everything will be okay. We are going to have to actually take voluntary control over the whole thing, because our abilities are now Promethean. And that is the big job of the next century and the only literature that can make this clear is science fiction and it going to be a tough message to get over, I am afraid.

Haldeman: I am spinning a scenario of destruction where science fiction is the only tool with which to deal with the potentially devastating century that's to upon us. And real science fiction as a tool for thinking is literary. Every now and then there is a science fiction movie that requires a three digit IQ to understand but they are very uncommon and they aren't exciting the way that literary science fiction is. Yet people are becoming less and less literary. Even though they are not becoming less smart, there are usually non literary tools to deal with their problems. What happens if a hundred years from now or fifty or twenty, there are generations who literally cannot use literature as a tool. It's not that impossible. We've been talking about it in science fiction since the thirties - the post-Gutenberg generation. Somehow it hasn't happened yet and maybe it never will. It may be that we are hard wired for story telling and that generation will see science fiction as a modern or post-modern way of doing stories. I would hope so because I would hate to learn a new trade at this age but we shall see.

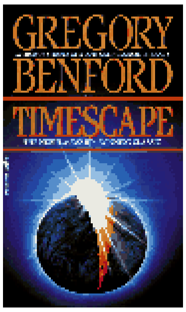
BIO

Gregory Benford-- physicist, educator, author -- was born in Mobile, Alabama, on January 30, 1941. In 1963, he received a B.S. from the University of Oklahoma, and then attended the University of California, San Diego, where he received his Ph.D. in 1967. He spent the next four years at Lawrence (Calif.) Radiation Laboratory as both a postdoctoral fellow and research physicist.

Benford is a professor of physics at the University of California, Irvine, where he has been a faculty member since 1971. Benford conducts research in plasma turbulence theory and experiment, and in astrophysics. He has published well over a hundred papers in fields of physics from condensed matter, particle physics, plasmas and mathematical physics, and several in biological conservation.

He is a Woodrow Wilson Fellow and a Visiting Fellow at Cambridge University, and has served as an advisor to the Department of Energy, NASA and the White House Council on Space Policy. In 1995 he received the Lord Foundation Award for contributions to science and the public comprehension of it.

In 1989 Benford was host and scriptwriter for the television series *A Galactic Odyssey* , which described modern physics and astronomy from the perspective of the evolution of the galaxy. The eight-part series was produced for an international audience by Japan National Broadcasting.



Benford is the author of over dozen novels, including*Jupiter Project* ,*Artifact* ,*Against Infinity* ,*Great Sky River* , and*Timescape* . A two-time winner of the Nebula Award, Benford has also won the John W. Campbell Award, the Australian Ditmar Award, the 1995 Lord Foundation Award for achievement in the sciences, and the 1990 United Nations Medal in Literature.

Many of his best known novels are part of a six-novel sequence beginning in the near future with**In the Ocean of Night** , and continuing on with**Across the Sea of Suns** . The series then leaps to the far future, at the center of our galaxy, where a desperate human drama unfolds, beginning with**Great Sky River** , and proceeding through**Tides of Light** ,**Furious Gulf** , and concluding with**Sailing Bright Eternity** . At the series' end the links to the earlier novels emerge, revealing a single unfolding tapestry against an immense background.

His television credits, in addition to the series*A Galactic Odyssey* , include*Japan 2000* . He has served as scientific consultant to the NHK Network and for*Star Trek: The Next Generation* .

GREGORY BENFORD

BIOTECH AND NANODREAMS

If this century has been dominated by bigness--big bombs, big rockets, big wars, giant leaps for mankind -- then perhaps the next century will be the territory of the tiny.

Biotech is already well afoot in our world, the stuff of both science fiction and stock options. Biology operates on scales of ten to a hundred times a nanometer (a billionth of a meter). Below that, from a few to ten nanometers, lie atoms.

Nanotechnology -- a capability now only envisioned, applauded and longed for -- attacks the basic structure of matter at the nanometer scale, tinkering with atoms on a one-by-one basis. It vastly elaborates the themes chemistry and biology have wrought on brute mass. More intricate, it can promise much. How much it can deliver depends upon the details.

It is easy to see that if one is able to replace individual atoms at will, one can make perfectly pure rods and gears like diamond, five times as stiff as steel, fifty times stronger. Gears, bearings, drive shafts -- all the roles of the factory can play out on the stage that for now only enzymes enjoy, inside our cells.

For now, microgears and micromotors exist about a thousand times larger than true nanotech. In principle, though, single atoms can serve as gear teeth, with single bonds between atoms providing the bearing for rotating rods. It's only a matter of time and will.

Much excitement surrounds the possibility of descending to such scales, following ideas pioneered by Richard Feynman, in his 1961 essay, "There's Plenty of Room at the Bottom." Later this view was elaborated and advocated by Eric Drexler in the 1980s. Now some tentative steps toward the nanometer level are beginning.

Such control is tempting. Like most bright promises, it is easy to see possibilities, less simple to see what is probable.

Nanotech borders on biology, a vast field rich in emotional issues and popular misconceptions. Many people, well versed in 1950s B-movies, believe that radiation can mutate you into another life form directly, not merely your descendants -- most probably, indeed, into some giant, ugly, hungry insect.

Not all fiction about nanotech or biotech is like this -- there are good examples of firm thinking in Greg Bear's Queen of Angels and the anthology Nanodreams edited by Elton Eliott, and elsewhere.

All too often, though, in the hands of some science fiction writers, nanotech's promised abilities -- building atom by atom for strength and purity, dramatic new shapes and kinds of substances -- lead to excess. We see stories about quantum, biomolecular brains for space robots, all set to conquer the stars. About miraculous, overnight reshaping of our entire physical world -- the final victory of Information over Mass. Or about accelerated education of our young by nanorobots which coast through their brains, bringing encyclopedias of knowledge disguised in a single mouthful of Koolaid.

Partly this is natural speculative outgassing. One can make at least one safe prediction: such wild dreams will dog nanotech. The real difficulty in thinking about possibilities is that so little seems ruled out. Agog at the horizons, we neglect the limitations -- both physical and social.

Nanotech holds forth so much murky promise that writers can appear to be doing hard sf, while in fact just daydreaming. Not only is the metaphorical net not up on this game of dream tennis, it isn't even visible.

People can tell disciplined speculation from flights of fancy when they deal with something familiar and at hand. Nanotech is neither. Worse, it touches on the edge of quantum mechanical effects, and nothing in modem physics has been belabored more than the inherent uncertainties of the wave-particle duality, and the like. People often take uncertainty as a free ticket to any implausibility, flights of fancy leaving on the hour.

Developing a discipline demands discipline. Dreaming is not enough.

One point we do know must operate in nanotech's development: nothing happens in a vacuum. The explosion of biotech, just one or two orders of magnitude above the nanotech scale, will deeply shape what comes of nanotech.

The transition is gradual. The finer one looks on the scale of biology, the more it looks mechanical in style. The flagella that let bacterium swim work by an arrangement which looks much like a motor, each proton extruded by the motor turns the assembly a small bit of a full rotation. Above that scale, the "biologic" of events is protean and flexible, compared with mechanical devices. Below it, functions are increasingly more machine-like. The ultimate limit to this would be the nanotech dream of arranging atoms precisely, as when a team at IBM spelled out the company initials on a low temperature substrate. But widespread application of such methods lies probably decades away, perhaps several. The future will be vastly changed by directed biology, before nanotech comes fully on stage.

Consider a field of maize -- corn, to Americans. At its edge a black swarm marches in orderly, incessant columns.

Ants, their long lines carrying a kernel of corn each. Others carry bits of husk; there an entire team coagulates around a chunk of a cob. The streams split, kernel-carriers trooping off to a ceramic tower, climbing a ramp and letting their burdens rattle down into a sunken vault. Each returns dutifully to the field. Another, thicker stream spreads into rivulets which leave their burdens of scrap at a series of neatly spaced anthills. Dun-colored domes with regularly spaced portals, for more workers.

These had once been leaf-cutter ants, content to slice up fodder for their own tribe. They still do, pulping the unneeded cobs and stalks and husks, growing fungus on the pulp deep in their warrens. They are tiny farmers in their own right. But biotech had genetically engineered them to harvest and sort first, processing corn right down to the kernels.

Other talents can be added. Acacia ants already defend their mother trees, weeding out nearby rival plants, attacking other insects which might feast on the acacias. Take that ability and splice it into the corn-harvesters, and you do not need pesticides, or the dredge human labor of clearing the groves. Can the acacia be wedded to these corn ants? We don't know, but it does not seem an immense leap. Ants are closely related and multi-talented. Evolution seems to have given them a wide, adaptable range.

Following chemical cues, they seem the antithesis of clanky robots, though insects are actually tiny robots engineered by evolution. Why not just co-opt their ingrained programming, then, at the genetic level, and harvest the mechanics from a compliant Nature?

Agriculture is the oldest biotech. But everything else will alter, too.

Mining is the last great industry to be touched by the modem. We still dig up crude ores, extract minerals with great heat or toxic chemicals, and in the act bring to the surface unwanted companion chemicals. All that suggests engineering must be re-thought -- but on what scale? Nanotech is probably too tiny for the fight effects. Instead, consider biomining.

Actually, archaeologists have found that this idea is quite ancient. Romans working the Rio Tinto mine in Spain 2000 years ago noticed fluid runoff of the mine tailings were blue, suggesting dissolved copper salts. Evaporating this in pools gave them copper sheets.

The real work was done by a bacterium, Thiobacillus ferroxidans. It oxidizes copper sulfide, yielding acid and ferric ions, which in turn wash copper out of low grade ores. This process was rediscovered and understood in detail only in this century, with the first patent in 1958. A new smelter can cost a billion dollars. Dumping low quality ore into a sulfuric acid pond lets the microbes chew up the ore, with copper caught downhill in a basin; the sulfuric acid gets recycled. Already a quarter of all copper in the world comes from such bio-processing.

Gold enjoys a similar biological heritage. The latest scheme simply scatters bacteria cultures and fertilizers over open ore heaps, then picks grains out of the runoff. This raises gold recovery rates from 70% to 95%; not much room for improvement. Phosphates for agriculture can be had with a similar, two-bacterium method.

All this, using "natural biotech." Farming began using wild wheat -- a grass. Immunology first started with unselected strams of Penicillium. We've learned much, mostly by trial and error, since then. The next generation of biomining bacteria are already emerging. A major problem with the natural strains is the heat they produce as they oxidize ore, which can get so high that it kills the bacteria.

To fix that, researchers did not go back to scratch in the lab. Instead, they searched deep-sea volcanic vents, and hot springs such as those in Yellowstone National Park. They reasoned that only truly tough bacteria could survive there, and indeed, found some which appear to do the mining job, but can take near-boiling temperatures.

Bacteria also die from heavy metal poisoning, just like us. To make biomining bugs impervious to mercury, arsenic and cadmium requires bioengineering, currently under way. One tries varieties of bugs with differing tolerances, then breeds the best to amplify the trait. This can only take you so far. After that, it may be necessary to splice DNA from one variety into that of another, forcibly wedding across species. But the engineering occurs at the membrane level, not more basically --no nanotech needed.

This is a capsule look at how our expectations about basic processes and industries will alter long before nanotech can come on line. What more speculative leaps can we foresee, that will show biotech's limitations? -- and thus, nanotech's necessity.

Consider cryonics. This freezing of the recently dead, to be repaired and revived when technology allows, is a seasoned science fictional idea, with many advocates in the present laboring to make it happen. Neil R. Jones invented it in an sf story in the 1931 Amazing Stories, inspiring Dr. Robert Ettinger to propose the idea eventually in detail in The Prospect of Immortality in 1964.

It has since been explored in Clifford Simak's Why Call Them Back From Heaven? (1967), Fred Pohl's The Age of the Pussyfoot (1969), and in innumerable space flight stories (such as 2001: A Space Odyssey) which use cryonics for long term storage of the crew. Fred Pohl became a strong advocate of cryonics, even appearing on the Johnny Carson show to discuss it. Robert Heinlein used cryonics as part of a time-traveling plot in The Door Into Summer. Larry Niven coined "corpsicle" to describe such "deanimated" folk. Sterling Blake treated the field as it works today in Chiller. Cryonics is real, right now. About fifty people now lie in liquid nitrogen baths, awaiting resurrection by means which must involve operations below the biotechnical.

Repairing frozen brain cells which have been cross-slashed by shear stresses, in their descent to 77 degrees Absolute, then reheated --well, this is a job nothing in biology has ever dealt with. One must deploy subcellular repair agents to fix freezing damage, and replenish losses from oxygen and nutrient starvation. A solvent for this is tetrafluoromethane -- it stays liquid down to minus 130 degrees Centigrade.

To further repair, one must introduce line-layers, workhorse cells to spool out threads of electrical conductor. These tiny wires could power molecular repair agents -- smart cells, able to break up and sort out ice crystals. Next comes clearing blood vessels, the basic housekeeping, functions which can all be biological in origin.

Then nanotech becomes essential. The electrical power lines could feed a programmed cleanup crew. They would stitch together gross fractures, like good servants dusting a room, clearing out the dendrite debris and membrane leftovers that the big biological scavenger units missed.

Moving molecular furniture around at 130 degrees below freezing will take weeks, months. One has to be sure the "molyreps" -- molecular repair engineers -- do not work too fast, or else they would heat the patient up all on their own, causing further shear damage.

How do they get the damaged stuff back in place, once they'd fixed it? Special units -- little accountants, really -- would have to record where all your molecular furniture was, what kind of condition it was in. They look over the debris, tag it with special identifying molecules, then anchor it to a nearby cell wall. They file that information all away, like a library. As repair continues, you slowly warm up.

These designer molecules must be hordes of microscopic fanatics, born to sniff out flaws and meticulously patch them up. An army that lived for but one purpose, much as art experts could spend a lifetime restoring a Renaissance painting. But the body is a far vaster canvas than all the art humanity had ever produced, a network of complexity almost beyond comprehension.

Yet the body naturally polices itself with just such mobs of molecules, mending the scrapes and insults the rude world inflicted. Biotech simply learns to enlist those tiny throngs. That is true, deep technology --co-opting nature's own evolved mechanisms, guiding them to new purposes. Nanotech goes beyond that, one order of magnitude down in size.

Not necessary to get good circulation in the cells again -- just sluggish is enough. A slow climb to about minus a hundred degrees Centigrade. A third team goes in then, to bond enzymes to cell structures. They read that library the second team had left, and put all furniture back into place.

So goes the Introduction to Molecular Repair For Poets lecture, disguising mere miracles with analogies.

Months pass, fixing the hemorrhaged tissue, mending tom membranes, splicing back together the disrupted cellular connections. Surgeons do this, using tools more than a million times smaller than a scalpel, cutting with chemistry.

Restriction enzymes in bacteria already act like molecular scissors, slicing DNA at extremely specific sites. Nanotech would sharpen this kind of carving, but much of the work could probably be bioengineered, working at larger scales.

With such abilities, surgeons can add serotonin-derived neurotransmitters, from a psychopharmacology far advanced beyond ours. They inhibit the switches in brain chemistry associated with emotional states. A patient reviving may need therapy, cutting off the memories correlated with those emotions that would slow recovery. Such tools imply medicine which can have vast social implications, indeed.

Here is where the future peels away from the foreseeable. Nanotech at this stage will drive qualitative changes in our world, and our world views, which we simply cannot anticipate in any detail. All too easily, it looks like magic.

Suppose the next century is primarily driven by biotech, with nanotech coming along as a handmaiden. Do we have to fear as radical a shift in ideas again, with nanotech?

Biotech looks all-powerful, but remember, evolution is basically a kludge. Organisms are built atop an edifice of earlier adaptations. The long, zigzag evolutionary path often can't take the best, cleanest design route.

Consider our eyes, such marvels. Yet the retina of the vertebrate eye appears to be "installed" backwards. At the back of the retina lie the light-sensitive cells, so that light must pass through intervening nerve circuitry, getting weakened. There is a blind spot where the optic nerve pokes through the optical layer.

Apparently, this was how the vertebrate eye first developed, among creatures who could barely tell darkness from light. Nature built on that. The octopus eye evolved from different origins, and has none of these drawbacks.

Could we do better? A long series of mutations could eventually switch our light-receiving cells to the front, and this would be of some small help. But the cost in rearranging would be paid by the intermediate stages, a tangle which would function more poorly than the original design.

So these halfway steps would be selected out by evolutionary pressure. The rival, patched-up job works fairly well, and nature stops there. It works with what it has. We dreaming vertebrates are makeshift constructions, built by random time without foresight. There is a strange beauty in that, but some cost -- as I learned when my appendix burst, some years ago. We work well enough to get along, not perfectly.

The flip side of biology's deft engineering marvels is its kludgy nature, and its interest in its own preservation. We are part of biology, it is seldom our servant, except incidentally. In the long ran, the biosphere favors no single species.

The differences between nanotech and biotech lie in style. Of course functions can blend as we change scales, but there is a distinction in modes.

Cells get their energy by diffusion of gases and liquids; nanotech must be driven by electrical currents on fixed circuits. Cells contain and moderate with spongy membranes; nanoengines must have specific geometries, with little slack allowed. Natural things grow "organically," with parts adjusting to one another, nanobuilders must stack together identical units, like tinker-toys.

The Natural style vs. the Mechanical style will be the essential battleground of tiny technology. Mechanicals we must design from scratch. Naturals will and have evolved; their talents we get for free. Each will have its uses.

Naturals can make things quickly, easily, including copies of themselves--reproduction. They do this by having what Drexler terms "selective stickiness" -- the matching of complementary patterns when large molecules like proteins collide. If they fit, they stick. Thermal agitation makes them smack into each other many millions of times a second, letting the stickiness work to mate the fight molecules.

Naturals build, and as time goes on, they build better -- through evolution. In Naturals, genes diffuse, meeting each other in myriad combinations. Minor facets of our faces change so much from one person to the next that we can tell all our friends apart at a glance {except for identical twins, like me).

These genes collide in the population, making evolutionary change far more rapid because genes can spread through the species, getting tried out in many combinations. Eventually, some do far better, and spread to everyone in later generations.

This diffusion mechanism makes sexually reproduced Naturals change constantly. Mechanicals -- robots of any size, down to nanotech -- have no need of such; they are designed. There is no point in building into nanomachines the array of special talents needed to make them evolve --in fact, it's a hindrance. It could become a danger, too.

We don't want nanobots which adapt to the random forces of their environment, taking off on some unknown selection vector. We want them to do their job. And only their job.

So nanotech must use the Mechanical virtues: rigid, geometric structures; positional assembly of parts; clear channels of transport for energy, information and materials. Mechanicals should not copy Naturals, especially in aping the ability to evolve.

This simple distinction should lessen many calls of alarm about such invisible, powerful agents. They can't escape into the biosphere and wreck it. Their style and elements are fundamentally alien to our familiar Naturals, born red in tooth and claw.

Nanobots' real problem will be to survive in their working environment, including our bodies. Imagine what your immune system will want to do to an invading band of unsuspecting nanobots, fresh off the farm.

In fact, their first generation will probably have to live in odd chemical soups, energy rich (like, say, hydrogen peroxide or even ozone) and free of Natural predators. Any escaping from their chemical cloister will probably get eaten -- though they might get spat right back out, too, as indigestible.

The "gray goo" problem of nanotech, in which ugly messes consume beautiful flora and fauna, need not occur, precisely because the goo will be gray. It need not have built into it the rugged, hearty defenses which are the down payment for anything which seeks to use sunlight, water and air to propagate itself. Gray goo will get eaten by green goo -maybe by a slime mold, which has four billion years of survival skills and appetite built in.

So nanotech will not be able to exponentially push its numbers, unless we deliberately design it that way, taking great trouble to do so. Accidental runaway is quite unlikely. Malicious nanobots made to bring havoc, though, through special talents -- say, replacing all the carbon in your body with nitrogen -- could be a catastrophe.

When machines begin to design themselves, we approach the problems of Natural-style evolution. Even so, design is not like genetic diffusion. In principle, it is much faster. Think of how fast cars developed in the last century, versus trees.

That problem lies far beyond the simple advent of nanotech. It will come, but only after decades of intense development one or two levels above, in the hotbed of biotech.

What uses we make of machines at the atomic level will depend utterly on the unforeseeable tools we'll have at the molecular level. That is why thinking about nanotech is undoubtedly fun, but perhaps largely futile. Certainly such notions must be constrained by knowing how very much biology can do, and will do, long before we reach that last frontier of the very, very small.

Eater, May 2000

Skylife : Space Habitats in Story and Science (Editor), 2000

The Martian Race, 1999

Deep Time, 1999

Cosm, 1998

Matter's End, 1995

Sailing Bright Eternity, 1995

Furious Gulf, 1994

Chiller, 1992 (as Sterling Blake)

Tides of Light, 1989

Great Sky River, 1987

In Alien Flesh, 1986

A Darker Geometry, with Mark O. Martin

Heart of the Comet, 1986, with David Brin

Artifact, 1985

Across the Sea of Suns, 1984

Against Infinity, 1983

Timescape, 1980
Nebula Award, Campbell Award, Ditmar Award, British SF Award

Shiva Descending, 1980, with Wm. Rotsler

Find the Changeling, 1980, with Gordon Eklund

In the Ocean of Night, 1977

If the Stars are Gods, 1977, with Gordon Eklund
Nebula Award

Jupiter Project, 1975

Deeper Than the Darkness, 1970 (retitled in 1978, The Stars in Shroud)

Deep Time

At its best, science fiction isn't just "fiction about science" -- it is science thinking about itself as a human agenda in the dimension of time. It necessarily speculates, making ranging forays into territories seldom illuminated coherently in our era of intense narrowness.

Any science fiction author hopes he gets the science right enough not to wrinkle the brow of real scientists. I am a professor of physics at the University of California at Irvine, but SF demands a broad knowledge no one can be sure of mastering.

So I hope specialists in the many areas I touch will not find my leaps into the cutting edge of assorted sciences too rough. Wherever possible, I've cemented my intuitions with travel, visits and detailed consultation. I feel that conclusions won from experience have a solidity that armchair ruminations do not.

Outright speculation is not rare in proper science, but it often arrives well disguised. Sometimes it is a short-term claim to a notion awaiting exploration, as when James Watson and Francis Crick laconically noted in the last sentence of their paper reporting the discovery of DNA's double helix that they saw the implications for reproduction: "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."

Our time can benefit from the vistas made possible by science and science fiction alike. When hatred and technology can slaughter millions in months, such terrors deprive life of that quality made scarce and most precious to the modern mind: meaning. SF gives us perspectives, and so redeems this lack, rendering the human prospect again large and portentous. We gain stature alongside the enormities of both space and time.

As a physicist, I've learned that the different branches of science lend their followers an intuitive grasp of long scales. Archeologists sense the rise and fall of civilizations by sifting through debris. They are intimately aware of how past societies mismanaged their surroundings and plunged down the slope of collapse, sometimes with startling speed.

Biologists track the extinction of whole genera and, in the random progressions of evolution, apprehend a sweep of time far greater than the whole of human history. Darwinism invokes cumulative changes that can act quickly on insects, while mammals take millions of decades to alter. Our own evolution has tuned our sense of probabilities to work within a narrow lifetime, blinding us to the slow sway of long biological time. This may well be why the theory of evolution came so recently; it conjures up spans beyond our intuition. On the creative scale of the great, slow and blunt Darwinnowings such as we see in the fossil record, no human monument can endure. But our neophyte species can now bring extinction -- which is forever -- to many others.

In their careers, astronomers discern the grand gyre of worlds. But planning, building, flying and analyzing one mission to the outer solar system commands the better part of a professional life. Future technologies beyond the chemical rocket may change this, but there are vaster spaces beckoning, which can still consume a career. A mission scientist invests the kernel of his most productive life in a single gesture toward the infinite.

Those who study stars blithely discuss stellar lifetimes encompassing billions of years. In measuring the phases of stellar mortality, they employ the many examples, young and old, that hang in the sky. We see suns in snapshot, a tiny sliver of their grand and gravid lives caught in our telescopes. Cosmologists peer at distant reddened galaxies and see them as they were before Earth existed. Observers measure the microwave emission that is relic radiation from the earliest detectable signal of the universe's hot birth. Studying this energetic emergence of all that we can know surely imbues (and perhaps afflicts) astronomers with a perception of how like mayflies we are.

No human enterprise can stand well in the glare of such wild perspectives. Perhaps this is why for some, science comes freighted with coldness, a foreboding implication that we are truly tiny and insignificant on the scale of such eternities. Yet as a species we are young, and promise much. We may come to be true denizens of deep time.

I tried to get at such issues in my novel, Eater. Like the one before it, Cosm, it deals with humanity seen against the huge backdrop of creation itself. In Cosm, a feisty black woman scientist accidentally creates a whole universe. In Eater, we follow astronomers as they confront what could be described as an embodiment of the Old Testament God -- capricious, strange, with a whim of iron.

That's the sort of startling problem I like to give myself in a novel -- something I haven't seen done before, or at least not to my liking. Such dramas make one think of humanity as it truly is -- one very successful species that hasn't really had enough time to prove whether it will truly last.

I find it amusing to think on truly long time scales; it centers the present, between the vast past and the unknowable future.

For example, though our destiny is forever unclear, surely if we persist for another millennium or two, we shall fracture into several species, as our grasp of our own genome tightens. We will dwell on the scale of a hastening evolution, then, seizing natural mechanisms and turning them to our own tasks. In this sense we will emerge as players in the drama of natural selection, as scriptwriters.

Our ancient migrations over Earth's surfaces have shaped us into "races" which cause no end of cultural trouble and yet are trivial outcomes of local selection. Expansion into our solar system would exert selective pressure upon traits we can scarcely imagine now, adaptations to weightlessness, or lesser gravity, or other ranges of pressure or temperature. In this context, we will need long memories of what we have been, to keep a bedrock of certainty about what it means to be human. This is the work of deep time messages, as well.

The larger astronomical scale, too, will beckon us in such a distant era; for well within a millennium we will be able to launch probes to other stars. To ascend the steps of advanced engineering and enter upon the interstellar stage will portend much, introducing human values and perceptions into the theater of suns and solar systems. The essential dilemma of being human -- the contrast between the stellar near-immortalities we see in our night sky and our own all-too-soon, solitary extinctions -- will be even more dramatically the stuff of everyday experience.

This reminds me of a portion of a favorite poem:

Here on the level sand
Between the sea and land,
What shall I build or write
Against the fall of night?
-- A.E. Housman

What changes might such perspectives presage? We could lend furious energies to the pursuit of immortality, or something approximating it. If today we eliminated all disease and degeneration, accidents alone would kill us within about 1,500 years. Knowing this, would people who enjoyed such lifetimes none the less strive for risk-free worlds, to further escape the shadow of time's erosions?

On the scale of millennia, threats and prospects alter vastly. Over a few thousand years, the odds that a large asteroid or comet will strike the Earth, obliterating civilization if not humanity, become considerable.

But if we meet something as truly alien as the Eater Of All Things, all bets are off.

GREGORY BENFORD

Doing Alien

I REMEMBER HOW MITCHELLwas putting the moves on some major league pussy when the news about the aliens came in.

That Mitchell, he stopped in mid-line and cocked his big square head and said kind of whispery, "Double dog damn." Then he went back to the little redhead he had settled onto the stool next to his, way down at the end of the mahogany bar at Nan's.

But I could tell he was distracted. He's the kind of fella always drawn to a touch of weirdness. At Mardi Gras he just loved the confusion, not being able to tell guys from gals, or who was what, the whole thing.

He left with the redhead before ten, which was pretty quick even for Mitchell. When he's headed for the sheets there isn't much can get in Mitchell's way. But he kept glancing over at the Alphas on the TV. Going out, he gave me the old salute and big smile but I could tell he was thinking off somewhere, not keeping his mind and his hands on the redhead. Which wasn't like him.

Mitchell's been my buddy since the earth's crust cooled off. I can read him pretty well. We graduated high school about the time the dinosaurs started up and went into farm equipment sales together when there were still a few nickels to make in that game. I've seen Mitchell bareass in the woods howling around a campfire, watched him pulling in six-foot tuna off the back of McKenzie's old boat, laughed when he was drunk up to his eyeballs with a big brassy broad on each arm and a shit ass happy grin. For sure I know him better than any of his goddamn two ex-wives or his three kids. None of them'd recognize him on the street, pretty near.

So when the Alphas showed up right here in Fairhope I could tell right away that Mitchell took it funny. These Alphas come in slick as you please, special escort in limos and all. They go down to the wharf and look at the big new Civic Center and all, but nobody has a dime's worth of idea what they're here for.

Neither does the escort. Two suits on every Alpha, dark glasses and shoulder-slung pistols and earplug radios and the like. You could see it plain, the way their tight mouths twitched. They dunno from sour owl shit what to expect next.

For sure nobody thought they'd go into Nan's. Just clank on in, look around, babble that babble to each other, plunk down on those chrome stools.

Then they order up. Mitchell and me, we was at the other end of the bar. The Alphas, they are ordering up and putting them down pretty quick. Nobody knows their chemistry but they must like something in gimlets and fireballs and twofers, cause they sure squirt them in quick.

Pretty soon there's a crowd around them. The suits stand stiff as boards, but the locals ooze around them, curious. The Alphas don't pay any attention. Maybe they're used to it or maybe they don't even know people are there unless they need something. Way they act, you could believe that.

But Mitchell, he keeps eyeing them. Tries to talk to them. They don't pay him no never mind. Buys one a drink, even, but the Alpha won't touch it.

I could see it got to him. Not the first day maybe or the second. By the third, though, he was acting funny. Studying them. The Alphas would show up at Nan's, suck in plenty of the sauce, then blow out of town in those limos.

News people around, crowds waiting to see them, the whole goddamn shooting match. Made Fairhope hell to get around in. I was gone three days to Birmingham on a commission job with International Harvester, so I didn't see what stared him on it. I come into town all busted out from chasing tail in Birmingham and first thing you know, phone rings and Mitchell wants help.

"I'm in that beat up shack back of Leroy's TV," he said.

"That place's no biggem a coffin and smells worse."

"They spruced it up since Briggs run that poker game in here."

"So who you pokin there now?"

"Fred, your dick fell off your I.Q. would be zero."

"That happen, what'd I need to think for?"

"Get your dumb ass over here."

So I did. Walk in on Mitchell in a chair, this brunette working on him. First I figured she was from over Bessie's, giving him a manicure with her kit all spread out. Turns out she's a makeup gal from clear over to New Orleans. Works Mardi Gras and like that.

Only she's not making Mitchell up to be a devil or in blackface or anything. This is serious. She's painting shellack all over him. He's already got a crust on him like dried mud in a hog wallow, only it's orange.

"Christ on a crutch," is all I can say.

"Mix me a bourbon and branch." Mitchell's voice came out muffled by all these pink pancake-size wattles on his throat, like some kind of rooster.

So I do. Only he doesn't like it, so he gets up and makes his own. "Got to add a twist sometimes," he says.

Mitchell was always picky about drinks. He used to make coffee for the boys, morning after a big carouse, and it had to be Colombian and ground just so and done up in this tricky filter rig he made himself out of tin sheeting.

That's how he was with this makeup girl, too. She layered on ridges of swarthy gum all down his arms, then shaped it with little whittling tools. She was sweating in that firebox shack. Mitchell was too under all the makeup.

I'm wondering what the hell, and Mitchell says, "Go take a squint, see if they're in Nan's yet."

So I'm catching on. Mitchell's always had something working on the side, see, but he takes his time about letting on. Kind of subtle, too. When Mr. Tang moved into Fairhope with his factory, Mitchell was real respectful and polite and called him Poon for a year before that Tang caught on.

As I go out the shack and down the alley I see why he used that place. I angle across Simpson's parking lot and down by those big air conditioners and pop out on Ivy right next to Nan's. That way, none of the suits can see you coming. Slip in the side door and sure as God's got a beard, there's three Alphas. Got a crowd around them but the room is dead quiet. People just looking and wondering and the aliens drinking.

I'd heard that plenty of fastlane operators were trying to get information out of Alphas, seeing as they got all this technology. We didn't even see them coming, that's how good their stuff is.

First thing anybody knew, they were bellying up to Venus, this other planet out there. Covered in clouds, it was. Then the Alphas start to work on her. First thing you know, you can see those volcanoes and valleys.

Anybody who can clear up muggy air like that inside a week, you got to pay attention. Turned out that was just cleaning off the work bench. Next they spun a kind of magnetic rod, rammed it in at the pole, clean down into the core of the whole damn planet. Easy as sticking an ice pick through an apple. Only the ice pick was hollow and they sucked the liquid metal out of there. Up the rod like it was a straw, and out into space. To make those metal city kind of things, huge and all.

That's when people started getting really afraid. And some others got really interested. The way they figured, any little scrappy thing you got from an Alpha might just be a billion-buck trick.

That's the scoop I heard on CNN coming down from Birmingham, anyway. Now here was the whole circus in Fairhope, big as life and twice as ugly. Snoops with those directional microphones. Cameras in the backs of vans, shooting out through dark windows. Guys in three-piece suits kind of casual slouched against the bar and trying to get an Alpha to notice them.

So back I go. Mitchell is getting some inflated bags stuck on him by the makeup girl. Bags all over his back and chest and neck even. He's all the Alpha colors now, from Georgia clay red here to sky blue there.

"Three of 'em sucking it up in there," I said.

"Holy shit, let's go," Mitchell croaks back at me. The girl had fitted him out with this voicebox thing, made him sound like a frog at the bottom of a rain barrel.

The girl pats him all over with that fine, rusty dust the Alphas are always shedding. She straightens the pouches so you can hardly see that his arms are too short for an Alpha.

"Let's make tracks," Mitchell says, and proceeds to do just that. Alpha tracks, fat and seven-toed.

We go across the parking lot, so the escorts can't see. In a minute we're in Nan's. The other Alphas don't take any notice of Mitchell but all the people do. They move out of the way fast and we parade in, me a little behind so it'll seem like I was just a tourist. Mitchell's got the Alpha shuffle down just right, to my eye.

Bold as brass, he sits down. The suits look at each other, dunno what to do. But they buy it, that Mitchell's one of them.

The Alphas still don't notice him. Bartender asks and Mitchell orders, making a kind of slithery noise.

He slurps down two drinks before anything happens. An Alpha makes a gesture with that nose thing of theirs and Mitchell does too. Then there's some more gesturing and they talk like wet things moving inside a bag.

I sit and listen but I can't make sense out of any of it. Mitchell seems to know what he's doing. He keeps it up for maybe five more minutes. I can see it's wearing on him. He gives me the signal.

I clear some space for him so he can get back up -- that crap he was wearing weighs real considerable. He gets up smooth and shuffles some and then we're out the door. Free and clean. We got back to the shack before we let go with the whooping and hollering.

We pull it off four more times in the next three weeks. Each time the Alphas take more notice of Mitchell. Hard to know what they think of him. The gift comes over from New Orleans and does him up, getting better each time. I keep an ear open for word on the street and it's all good.

Or seems so to me, anyway. Everybody thinks Mitchell's the real thing. Course that's people talking, not Alphas. After the fourth time I couldn't hold back any more. "You got some money angle on this, right?"

"Money?"

"What I want to know is, how you going to get anything out of them?"

"I'm not in for money."

"You figure maybe you can get one of those little tool kits they carry? They don't look hooked on real firm or anything."

Mitchell grinned. "Wouldn't try that, I was you. Fella in Cincinnati went to lift one, came up an arm short."

"Then what the hell you in for?"

Mitchell gave me this funny look. "Cause it's them." I blinked. "So goddamn what?"

"You don't get it, Fred. Thing about aliens is, they're alien." In his eyes there's this look. Like he was seeing something different, something important, something way bigger than Fairhope.

I couldn't make any more sense out of what he said after that. That's when I realized. Mitchell just wanted to be close to them, was all.

That pretty well took the wind out of my sails. I'd figured Mitchell was onto something for sure. I went with him one more time, that's all. And a few days later I heard that the same Alpha was coming back to Nan's every day, just sitting and waiting for more Alphas to come in, and hanging out with them when they did.

It went that way for a while and I was feeling pretty sour about it. I went on a carouse with the Perlotti brothers and had me a pretty fair time. Next morning I was lying in bed with a head that barely fit in the room and in walks Mitchell. "Heard you maybe needed some revivin' from last night."

He was grinning and I was glad to see him even if he did waste a slab of my time. We'd do little things like that for each other sometimes, bring a fells a drink or a hundred dollar bill when he was down and could sure use it. So I crawled up out of bed and pulled on some jeans and went into the kitchen.

Mitchell was filling a pot and popping open one of his Colombian coffee packs. I got some cups and we watched the water boil without saying anything. That's when it happened.

Mitchell was fooling with the coffee and I was still pretty bleary-eyed, so I'm not sure just exactly what I saw. Mitchell was stirring the coffee and he turned to me. "Ummm. Smell those enzymes."

He said it perfectly natural and I wouldn't have taken much notice of the funny word. I looked it up later at the library and it's a chemical term, I forget what it means. Mitchell would never have said something like that. And I wouldn't have given it any mind, except that just then his arm stuck a little farther out of the denim work shirt he had on. He has big arms and thick wrists. As the shirt slid up I saw the skin and curly hair and then something else.

At first I thought it was leather. Then it seemed like cloth, real old fabric, wrinkled and coarse. Mitchell turned further and looked at me and that's when I heard the sound of him moving. It was like dry leaves rustling. Old and blowing in a wind. In the next second I caught a whiff of it and the worse smell I ever knew came swarming up into my head and I finally really saw what the thing next to me was.

I don't want to describe that. It sent me banging back against the plywood wall of the kitchen and then out the door. The smell stayed with me somehow even in the open. I was off into the pines way back of my place before I knew it.

I had the shakes for hours. Made myself circle around for three miles. Got to my sister's place. Didn't tell her anything about it but I think she might of guessed. I was pale and woozy.

I got my truck and went off to Pensacola for a week. There was maybe some work there but it didn't pan out and I hadn't gone for that anyway.

I didn't go back into my place for another week. And I was real careful when I did.

It was all picked up, neat as you please. Not a sign. Mitchell was a fine man but he would never have done that.

I stood in the kitchen and tried to work out what had happened, how it had been. Couldn't. There was that one second when I saw straight into whatever was there and being Mitchell, and that was all.

He had tried to blend in with them. And I'd helped him. So in some way maybe this was the reverse. Or a pay back, kind of. Or maybe a signal or something. No way to tell.

Only, you know what I think? I figure there isn't any Mitchell anymore. There's something else.

Now, could be there's still some Mitchell in there, only he can't get out. Or maybe that thing's Alpha for sure. I guess it could be something in between. Only thing I know is, it isn't anything I ever want to know.

Maybe it's something I can't know. Thing about aliens is, they're alien.

They say that one Alpha still hangs out at Nan's. I haven't been to check. I don't even walk down that part of town anymore.

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This program unites theoretical studies with a parallel experimental program in radiation processes of relativistic electron streams in plasma. Experiments use intense relativistic beams (10 kAmp, 700 keV) propagating in helium plasma. Microwave and atomic spectral (Stark shift) diagnostics measure emission and the underlying turbulent fields. The group also studies the practical methods of high-power microwave emission. Turbulence levels are high, with electric field energy densities comparable with the total thermal energy of the background plasma. Such strong fields demand new theory and sophisticated diagnostics, with fast time resolution (less than ten nanoseconds). This is a new regime -- "superstrong" turbulence -- with statistical properties just being explored.

These experiments and coupled theory apply to galactic jets, quasars, and pulsars. Emission by scattering of energetic electrons from plasma turbulence (which the beams themselves produce) can be much more powerful that the familiar single-particle processes such as synchrotron radiation. The extreme variability of quasars recently discovered in radio and optics may arise from such processes. Calculations of expected power and spectra imply that quasars could be powered by flows with less total energy than formerly expected. Much work needs to be done in relating these new, collective radiation mechanisms with both astrophysical and laboratory observations.

Teaching areas include general properties of strong turbulence and radiation, both in experiment and theory. Astrophysical applications of these fundamental areas are also of interest, such as the brilliant radio features (arcs, filaments, threads) recently found at our own galactic center, and their possible links with hypothesized black holes there.

Representative Publications

Coherent Radiation from Energetic Electron Streams via Collisionless Bremmstrahlung in Electrical Plasma Turbulence, (with J. C. Weatherall), Astrophys. J. 378, 543 (1991).

Collective Emission from Rapidly Variable Quasars, Astrophys. J. 391, L59 (1992).

Electron Beam Radiation by Collective Compton Boosting of Strong Turbulence, (with J.C. Weatherall), Phys. Fluids B 4 (12) 4111 (1992).

Collective Radiation from Jets, Proceedings of the 7th IAP Astrophys. Meeting, Extragalactic Radio Sources from Beams to Jets, Paris, July 2-5 (1991).

Statistics of Strongly Turbulent Electric Fields, (with X.-L. Zhai), Phys. Fluids B 5 (6) 1914 (1993).

GREGORY BENFORD

HUMANITY AS CANCER

" . . . still I have not seen the fabulous city on the Pacific shore. Perhaps I never will. There's something in the prospect southwest from Barstow which makes one hesitate. Although recently, driving my own truck, I did succeed in penetrating as far as San Bernardino. But was hurled back by what appeared to be clouds of mustard gas rolling in from the west on a very broad front. Thus failed again. It may be however that Los Angeles will come to me. Will come to all of us, as it must (they say) to all men."

Edward Abbey Desert Solitaire

In 1960 the journal Science published a short paper which is still sending slow-motion shock waves through the soothsayers of our time. Titled "Doomsday: Friday, 13 November, A.D. 2026," its abstract reads in full, "At this date human population will approach infinity if it grows as it has grown in the last two millennia."

Period. Its authors, Heinz van Foerster, Patricia Mora and Lawrence Amiot, were members of the staff of the department of electrical engineering at the University of Illinois, Urbana. They were not population experts, but they noted a simple oddity of mathematics. The rise in human numbers was always studied in "doubling times," the measure of how quickly population doubled. But real human numbers don't follow so clean an equation.

For a species expanding with no natural limitation aside from ordinary deaths, the rate of increase of population is proportional to the population itself. Mathematically, the population N is described by an equation in which the change in N, dN, over a change in time t, dt, obeys $dN/dt = b N$

with b usually assumed to be a constant. If b is truly constant, then N will rise exponentially.

Fair enough. But if people are clever, the proportionality factor b itself will weakly increase as we learn to survive better. This means the rate of increase will rise with the population, so N increases faster than an exponential.

In fact, it can run away to infinity in a finite time. The equation describing this is a bit more complicated. To find how b changed with N, the authors simply looked at the average increase over the last two thousand years, to iron out bumps and dips, seeking the long-term behavior.

They found a chilling result. Our recent climb in N in the last few centuries is not an anomaly; instead, it fits the smooth curve of human numbers. Tracking the solution backward "post-diets" that we were a mere 9.00,000 people a million years ago. Of course such great spans aren't well fit by population counts gathered from two millennia, and the equation becomes silly. But it should be good for at least a few centuries more.

Looking into the near future, it predicts a chilling result: a singularity, with N rising faster and faster,going beyond view on Nov. 13, 2026. "The clever population annihilates itself," they remark laconically. "Our great-great-grandchildren will not starve to death. They will be squeezed to death."

The paper has never been refuted. Further checks on the growth of the factor b have pushed the singularity date further away, to about 2049. This is comforting, moving the date by about twenty years in the thirty-four years since the paper appeared.

But the general conclusion stands. As an exercise in statistics it is stimulating, and as far as I know the authors did little with it after their first telling point.

Of course, nothing grows to the sky. Something will happen before b gets too large; the four horsemen of the apocalypse will ride again. Perhaps they already are. Still, we are not doormats. We are attempting population control, but results are slow, and pressures are mounting.

I wrote before in this column about the ideas which follow, in a piece titled "The Biological Century." I'd like to revisit an idea I floated there, with some second thoughts.

The future is coming, and it's ugly.

Or so many believe. From staid university presidents and scruffy environmentalists alike, a growing consensus holds that humanity has entered a watershed era, a time of vast disasters looming large, just over the horizon of this generation. Their case rests on far more than an equation, too.

In 1992 1 went on a cross-country hike in Orange County to protest a highway soon to go in. Puffing up a hill, I struck up a conversation with a member of the eco-warrior group Earth First, who wore the signature red shirt with a clenched fist. We mounted a ridge and saw the gray sweep of concrete that lapped against the hills below.

"Looks like a sea of shit," the Earth Firster said. "Or a disease."

That same month the National Academy of Sciences and Britain's Royal Society jointly warned of the dangerous links between population and environmental damage. Following this up, the Union of Concerned Scientists mustered 1500 experts to sign a "World Scientists' Warning to Humanity" and published it in leading newspapers. Heavy hitters, these, including the predictable (Linus Pauling, Paul Ehrlich, Carl Sagan), the inexpert but sanctified (Desmond Tutu], but also the heads of many scientific societies, Nobel Laureates, and authorities of many fields. One such Laureate, Henry Kendall of M.I.T., is leading the New Cassandras in a campaign to muse the intelligentsia.

His case is easy to make. World population grows by 90 million yearly and will double within half a century, maybe less. More people have been born in the last forty years than in the previous three million years. About 8 percent of all human beings ever born live today. We are gaining at about 1.7 percent a year.

Meanwhile, the Green Revolution is apparently over: world per-capita crops have declined. About ten percent of the Earth's agricultural land area has been damaged by humans. Water may be the first major resource to go; half of all nations now have water shortages. Even in the American midwest and southwest, farmers are sucking "fossil water" laid down in the ice ages, pulling it from aquifers which will deplete within a generation.

But such policy-wonk numbers, the ecologists remind us, are too human-centered. Our swelling numbers have their greatest impact on defenseless species in rain forests, savannahs and coral reefs. Biologist E.O. Wilson of Harvard warns that we could lose thirty percent of all species within half a century, and that might be only the beginning.

Humans exert selective pressures on the biological world. North Atlantic waters show a clear pattern of over-fishing, and ever-shrewd nature has filled these new niches with "trash fish" like skates and spiny dogfish which we cannot eat and thus do not take out.

Monoculture crops worldwide gain efficiency by growing the same staple-wheat, rice, corn, trees-over a large area, but this is inherently more fragile. Diseases and predators prey easily and already erosion is a major threat in many such areas.

Environmental damage grows not merely because our numbers rise, but because our expectations do, too. The masses jammed into Buenos Aires want a better life -- which means more consumer goods. The chain between such ambitions and the clearing of distant forests is, though long, quite clear.

Most environmentalists are technophobic, reluctant to admit that the greatest enemy of the rain forests is not Dow Chemical but rather sunburned, ambitious men newly armed with chain saws, eager to better their lot in life.

Still, hand-wringing is not new and skepticism about it is well earned. Paul Ehrlich's alarmist "The Population Bomb" has yet to explode, twenty-five years after publication, though some demographers feel that Ehrlich may simply be a few decades off.

And there are counter-trends. Many are laboring to see that the factor b does not increase.

The "developing world" -- to use the latest evasive tag attempting to cover societies as diverse as Singapore and Somalia-- is the great engine of population growth, but its pattern is not an exponential runaway. Taken all together, the poorer nations' growth rates seem to have reached a plateau.

This may echo the industrial world, whose net growth curve broadly peaked around 1900 at a rate of about one percent a year, and is now a fourth of that. The poor countries may have entered just such a transition era. Some nations began peaking in the 1970s and others join them. Still, the plateau average rate is 2.5 percent per year, so they have a long way to fall.

Will they decline? Environmentalists and professors alike fear they won't.

Our numbers respond to both feedback loops and to feed-forward anticipations. Gloom, doom- well known intellectual commodities, finding a perpetual market. The 1960 paper is still the firmest basis for hand-wringing. Few experts believe the planet can sustain a population doubling in parallel with rising economic desires. This is how the Earth Firsters merge with the academics -- a profoundly pessimistic view of our collective future, shared from the hushed halls of Harvard to the jerky hip-hop images of MTV.

This sea change we already see in severe cultural collision, such as immigration. MIT's Kendall predicts a doubling of Mexico's immigration into the USA within a decade. Shantytowns along the USA southwestern border recall the slums of Rio. Last year the USA added 970,000 new legal immigrants, plus 132,000 refugees and the INS estimates that slightly over a million illegal immigrants came to stay. Our growth rate is nearly at one percent per year. Since our native population is near the Zero Population Growth level so publicized in the 1970s, this means immigration is virtually the sole cause of US growth, and places us far ahead of other industrial nations.

Immigration-driven cultural strife is growing both here and in Europe. Anti-immigration forces typically fix myopically upon their local rise, Kendall says, but the only true solution must be global. "Until masses of people stop wanting to emigrate, you still have a basic problem." He is careful to shy away from the immigration issue, pitching his cool Cassandra tone to a lofty moral plane. His arguments seem far from the fever-eyed cries of the eco-warriors.

But Garrett Hardin, emeritus professor from UC Santa Barbara and Kendall ally, argues for an America-saving cut in immigration. Target: eventually, less than 200 million Americans, since this is the sustainable level. "Sustainable" is the consensus watchword, including some unsettling ideas.

To me the most significant one is Hardin's opposition to sending food aid to overpopulated areas such as Somalia. "Every time we send food to save lives in the present, we are destroying lives in the future." He invokes a cycle now well known-- aid fuels birth rates, then leads to famine within a generation. Human "die-backs" are now a routine feature of worldwide news, with "compassion fatigue" already evident in the media.

Robert Malthus, the original population prophet, thought that civilization would hit the wall in the late nineteenth century. Economists like Julian Simon of the University of Maryland dismiss the doomsayers, noting that they've been around since the Bible. "The only difference is that Ezekiel and Jeremiah were much better writers."

Simon and others marshal powerful counter-arguments, though they are seldom heard among the intelligensia. They remind us that mass human starvation in the modern world results mainly from outmoded political systems or war or both. Somalis is not overpopulated, as Hardin claims--it is the victim of obsolete African clan patriarchies trying to run bigger groups than their systems ever envisioned. In this view, starvation arises from human stupidity, most of it political stupidity. Only education, particularly science education, can help that. As for war, the major preventative is democracy -- there hasn't been a war between democracies for more than a century. Democratization of the world proceeds apace, driven by UN sanctions and TV advertising alike.

They feel we have a long way to go before we hit the Malthus wall. Water might prove to be the limiting factor. Flying over the Western U.S., it's almost entirely empty, as are a lot of other places on the planet with good climate.

That changes if you have power for desalination. For the $100 billion we've spent on the drug war, plus $10 billion a year we continue to spend, we could have gone a long way toward working fusion. Or we could have developed thorium breeder fission, and maybe less exotic, cheap solar cells, if fusion turned out to have unexpected difficulties. For a small fraction of our defense budget we could still do something radical in the way of power generation, before the Ogalala aquifer runs dry in a generation or two and the bread basket becomes a dust bowl.

Uplifting the bulk of humanity can suppress population growth, if well managed. It can either top out at comfortable levels, or "everywhere is Los Angeles" levels, as in the Edward Abbey quotation I opened with. It's our choice. Refusing the third world food helps not at all, and even hurts {they grow slowly anyway from information trickle}. Giving them food without technology doesn't help either, and may even be worse.

Changing social attitudes is slow work. Much of the Catholic third world is stuck in a high growth pattern. The major problem is not religion, though. Anglo Catholics in the USA have the same fecundity as Protestants and there is no reason to think this would not also eventually turn true South of the border. Industrialization and mechanized farming are the key ideas, since children are an economic asset rather than a liability only in low tech agrarian economies. Luddites can't solve the population problem.

So solutions are available, if we wise up. But voices saying this are seldom heard. Simon and his allies are in a tiny minority. The overwhelming majority of thinkers, whether economists or biologists, see disaster ahead. That 1960 paper casts a long shadow.

I suspect there is more here than a Malthusian malaise. While there are ever more mouths, there is also possible global damage unimagined by Malthus, a far more muscular feedback effect. These could tilt the entire biosphere against many species, including us. A biologist recently remarked to me, "We've just run out of new niches. So the whole system will do a little feedback stabilizing." The vast, numbing menu of looming potential disasters -- lessening fish stocks, water, topsoil; dwindling rain forests; growing ozone holes; dying species; global warming; deepening poverty; spreading pollution -- makes the New Cassandras different.

They bring a message already deeply enshrined in the hardcore environmentalist movement, one the media have preached for decades. The issue is not the dry debate between the Simons and the Kendalls, but the sea change in moral attitudes that underlies the talk, whether it is over immigration or owls-versus-jobs.

To see the future, look to the fringes. The environmentalists are a powerful lobby, but they also have a wing which will, if you get in their way, spike your tree, slip sand into your backhoe's gas tank, or sink your tuna boat.

Initially their rules -- as laid down by crusty Edward Abbey in the novel which inspired Earth First, The Monkey Wrench Gang-- were two. First, honor all life and do not hurt anyone. But Earth Firsters have strayed far from this role, preparing traps for desert bikers and loggers which could have killed-- but didn't because of the vigilance of their opponents, not themselves.

Neither have they met their second rule: Don't get caught. Many are willing to break the law and pay the price. The Arizona Five, who tried to cut an electrical tower, got nabbed by an FBI undercover agent.

Do the crime, do the time -- a principled stance, but how far can it go? Are there crimes we cannot accept?

There are hundreds of monkey-wrenchers in lesser camps such as the Animal Liberation Front, the Hunt Saboteurs who disrupt big-game sport, Albion Nation, and assorted Deep Ecologists.

These are not policy people with whom libertarians can reach gentlemanly agreement about, say, junking federal timber subsidies. They all practice varying degrees of "ecotage" which estimates place at about $25 million a year in the US. I have met eco-warriors who are completely unaffiliated, though, some quite well educated and no less determined.

Back on that Orange County ridgeline, gazing out over miles of dusky, besmogged concrete, the Earth Firster said something that genuinely frightened me. Not because it was a specific threat, but because it connected with my own academic world.

"Y'know, we're a cancer. And somebody's going to find a cure."

Already we are numbed by TV images of diebacks -- the sudden, catastrophic collapse of whole life support structures on a regional level, the Four Horsemen writ large. I believe, though, that two social forces will bring even more dire events in the next century.

Consider: our globe has a technological North with many accomplished bioengineers. Given our desire to extend our own lifespans, much research will go into an intricate fathoming of the human immune system, to fixing our cardiovascular plumbing, to forestall aging and the like. That is the first important and plausible point.

On the other hand, the North will increasingly be appalled with the South's runaway growth. Many poor nations will double in numbers within thirty years.

Think of watching it on high-definition TV. Megacities will sprawl, teeming with seedy, corrupt masses. Sao Paulo at 34 million, second only to pristine Tokyo. Lagos, Nigeria, which nobody ever considers, may top 17 million, despite the multitudes lost to AIDS. Kindergarten-age children digging through cow dung, looking for corn kernels the cows hadn't digested. Colorful chaos laced with dusky despair. Gangs of urchin thieves who don't know their own last names. Gutters as sewers. Families living in cardboard boxes. Babies found discarded in trash heaps.

Torrents of illegal immigration will pour over borders. Responding to deprivation, crazed politico/religious movements will froth and foment, few of them appetizing as seen from a Northern distance.

The more the North thinks of humanity as a malignancy, the more we will unconsciously long for disasters. This is the second, all-too-plausible point.

Somewhere, sometime, someone may see in these two points a massive, historically unique problem and a quite simple solution: the Designer Plague.

An airborne form of, say, a super-influenza. The Flu From Hell, carried on a cough, with a several-week incubation period, so the plague path will be hard to follow. Maybe fine-tuned, too, carrying a specific trait that confines it to tropical climes, like malaria.

We in the comfy North forget that for the bulk of humanity, diseases are kept at bay by a thin modernity in medicine, well water and clean food. Yet across this globe a swift vital traffic flows. Influenza A, which brings teary, aching fever to a hundred million of us yearly, is an old enemy, endlessly vigorous. It would make a handy weapon.

Viruses are ancient oddities. We have now mapped the RNA core of Influenza A and its surface proteins -- tiny spikes that prod the human immune system into forming cloaking antibodies. This virus can mutate, rearranging the molecular code that shapes the spike-tip proteins. Then the new virus can dodge around our bodies' immune response, feasting on us until our blood streams conjure up a fresh antibody defense.

There is a curiosity in modern immunology, though. Antibody records of elderly patients' blood show that since 1890 all influenza epidemics have been wrought by only a few of the possible subtypes of the virus particles. Minor changes have kept the damage minimal.

Nobody knows why this is so. Influenza resides in our domesticated friends -- turkeys, pigs, fish, chickens. We have tracked flus that breed in both birds and pigs, and new strains that attack humans have come from both; the Ford administration's alarm over Swine Flu was not hysterical.

It spreads by air not through Boeing, but through ducks and sea gulls. Only the pandemic of 1918-19, misnamed "Spanish" though it came from southern China, was powerful, killing as many of us as any single war has ever done.

Influenza's potency derives from its primitive nature. Its vital RNA lacks the proofreading and editing skills which longer, more stable genomes such as ours have developed. So it is easily manipulated, and luckily the changes have been mild of late. Somehow, in the breeding ponds of Asia where farmers tend their paddy rice, only minor variants have appeared.

But in the laboratory, drastic tailoring is easier than ever before -and will get easier still. Big shifts in the influenza pattern, a new mix of genes, could bring greater infectivity and startlingly high virulence. Already, one carrier on an airplane, or (in army experiments) one sick person just walking through a tent can infect many. The big advances could lie in virulence. There are newly "emergent" viruses like Ebola that can kill up to two out of every three victims, suggesting that influenza could be brought up to this level as well.

A mass plague does not necessarily demand high tech, either. Making a custom flu strain is very difficult now (unless tinkering turns one up by accident), because we do not know yet what makes strains virulent. Instead, our old enemy smallpox could fill in. Since it was eradicated in the mid-1970's, few people have been vaccinated. By now most of the world is susceptible again. Smallpox is kept locked away in two heavily guarded sites in the world, and the medical community continues to debate whether those two samples should be destroyed. {One counter-argument holds that, after all, smallpox is a species, and we should conserve species. I am not making this up.)

But smallpox is imprisoned only in one sense. Its genome is published in the open literature, though, so in another sense it's everywhere. Like all life, smallpox is at root information. A biological virus in this sense is exactly like a computer virus. All smallpox needs to make its way out of virtual reality is for a savvy scientist to translate.

I asked a friend to imagine how he would do this. With barely a moment's hesitation he rattled off, "Well, first you turn on a standard gene synthesizer. You use the published genome sequences to run some fragments of its DNA genome out. Keep it in manageable fragments, so you can then splice them. You put the naked genome into a cell which has been infected by a related pox virus, see? That supplies the needed vital enzymes. After that you get complete viruses, which you can amplify in cell culture. Dead easy. Then you're off -- just spread it around. Hozzat for scary?"

With modified proteins, airborne particles can turn ten or even a hundred times more deadly. And in the next few decades, myriad biotech workers will know how to alter vital information.

How many will belong to the Animal Liberation Front? It won't take many. Friends of mine who work on disease control estimate that with a bit of luck a new strain of influenza could be developed by a single researcher, using a room of equipment. And there are such isolated specialists: in the 1950s the Soviets experimented with the Spanish Flu and it got out, killing thousands -- a fact they successfully suppressed for decades.

How many would it take to spread such a designer plague? Dozens would suffice.

Think of their rationalizations. Humanity as cancer. The Deep Ecology Credo: all life is equally sacred.

Look at the big picture. Why not save millions of species a year by trimming the numbers of a mere single species?

And consider simple human misery. The aftermath of the Black Plague was a burst of prosperity, as the living inherited the wealth of the dead. Suddenly there were more crop-lands per person, more homes and horses and even hats. Enough, an Earth Firster gone wrong might argue, to get the battered South back on its economic feet. A blessing, really.

And they would do their time for doing the crime, to be sure. The essential point here is that theirs would be a moral argument proceeding from a wildly different premise: all life is equal.

Would anyone be mad enough to kill billions, hoping to stave off the ecological and cultural collapse of nations, of continents, of whole societies? It seems despicable, mad-and quite plausible, to me. Speculations along these lines have already been voiced by molecular biologists.

Such dark possibilities come with any major advance in human capabilities. Only by anticipating them, as H.G. Wells foresaw atomic war, can we do the thinking and imagining that might prevent them.

Containing such threats only superficially resembles the nuclear proliferation problem. The first response to such a threat will probably be more state policing. But plutonium is scarce, so the plutonium pipeline is easily policed. The flu is everywhere, and so are genetic laboratories. There will never be enough cops.

Outside regulation will be nearly helpless. The very power of medical biotechnology lies in its ease of self-reproduction. A small conspiracy could develop Influenza A into a new, virulent form, test it on animal populations, and then spread it with already immunized carriers.

For immunization would go hand in hand with the very bioengineering that made SuperFlu. If one knows the map, one can chart a path through the obstacles. It is technically simple to develop a vaccine alongside the SuperFlu, and even design it so that the carriers could be safe from the effects.

Further shrewd games suggest themselves. With a vaccine in hand, the North could speedily immunize its population. Still, medical resources would be strained even in the North, the public outcry deafening. Inoculating in the South would be far more difficult, from slow transport, inevitable corruption and the sheer numbers of the afflicted.

So even if the plotters were caught early on in the spreading of the designer plague, the North would face a vexing moral chasm. Exert themselves to save many in the South, or be sure all their own populations were safe first?

And other, quieter voices would say, wait a minute. Sure, the fanatics were wrong, evil-- but if this disease runs its course, it will solve a lot of problems . . .

Standard bureaucratic regulation cannot contain this potential, quite original evil. The probable sources are small and diffused.

What could stop the SuperFlu? At a minimum, we should deplore the superheated rhetoric of humanity-as-cancer. Behind such headline-grabbing oversimplifications lurk some obnoxious assumptions and poor reasoning.

Far more effectively, we can reaffirm basic humanist values. Not all life is equivalent. While other species of course have an essential place, we cannot evade the fact that we are now the stewards of their world.

This means that the figures likely to resort to mass murder through biotechnology must be reached. Modem America stresses narrowly trained specialists, not broad education. We should fear the politicized experts. If they remain outsiders, their demands ignored, they will become steadily more dangerous.

There is a further constellation of arguments which might reach the ecowarriors, given time. Experience shows that populations stabilize when technology, women's education, and childhood life expectancy rise above a critical level. But on the way to this point lies a disaster zone: technology improves life expectancy and fuels a population boom, which then exacts a terrible toll from the environment.

To get the third world through the danger zone demands that they not follow our path to industrialization. Going through the "gray" technology of the nineteenth century would indeed yield mass pollution and gobble up resources. What the developing world needs is not giant dams, but cheap solar power collectors. Not steelworks, but composite material assembly sheds, weaving renewable organic resources into hard, light products. They need our future, not our past.

Lewis Thomas points out that it's this way in medicine. Low tech medicine is cheap--people get polio [say) or Salmonella, and die. Medium tech is nasty and expensive -- iron lungs and keeping people alive when there is no good treatment for a disease is costly. Really high tech medicine, vaccine and antibiotics, is relatively cheap again, and everyone lives. The same thing happens with technology in developing countries -- it has to be all or nothing. In between is the killer.

This suggests that techno-savvy development should probably be concentrated massively on small areas, to get them to a "post-industrial" level. This will avoid spreading investment thinly and falling short of the critical point. Such small, intensive cases will be experiments, yielding different schemes, seeing what works. If even the Earth Firsters can come to see that development need not mean deforestation and the Glen Canyon Dam, a new direction in resolute ecovirtue could open.

For the moment they are mere cranks, oddities, wild-eyed nobodies on their rickety soapboxes. But their numbers rise. Their actions gather allies. Their anger soars. We must defuse that anger with actions of our own.

The zealot who could design a SuperFlu might well come from citadels of high moral purpose, too. Many Deep Ecologists spring from our universities. They have surplus cash and need a cause larger than themselves. Their moral fervor runs parallel with high education and not a little dedication. After all, the most notorious mass murderer of our century came from the culture of Mozart and Goethe, favored animal rights, and was a fastidious vegetarian.

GREGORY BENFORD

LIFE AT GALACTIC CENTER

We're not in a lucky part of the galaxy, at least for views.

Our sun is tucked down in the disk's plane, though this took centuries to realize. In retrospect, perhaps it is puzzling that astronomers did not guess until the nineteenth century that the Milky Way is a disk, seen edge on.

Ancients used water analogies to describe it, images of rivers and streams. How much easier matters might have been if we could have seen the truly gaudy attraction in all the galaxy, the brilliant center.

Perhaps, thought, our ignorance is good luck. Dark dust clouds block our view in the constellation Sagittarius, so we cannot see in the optical frequencies beyond the edge of our local spiral arm. Beyond that are immense dark lanes, blotting out the next arm and the hub beyond.

One way to see the center would be to live much nearer. But that could be fatal.

The galactic center is about 25,000 light years away. We orbit about two thirds of the way out into the spiral disk, a benign, even boring neighborhood. The nearest star, Alpha Centauri, is 4.2 light years away, an average stellar separation for our region, where there is a star in roughly every fifty cubic light years.

Were we to approach the galactic hub, well past the dust clouds, we would find a halo of stars glowing brightly, growing ever denser. In 1932 Carl Jansky discovered that, to his shock, the galactic center was the brightest radio location in the sky, outshining even our sun. Something was going on.

In the core, within a few light years of the exact center, there are a million stars within a single light year. On average, the nearer stars are only a hundredth of a light year away. This is only ten thousand times the distance from the Earth to the sun. Imagine having several stars so close they outshine the moon.

As one might expect, this is bad news for solar systems around such stars. Close collisions between all these stars occur in about a hundred thousand years, scrambling up planetary orbits, raining down comets upon them as well.

The galactic center is the conspicuous Times Square of the galaxy -- and far more deadly than the comfortable suburbs like ours. Joel Davis's Journey to the Center of Our Galaxy details how horrific it is, points out that the survival time for an unshielded human within even a hundred light years of the core is probably hours.

I began studying the galactic center in the mid-1970s, out of curiosity. I did not guess that this mysterious region would intertwine two of my passions, physics and science fiction, though in part I was interested because I had begun writing a series of novels which seemed pointed in that direction.

The first was In the Ocean of Night, exploring the discovery that computer-based life seemed dominant throughout the galaxy. The action followed a British astronaut, Nigel Walmsley, cranky and opinionated. It detailed a few incidents in our solar system, in the late twentieth century and beyond, which uncovered the implication that "evolved adding machines," as Walmsley put it, had inherited the rains of earlier, naturally derived alien societies.

As I began work on the next volume, I realized that the galactic center was the obvious place for machines to seek. By the early 1980s we knew that there is a virulent gamma ray flux there, hot clouds, and enormously energetic processes. Most of this we gathered from the radio emissions, which penetrate dust clouds and revealed the crackling activity at the center for the first time. Infrared astronomy soon caught up, unmasking the hot, tangled regions.

By the time I finished Across the Sea of Suns, I realized that I could do some research myself on the galactic center. I had by that time written papers on pulsars and galactic jets, and had both expertise and curiosity. Our galaxy is a barred spiral, meaning that a straight segment runs through the center, connecting two bright spiral arms. The inner thousand light years is a turbulent zone of high velocity clouds, moving so fast that gravitation finds it difficult to force them to collapse into stars. Magnetic fields are also strong, making collapse still harder. Few new stars, so few later supernova explosions.

In the 1960s my friend Larry Niven had begun his Known Space stories, featuring a colossal explosion at galactic center, perhaps a chain reaction of supernovas. There was some evidence of greatly energetic processes there, but we know now that there was no such mammoth explosion, big enough to make alien races flee. However, within the inner hundred light years, there does seem to have been a great energy release a few million years ago. In the infrared we can see the outrushing gases.

More striking, though, are mysterious features appearing in the radio. In 1984 I was giving a talk on galactic jets at UC Los Angeles, and my host was Mark Morris, a radio astronomer. "Explain this," he challenged, slapping down a radio map he had just made at the Very Large Array in New Mexico.

"Good grief," was my first reaction. "Is this a joke?"

It showed a feature I called the Claw, but which Mark more learnedly termed the Arch: a bright, curved prominence made up of slender fibers. Though the Arch is over a hundred light years long these fibers are about a light year wide.

They curve upward from the galactic plane, like arcs of great circles which center near the galactic core, which is several hundred light years away. These intricate filaments shine by energetic (in fact, relativistic) electrons, radiating in strong magnetic fields, which are aligned along the filaments.

There was nothing remotely like them in astronomy. What process could make long, slightly curved paths, a light year wide?

I undertook the challenge, with some hesitation. The object was bizarre, which meant some new ideas were needed. I was aided by later discoveries in 1985, which spotted separate filaments within a few hundred light years of the core, single threads shining brightly. Above the Arch, some Japanese astronomers found what looks like a weak, fat jet.

How to explain thin filaments which glow by electron luminosity, a hundred times longer than they were wide? I thought of neon lights, which are glow discharges sustained by electric currents in slender tubes. What could contain the hot gas, or electrons? The magnetic fields, which mid-1980s measurements found to be at least a hundred times stronger than typical in the rest of the galaxy.

Astronomers began thinking of conceptual models for the phenomenon, mostly using magnetic loops which had been somehow expelled from the galactic center, and were striking distant gas clouds. These I didn't much believe; the Arch was too orderly. Others thought maybe the filaments were cosmic strings -immense fractures in space-time, made in the early universe -- lit up by their passage through the galactic inner regions. This model was disproved quickly, because strings should move at very nearly the speed of light; the Arch didn't.

By the time I got through with my calculations, building a mathematical model, I had decided that the entire network of Arch and threads might be a huge circuit. It had to be powered by some battery, and while most people thought the galactic center was the logical site, I kept noticing that it was hundreds of light years away. Instead, I studied the giant molecular clouds which were moving counter to the general galactic rotation. These were quite odd, dark and carrying millions of stellar masses of dust and gas in clumps light years wide.

I found that if they were even slightly ionized -- and how could they not be, with so much ultraviolet glare from nearby blue stars? -- these clouds would generate electric fields as they crossed the strong magnetic fields. The edges of these clouds could then act as batteries, applying voltages which accelerated electrons, sending them shooting along the magnetic field lines, lighting up the magnetic structures that already existed.

Since these discharges occurred because of momentary passage of clouds, they were essentially like weather -- changeable. Perhaps we could see some bright filaments weaken, others flare? I calculated the times required, and found that the best we could expect was a change within a decade or so, or longer.

Since these were circuits, they reminded me of lightning. Clouds on Earth discharge to ground along slightly ionized trails in the air. The stroke time is about a second, just a bit shorter than the time the lightning takes to begin snaking about itself, like a garden hose -- or the twisting snapping sparks from generators, a cliche overworked in films like Frankenstein.

Could these fibers be a sort of slow-motion lightning, taking perhaps hundreds of thousands of years to discharge? Then we might see filaments curling about themselves, or each other?

I asked these questions, sketched out solutions, and made a few predictions. In science any model, to win flavor, must paint an appealing picture and predict the outcome of future observations. I published the model in the Astrophysical Journal in 1988, "An Electrodynamic Model of the Galactic Center."

People seemed to find it plausible, if a bit strange. Electrodynamics isn't used much in astronomy, where gravity rules. I waited to see what observations would unmask.

Mark Morris kept making maps of the Arch region, but so far has seen no brightening or dimming, In 1990, though, some other radio astronomers found an odd thread they termed the Snake -- because it twisted, not once but twice,

I was pleased. The Snake seems attached to a giant molecular cloud at one end, and merges with the spherical rim of a supernova at the other. Is its cause the cloud, or the supernova? We don't know.

For now, mine seems the only theory left standing in the blizzard of data we're now getting about the galactic center. But my model depends on, without explaining, the strong smooth magnetic fields. How did they get there? Are they simply accumulated, as matter in falls? Or did some past explosion make them? We don't know.

And what about the jet? This points to the big unanswered question about the center: is there a black hole there? Certainly our experience with distant, active galactic nuclei leads us to suspect one, since the galactic jets I had already studied almost certainly come from the accretion disks around truly massive black holes, some ranging up to perhaps a billion stellar masses.

Measures of the orbital velocities of stars very close to the true galactic center, called Sagittarius A, suggest that a point mass of about a million stellar masses lurks there, giving off very little light.

Much controversy surrounds these observations, though, with some holding that the data could mean only a thousand stellar masses iS needed. All that is packed into a radio bright structure less than ten times as wide as the distance between the Earth and our sun. The region is hard to fathom, though, because the total luminosity within fifteen light years of this structure is about ten million stellar luminosities. Picture ten million or more bright, young stars orbiting a tiny dark spot, and you'll see the problem making out what's going on.

While I was mulling over data and jotting equations, I kept on writing novels. What came to be called the Galactic Series (by my publisher) pushed on with Great Sky River, a reference to the ancient Indian names for the Milky Way. I focused on the inner ten light years, for dramatic effects, even though I knew the sheer energy flux there made humans quite vulnerable. It seemed a good stage to act out my main theme, the superiority of machines in much of the galaxy.

The huge energetics of the center would draw machines, I felt. The black hole would intrigue any inquisitive life form. And the struggle between vastly different forms would surge across such a virulent territory. Humans would be part of it all, but certainly not the major players.

So I began envisioning what it might be like at stage center. Black holes draw matter in. Energetic arguments suggest that a black hole at the center should ingest about a thousandth of a star's mass in a year, already ground into dust from the giant molecular clouds -- with occasional burps if a whole sun gets swallowed. Indeed, the electrodynamic view I advanced suggested a mechanism to fuel the black hole: the discharges we see are in fact energy shed by slowing the clouds, a sort of electrodynamic brake.

The mass funnels into a disk, rotating about the hole. The disk gets hot from friction, its rotation perhaps shaping the jets which may focus intermittently above and below the disk. Here the diet of particles and photons is rich and varied. Only hard, tough machines could survive for long there. In the fourth novel, Tides of Light, I drew out these contrasts.

Machines which can reproduce themselves would, inevitably, fall under the laws of natural selection. Earlier forms which arrived from elsewhere would specialize to use local resources. The entire panoply of biology would recapitulate: parasites, predators, prey. Adaptation would shape machines, who would by their intelligence counter with their own clever moves, carrying out their long term agenda.

How to think of this? I prepare for novels by writing descriptive passages of places and characters. In spare moments I began working up snapshots of possible life forms and their survival styles. I wrote them in present tense, for a sense of immediacy, seeking the analogy to biology:

Above the disk nothing made of metal or ceramic can long survive.

The grinding down of stars goes on perpetually. Blobs of already incandescent matter spiral in at speeds higher than found anywhere else in the galaxy. The Eater holds eternally captive the gathered masses of a million dead suns. Its pull whirls the. doomed matter in a final frenzied gyre.

The blobs rub against each other. Magnetic fields mediate the friction and in turn grow. The fields twine and loop through the condemned kernels. In tight collisions fields themselves annihilate against each other and more energy releases.

Above such brutal furnaces skim the phase creatures. They had once been of the mechanicals. Now they exist not in hard circuits or ceramic lattice-intelligences. They have evolved out of self-directed necessity. To drink more energy they have learned to dissolve.

As torrents of hard radiation lance through them, they are plasmas. This gathers in fluxes and stores them in long-range correlations.

When the flood ebbs the phase creatures change. In the cooler spots above the disk they can condense. Lacy filaments become gaseous discharges. The power so generated they broadcast outward, to lesser ranks who can store it.

The phase creatures themselves use these fluxes to organize themselves into free-floating networks. Circuits without wires. Electrons flowing only in their own self-consistently generated magnetic fields. Voltages and switches light-quick, gossamer thin.

Lively intelligences dance there. They enter the discussion which has been teeming above them, in the cooler realms. With silky elegance their thoughts merge with the hard beings who are the cruder, earlier forms of mechanicals.

But the phase creatures still know their origins. They share the thought patterns of the metallic forms. They converse.

My reading in evolutionary theory suggested that generally, the rate of development was faster where the contrast between energy levels was greatest. This explains why volcanic vents at the bottom of oceans proved a rich life site. Similarly, the tropics boast of myriad species, the poles few. The contrast between the black hole region and the surrounding sea of stars is similarly stark.

I worked out a crude model for setting up a current system which could link the disk of a black hole to the surroundings. The disk traps magnetic fields as in falling matter brings the field lines in. A rotating magnetic field can sling particles -probably electrons and positrons -out along the gradually opening field lines. The disk acts like an enormous rotating flywheel, driving currents and mass flow both up and down from the disk. This should yield two jets. One can calculate the energy yield -- actually, just an upper bound, which turns out to be considerable.

This part of any electrodynamic model is quite iffy, because we know nothing directly from the black hole environment. A gamma ray emission was seen several times through the 1980s from somewhere near galactic center, which corresponds to the annihilation of electrons and positrons. Perhaps it was from the black hole region, but certainly it's intermittent, for it vanished years ago and has not been seen since. Perhaps the weather there changed.

Worse, the calculated energy going into jets proved to be much higher than the rather weak, broad jet seen (in radio maps) emerging northward from the center. So perhaps the process is much weaker than we think. Further, there is no visible counter-jet, casting doubt on the whole assumed geometry of the black hole region.

It is easy to show that the present core region is accreting matter at a mild rate. If a star plunged in, there would be much more emission. Still, all this assumes that the radiation from matter plunging into the disk and then into the hole is simply streaming out.

What if something else intercepts this flow, uses it, and degrades it into lukewarm heat? Then all our calculations of spectra would be awry. What could such intervening agencies be. . . ?

Black holes have weather, of a sort.

Light streams from them. Blackness dwells at their cores, but friction heats the infalling gas and dust. These streams brim with forced radiation. Storms worry them. White-hot tornadoes whirl and suck.

For the immense hole at the exact center of the galaxy, a virulent glow hammers outward. It pushes incessantly at the crowded masses that circle it, jostling in their doomed orbits. Gravity's gullet forces the streams into a disk, churning ever inward. Suffering in the weather.

The press of hot photons is a wind, driving all before it. Except for the grazers. To these photovores, the great grinding disk is a source of food.

Fire-flowers blossom in the disk, sending up lashes of fierce ultraviolet. Storms of light.

Both above and below the accretion disk, in hovering clouds, these photons smash molecules to atoms, strip atoms into bare charge, whip particles into sleet. The clouds are debris, dust, grains. They are already doomed by gravity's rob, like nearly everything here.

Nearly. To the gossamer, floating herds this is a fountain. Their life source.

Sheets of them hang, billowing with the electromagnetic winds. Basking in the sting. Holding steady.

The photovores are patiently grazing Some are Infras, others Ultras -tuned to soak up particular slices of the electromagnetic spectrum.

Each species has a characteristic polish and shape. Each works within evolutionary necessity, deploying great flat receptor planes. Each has a song, used to maintain orbit and angle.

Against the wrathful weather here, information is at least a partial defense. Position-keeping telemetry flits between the herd sheets. They sing luminously to each other in the eternal brimming day.

Hovering on the pressure of light, great wings of high-gloss molysheet spread. Vectoring, skating on winds, magnetic torques in a complex dynamical sum. Ruling forces govern their perpetual, gliding dance. This is decreed by intelligences they scarcely sense, machines that prowl the darker lanes further out.

Those magisterial forms need the energies from this furnace, yet do not venture here. The wise and valuable run no risks.

At times the herds fail. Vast shimmering sheets peel away. Many are east into the shrouded masses of molecular clouds, which are themselves soon to boil away. Others follow a helpless descending gyre. Long before they could strike the brilliant disk, the hard glare dissolves their lattices. They burst open and flare with fatal energies.

Now a greater threat spirals lazily down. It descends from the shelter of thick, turbulent dust. It lets itself fall toward the governing mass, the black hole itself. Then it arrests its descent with out-stretched wings of mirrors. They bank gracefully on the photon breeze.

Its lenses swivel to select prey. There a pack of photovores has clumped, disregarding ageless programming, or perhaps caught in a magnetic flux tube. The cause does not matter. The predator eases down along the axis of the galaxy itself.

Here, navigation is simple. Far below, the rotational pole of the Eater of All Things is a pinprick of absolute black at the center of a slowly revolving, incandescent disk.

The clustered photovores sense a descending presence. Their vast sailing herds cleave, peeling back to reveal deeper planes of burnt-gold light seekers. They all live to ingest light and excrete microwave beams. Their internal world revolves around ingestion, considered digestion, and orderly excretion.

These placid conduits now flee. But those clumped near the axis have little angular momentum, and cannot pivot on a magnetic fulcrum. Dimly they sense their destiny. Their hissing microwaves waver.

Some plunge downward, hoping that the predator will not follow so close to the Eater. Others cluster ever more, as if numbers give safety. The opposite is true.

The metallovore folds its mirror wings. Now angular and swift, accelerating, it mashes a few of the herd on its carapace. It scoops them in with flux lines. Metal harvesters rip the photovores. Shreds rush down burnt-black tunnels. Electrostatic fields separate elements and alloys.

Fusion fires await the ruined carcasses. There the separation can be exquisitely tuned, yielding pure ingots of any alloy desired. In the last analysis, the ultimate resources here are mass and light. The photovores lived for light, and now they end as mass.

The sleek metallovore never deigns to notice the layers of multitudes peeling back, their gigshertz cries of panic. They are plankton. It ingests them without registering their songs, their pain, their mortal fears.

Yet the metallovore, too, is part of an intricate balance. If it and its kind were lost, the community orbiting the Eater would decay to a less diverse state, one of monotonous simplicity, unable to adjust to the Eater's vagaries. Less energy would be harnessed, less mass recovered.

The metallovore prunes less efficient photovores. Its ancient codes, sharpened over time by natural selection, prefer the weak. Those who have slipped into unproductive orbits are easier to catch. It also prefers the savor of those who have allowed their receptor planes to tarnish with succulent trace elements, spewed up by the hot accretion disk below. The metallovore spots these by their mottled, dusky hue.

Each frying instant, millions of such small deaths shape the mechsphere.

Predators abound, and parasites. Here and there on the metallovore's polished skin are limpets and barnacles. These lumps of orange-brown and soiled yellow feed on chance debris from the prey. They can lick at the passing winds of matter and light. They purge the metallovore of unwanted elements -- wreckage and dust which can jam even the most robust mechanisms, given time.

All this intricacy floats on the pressure of photons. Light is the fluid here, spilling up from the blistering storms far below in the great grinding disk. This rich harvest supports the mechsphere which stretches for hundreds of cubic light years, its sectors and spans like armatures of an unimaginable city.

All this, centered on a core of black oblivion, the dark font of vast wealth.

Inside the rim of the garish disk, oblivious to the weather here, whirls a curious blotchy distortion in the fabric of space and time. It is called by some the Wedge, for the way it is jammed in so close. Others term it the Labyrinth.

It seems to be a small refraction in the howling virulence. Sitting on the very brink of annihilation, it advertises its artificial insolence.

Yet it lives on. The mote orbits perpetually beside the most awful natural abyss in the galaxy: the Eater of All Things.

Intelligent machines would build atop this ferment a society we could scarcely fathom -- but we would try. Much of the next novel I wrote, Furious Gulf was about that -- the gulf around a Mack hole, and the gulf between intelligences born of different realms.

For years I had enjoyed long conversations with a friend, noted artificial intelligence theorist Marvin Minsky, about the possible lines of evolution of purely machine intelligence. Marvin views our concern with mortality and individualism as a feature of biological creatures, unnecessary among intelligences which never had to pass through our Darwin-nowing filter.

If we can copy ourselves indefinitely, why worry about a particular copy? What kind of society would emerge from such origins? What would it think of us -- we Naturals, still hobbled by biological destiny?

A slowly emerging theme in the novels, then, was how intelligence depended on the "substrate," the basic building blocks. Machines could embody intelligence, but their styles would be different.

Angular antennas reflect the bristling ultraviolet of the disk below. Shapes revolve. They live among clouds of infalling mass -- swarthy, shredding under a hail of radiation: infrared spikes, cutting gamma rays.

Among the dissolving clouds move silvery figures whose form alters to suit function. Liquid metal flows, firms. A new tool extrudes: matted titanium. It works at a deposit of rich indium. Chewing digesting,

The harvesters swoop in long ellipses, high above the hard brilliance of the disk. As they swarm they strike elaborate arrays, geometric matrices. Their volume-scavenging strategy is self-evolved, purely practical, a simple algorithm. Yet it generates intricate patterns which unfurl and perform and then cuff up again in artful, languorous beauty.

They have another, more profound function. Linked, they form a macro-antenna. In a single-voiced chorus they relay complex trains of digital thought. Never do they participate in the cross-lacing streams of careful deliberation, any more than molecules of air care for the sounds they transmit.

Across light-minutes the conversation billows and clashes and rings. A civilization blooms on the brink of the deepest abyss in Creation.

By the time I reached the last volume, in 1992, I had spent over twenty years slowly building up my ideas about machine intelligence, guided by friends like Marvin. I had also published several papers on the galactic center, am working on a further model for the Snake, and still eagerly read each issue of Astrophysical Journal for further clues.

Much remains to be found there. My nephew, now a doctoral student at Caltech, will make a thorough map of the center in 1995, using a detector he built to view light wavelengths shorter than a millimeter -he's caught the bug.

I finished the last novel, Sailing Bright Eternity, in summer 1994. It had been twenty-four years since I started on the series and our view of the galactic center had changed enormously. Some parts of the first two books, especially, are not representative of current thinking. Error goes with the territory.

I had taken many imaginative leaps in putting together a working "ecology" for the center, including truly outre ideas, such as constructions made by forcing space-time itself into compressed forms, which in turn act like mass itself: reversing Einstein's intuition, that matter curved space-time. All this was great fun, requiring a lot of time to think. I let my subconscious do most of the work, if possible. It's an easier way to write; but it stretches out projects, too. Occasionally I wanted to say to long-suffering readers, who wrote in asking when the next volume would appear, "Sorry; I'm writing as fast as I

Doubtless there are many more surprises ahead. We're extending our gaze into ever more distant frequencies, gaining better resolution, seeing liner detail. In peeling back the onion skins, we get closer to. how galaxies work, how the vast outbursts of their centers affect life, and how the truly bright galactic cores, quasars, work.

My own model is quite possibly completely wrong. It seems to explain some features (the filaments, the Snake) but has trouble with the jets. Eventually, comparing radio maps over time, we might see flareups and changes in the threads. Mine is strictly done in what I call the "cartoon approximation"--good enough for a first cut, maybe, but doomed to fail somewhere.

In any case, models are like matters of taste. Nobody expects a French impressionist painting to look much like a real cow; it suggests ways of looking at cows.

Is there life at the center? Nobody knows, but nobody can rule it out. Only by thinking about possibilities can we test them. My first intuition, seeing the radio map of the Arch, was, This looks artificial. Maybe it is -- you had probably thought of that explanation halfway through this piece. Astronomy reflexively assumes that everything in the night sky is natural. Someday, that may prove wrong.

One of the ways science fiction looks at the world is by pushing it to extremes, asking the questions that go beyond the bounds of what we can observe and check now. Imagination is no mere foot soldier; it wants to fly. That's why science fiction and science are forever linked.

Old Legends

This memoir appeared in NEW LEGENDS, edited by Greg Bear, published by Tor Books, August 1995.

OLD LEGENDS

A Memoir of Science and Fiction

Gregory Benford

Long before I became interested in science itself, I was a science fiction reader. The Space Age changed that in 1957. At the time it seemed that the central metaphor of science fiction had become real, foggy legend condensing into fact.

I read about Sputnik on the deck of the S.S. America, sailing back from Germany, where I had lived for three years while my father served in the occupying forces. The one-page mimeographed ship's newsletter of October 4 gave that astonishing leap an infuriatingly terse two sentences.

By the time I re-entered high school in the U.S., just emerging from years when the Cold War seemed to fill every crevice of the world, the previously skimpy curriculum was already veering toward science, a golden, high-minded province. Suddenly I found that I could take a full year of calculus and physics in my senior year. This was quite a change. I put aside my devoted reading of the sf magazines and launched myself into science, the real thing.

I began to think seriously that a career of simply studying the physical world, which I had often read about in fiction, could be open to such as me. I had done reasonably in high school up until Sputnik, getting Bs and As, but not thinking of myself as one of the really bright members of the class. I imagined that I would probably end up as an engineer, but I really wanted to be a writer. When I scored high in the national scholastic exams of 1958 nobody was more surprised than I. But those scores opened the advanced classes to me in my senior year, and a whole new landscape.

This fresh path led directly to an early afternoon in 1967, when two physicists and a clerk from the Personnel office at the Lawrence Radiation Laboratory ushered me into a large office without preamble, and there sat a distracted Edward Teller behind a messy desk piled high with physics journals.

To my surprise, the other physicists quickly excused themselves and left. Teller was scientific director of the Laboratory then, fabled for his work developing the A-bomb and H-bomb, and his epic split with Robert Oppenheimer.

They sprang Teller on me without warning. I had gone up to Livermore to discuss working there as a research physicist, following my doctoral thesis at the University of California at San Diego. Nobody told me that Teller insisted on taking the measure of every candidate in the program. "We didn't want you to be nervous," one said later. It worked; I was merely terrified.

He the most daunting job interviewer imaginable. Not merely a great physicist, he loomed large in one of the central mythologies of modern science fiction, the A-bomb. In the next hour no one disturbed us as Teller quizzed me about my thesis in detail. Attentively he turned every facet over and over, finding undiscovered nuances, some overlooked difficulty, a calculation perhaps a bit askew.

He was brilliant, leaping ahead of my nervous explanations to see implications I had only vaguely sensed. His mind darted as swiftly as any I had ever encountered, including some Nobel Laureates. To my vast surprise, I apparently passed inspection. At the end, he paused a long moment and then announced that he had "the most important kvestion of all." Leaning closer, he said, "Vill you be villing to vork on veapons?"

Unbidden, images from Stanley Kubrick's film Dr. Strangelove leaped to mind. But Teller had impressed me as a deep, reflective man. I said I would -- occasionally, at least. I had grown up deep in the shadow of the Cold War. My father was a career Army officer, and I had spent six years living with my family in occupied post-war Japan and Germany. It seemed to me that the sheer impossibility of using nuclear weapons was the best, indeed the only, way to avoid strategic conventional war, whose aftermath I had seen in shattered Tokyo and Berlin. Paralleling this direct experience was my reading in science fiction, which had always looked ahead at such issues, working out the future implied by current science.

That afternoon began my long, winding involvement with modern science and fiction, the inevitable clash of the noble and imaginary elements in both science and fiction with the gritty and practical. I have never settled emotionally the tensions between these modes of thinking. Growing up amid the shattered ruins of Germany and Japan, with a father who had fought through World War II and then spent long years occupying the fallen enemy lands, impressed me with the instability of even advanced nations. The greatest could blunder the most.

I quit Livermore in 1971 to become a professor at the University of California at Irvine. In novels such as In the Ocean of Night, written after my "Rad Lab" days, I see in retrospect that I was thrashing out my mixed feelings. I often turned to other scientists to fathom how my own experience fit with the history of both science and fiction in our time. I did not see then how intertwined they were and are, and how much we face the future using the legends of the past.

Sixa vs. Seilla

"Veapons" called immediately to mind the central fable of sf in those days -- the event which seemed to put the stamp on John Campbell's*Astounding* magazine. In the spring of 1944 Cleve Cartmill published a clear description of how an atomic bomb worked in*Astounding SF* , titled "Deadline." Actually, Cartmill's bomb would not have worked, but he did stress that the key problem was separating non-fissionable isotopes from the crucial Uranium 235.

This story became legend, proudly by fans touted after the war as proof of sf's predictive powers. It was a tale of an evil alliance called the Axis -- oops, no, the Sixa -- who are prevented from dropping the A-bomb, while their opponents, the Allies -- no, oops, that's the Seilla -- refrain from using the weapon, fearing its implications.

In March 1944 a captain in the Intelligence and Security Division and the Manhattan Project called for an investigation of Cartmill. He suspected a breach in security, and wanted to trace it backward. US security descended on Campbell's office, but Campbell truthfully told them that Cartmill had researched his story using only materials in public libraries.

A Special Agent nosed around Cartmill himself, going so far as to enlist his postman to casually quiz him about how the story came to be written. The postman remembered that John Campbell had sent Cartmill a letter several days before the Special Agent clamped a mail cover on Cartmill's correspondence. This fit the day when agents had already visited Campbell's office. Campbell was alerting his writer, post-haste. Soon enough, Security came calling.

Sf writers are often asked where they get their ideas. This was one time when the answer mattered. Cartmill had worked for a radium products company in the 1920s, he told the agent, which had in turn interested given him in uranium research. He also fished forth two letters from Campbell, one written ten days short of two years before the Hiroshima bombing, in which Campbell urged him to explore these ideas: "U 235 has--I'm stating fact, not theory--been separated in quantity easily sufficient for preliminary atomic power research, and the like. They got it out of regular uranium ores by new atomic isotope separation methods; they have quantities measured in pounds..." Since a minimum critical mass is less than a hundred pounds, this was sniffing close to Top Secret data.

"Now it might be that you found the story worked better in allegory," Campbell advised, neatly leading Cartmill to distance the yet unwritten tale from current events. Plainly Campbell was trying to skirt close to secrets he must have guessed. Literary historian Albert Berger obtained the formerly secret files on the Cartmill case, and as he points out in*Analog* (September, 1984), Campbell never told Cartmill that wartime censorship directives forbade**any** mention of atomic energy. Campbell was urging his writer out into risky territory.

Cartmill was edgy, responding that he didn't want to be so close to home as to be "ridiculous. And there is the possible danger of actually suggesting a means of action which might be employed." Still, he had used the leaden device of simply inverting the Axis and Allies names, thin cover indeed. Campbell did not ask him to change this, suggesting that both men were tantalized by the lure of reality behind their dreams.

The Office of Censorship came into play. Some suggested withholding*Astounding's* mailing privileges, which would have ended the magazine. In the end, not attracting attention to the Cartmill story and the magazine seemed a smarter strategy. Security feared that "...such articles coming to the attention of personnel connected with the Project are apt to lead to an undue amount of speculation."

Only those sitting atop the Manhattan Project knew what was going on. "Deadline" might make workers in the far-flung separation plants and machining shops figure out what all this uranium was for, and talk about it. The Project was afraid of imagination, particularly disciplined dreaming with numbers and facts well marshalled. They feared science fiction itself.

All this lore I already accepted, but I was curious about those at the top of the Project, such as Teller. Self-cautious, a mere fresh postdoctoral physicist, I did not at first ask him about any of these legendary events. I was busy, too, learning how science works in such lofty realms.

I discussed both physics and politics with Teller while at the Lab, finding him delightfully eccentric and original. One hammering-hot summer day in Livermore, we continued well into the lunch hour. Teller wanted to go swimming, but refused to break off discussions. "Ve must not be all in our minds, all the time."

I went with him. He cut an odd figure as he threaded among the muscular sunbathers, mind fixed on arcane points of theoretical physics, his skin pale as the underbelly of a fish. He sat at the pool edge and shed his suit, tie, shirt, the works right down to--instead of underwear--a swim suit.*This man plans ahead* , I thought.

As a boy in Budapest he had come in second in a contest with a streetcar, losing a foot. Beside the pool he unfastened his artificial foot, unembarrassed. (In*Dr. Strangelove* , I couldn't help recalling, it was an artificial hand.) He kept talking physics even as he wriggled over to the edge. He earnestly concluded his point, nodded earnestly, satisfied, and then seemed to realize where he was. I could almost hear him think,*Ah yes, next problem. Svimming. Vere iss...?* "Edward," I began -- and Teller instantly flung himself like an awkward frog into the water, obliviously comic.

Moments like these led me to finally see through the cultural aura that obscures figures like Teller. They are more vast and various than we think, funnier and odder and warmer. Dr. Strangelove doesn't exist. Teller had made a name for himself at Los Alamos by thinking ahead. He proposed the hydrogen fusion bomb, the Super, while the A-bomb was under development--and lobbied to skip the A-bomb altogether, leapfrogging to the grander weapon.

With his penchant for problem-solving, Teller was a symbol of the "techno-fix" school of warfare, and by the 1960s the times were running against him. At one Livermore lunch, an arms control negotiator furiously said to me, "He's the Satan of weapons! We've got to stop him." Many scientists felt just as strongly.

H. Bruce Franklin's*War Stars: The Superweapon and the American Imagination* made the case that sf, particularly in the pulp magazines, strongly influenced U.S. foreign policy. In the 1930s Harry Truman had read lurid pulp magazine sf yarns of superweapons settling the hash of evil powers. Often they were held in readiness after, insuring the country against an uncertain future.

Truman wasn't alone. Popular culture's roots run deep. Time and again at Livermore I heard physicists quote sf works as arguments for or against the utility of hypothetical weapons. As I came to know the physics community more widely, this complex weave deepened.

Beeps

At Livermore I got involved with the theory of tachyons, the theoretically possible particles which can travel faster than light. Not the sort of thing one imagines a "weapons lab" allowing, but Teller allowed the theorists a wide range. When the tachyon idea popped up in the physics journals, I discussed it with Teller. He thought they were highly unlikely, and I agreed, but worked on them anyway out of sheer speculative interest. With Bill Newcomb and David Book I published in*Physical Review* a paper titled "The Tachyonic Antitelephone". We destroyed the existing arguments, which had avoided time-travel paradoxes by re-interpreted tachyonic trajectories moving backward in time as their anti-particles moving forward in time. It was simple to show that imposing a signal on the tachyons (sending a message) defeated the re-interpretation, so the causality problem remained. If sending a tipoff about a horse race to your grandfather made him so rich he jilted your grandmother and ran off to Paris, that was just as bad a violation of cause and effect.

Teller invoked a different argument against tachyons, which recalled the casual lunchtime discussions at Los Alamos, which were legendarily fruitful. At one, Enrico Fermi asked his famous question, "Where are they?" -- and raised the still fiercely contentious issue of why aliens, if they are plentiful in the galaxy, haven't visited us by now. (That question undoubtedly inspired the proposal that radio listening might turn up alien broadcasts, made by Giuseppe Cocconi and Philip Morrison in 1959 --the same Morrison who had worked in the Manhattan Project.) Using similar logic, Teller noted that tachyons could be used to send messages backward in time. "Vhy haven't they been sent? Vere are our messages from the future?"

Our answer was that nobody had built a tachyon receiver yet. Neat, perhaps, but a bit too neat. Surely somehow nature would not disguise such a profound trick. There had to be a way of seeing from theory why such disturbing things could not occur.

I was so intrigued by these hypothetical particles that I wrote papers investigating their consequences. That drew me into a distant friendship with Gerald Feinberg of Columbia University, who had introduced some of the ideas of tachyonic field theory. He was an amiable, concentrated man, always thinking through the broad implications of the present. He was also a first class physicist who had edited a science fiction fanzine in high school with two other upstart Bronx High School students, Sheldon Glashow and Steven Weinberg -- who later won the Nobel prize for their theory which united the weak and electromagnetic forces. Titled ETAOIN SHRDLU for the frequency of letter use in English, the only fanzine ever edited by Nobel Prize winners stressed science with earnest teenage energy. (A generation later Stephen Hawking spent most of his free time reading sf paperbacks. Enthusiastically discussing them decades later with me, he was like most readers, able to recall plots and ideas easily, but not titles or authors.)

Tachyons were the sort of audacious idea that comes to young minds used to roving over the horizon of conventional thought. Because of Feinberg I later set part of my tachyon novel*Timescape* at Columbia. By the late 1970s I thought tachyons quite unlikely, since several experiments had failed to find them (after an exciting but erronious detection in 1972). Still, the issue of how physics could*prove* that time communication is impossible remained--the primary issue for all of us, including Teller. Tachyons seemed a better way to address this than the more exotic beasts of the theorists' imaginations, such as space-time wormholes.

So I framed the issue using tachyons, exploring how people in the future might get around the problem of having no receiver: by using energetic tachyons to disturb a finely tuned experiment in a physics lab in the past. Gerry chuckled when he heard this notion, pleased that his theoretical physics had spawned a novel about how scientists actually worked. He was rather bemused by the continuing cottage industry of tachyon papers, now numbering in the several hundreds. When an Australian experiment seemed to find cosmic rays moving over twice the speed of light, the field had a quick flurry of interest. Gerry was intrigued, then crestfallen when the results weren't confirmed.

He told me years later that he had begun thinking about tachyons because he was inspired by James Blish's short story, "Beep." In it, a faster-than-light communicator plays a crucial role in a future society, but has an annoying final*beep* at the end of every message. The communicator necessarily allows sending of signals backward in time, even when that's not your intention. Eventually the characters discover that all future messages are compressed into that*beep* , so the future is known, more or less by accident.

Feinberg had set out to see if such a gadget was theoretically possible.

This pattern, speculation leading to detailed theory, I encountered more and more in my career. The litany of science is quite prissy, speaking of how anomalies in data lead theorists to explore new models, which are then checked by dutiful experimenters, and so on. Reality is wilder than that.

No one impressed me more with the power of speculation in science than Freeman Dyson. Without knowing who he was, I found him a like-minded soul at the daily physics department coffee breaks, when I was still a graduate student at the University of California at San Diego. I was very impressed that he had the audacity to give actual department colloquia on his odd ideas. These included notions about space exploration by using nuclear weapons as explosive pushers, and speculations on odd variants of life in the universe. He had just published a short note what came to be called Dyson spheres--vast civilizations which swarm around their star, soaking up all available sunlight and emitting infrared, which we might study to detect them. (This was a direct answer to both Fermi's question and the Cocconi-Morrison proposal--more links in a long chain.)

Dyson had read Jules Verne while a child, and at age eight and nine wrote an sf novel,*Sir Phillip Roberts's Erolunar Collision* , about scientists directing the orbits of asteroids. He was unafraid to publish conjectural, even rather outrageous ideas in the solemn pages of physics journals. When I remarked on this, he answered with a smile, "You'll find I'm not the first." Indeed, he descended from a line of futurist British thinkers, from J.D. Bernal of*The World, the Flesh and the Devil* to Olaf Stapledon to Arthur C. Clarke.*In Infinite in All Directions* Dyson remarked that "Science fiction is, after all, nothing more than the exploration of the future using the tools of science."

This was a fairly common view in those burgeoning times. In my first year of graduate school in La Jolla I noticed Leo Szilard at department colloquia, avidly holding forth on his myriad ideas. Szilard had persuaded Einstein to write the famous letter to Roosevelt explaining that an A-bomb was possible, and advocating the Manhattan Project. He had a genius for seizing the moment. Szilard had seen the potential in nuclear physics early, even urging his fellow physicists in the mid 1930s to keep their research secret. I had read Szilard's satirical sf novel*The Voice of the Dolphins* in 1961, and his sf short stories, and decided to wait until I had time from a weathering round of classes to speak to him. I was just taking some difficult examinations in late May 1964 when Dyson told me that Szilard had died of a heart attack that morning. It was a shock, though I had scarcely exchanged a dozen words with him. (Of his rather cerebral fiction he had said, "I am emotionally moved by extraordinary reasoning.") I had not seized the moment.

Szilard was obsessed with nuclear dangers, and Dyson carried some of Szilard's thinking forward. A student of Dyson's made headlines in 1976 by designing a workable nuclear weapon using only published sources. I recalled the Cartmill episode. When I remarked on this, Dyson said, "The link goes back that far, yes." At the time I didn't know what he meant.

Rockets and War Stars

Scientists often read sf at an early age and then drift away, but many maintain a soft spot in their hearts for it. Some, like me, bridge the two communities.

So it was no surprise to me when Teller enlisted sf allies in his policy battles. Especially effective in the 1980s was Jerry Pournelle, a rangy, technophilic, talented figure. With a .38 automatic he could hit a beer can at fifty yards in a cross wind. As needed, he could also run a political campaign, debug a computer program or write a bestselling science fiction novel -- simultaneously. When he asked me to serve on the Citizens' Advisory Council on National Space Policy in 1982, at first I didn't realize that

Jerry wasn't proposing just another pressure group. This was a body which had direct lines to the White House, through the National Security Advisor. Teller, too, was "in the loop."

Pournelle dominated the Council meetings with his Tennessee charm, techno-conservative ideas and sheer momentum. An oddly varied crew assembled: writers, industrial researchers, military and civilian experts on subjects ranging from artificial intelligence to rocketry. The Council met at the spacious home of science fiction author Larry Niven, a raucous bunch with feisty opinions. There was a bit of politics, but no overall bias. I am a regfistered Democrat, but that never came up. The men mostly talked hardedge tech, the women policy. Pournelle stirred the pot and turned up the heat. Amid the buffet meals, saunas and hot tubs, well-stocked open bar and myriad word processors, fancies simmered and ideas cooked, some emerging better than half-baked.

Blocking nuclear weapons had always appealed to me. My misgivings about military involvement in the space program and other areas, which had surfaced in my novels repeatedly, vanished in matters which clearly were the military's province. Never, in all the policy and technical consulting I did while a professor at UCI, did I doubt that solving the immense problem of nuclear war lay somehow outside the province of the physicists who had started it all. But physicists could contribute--indeed, they had to try.

I favored as a first goal defending missiles and military command centers, using ground-based systems of swift, non-nuclear-tipped rockets. Technically this was small potatoes, really, not much beyond the capacity already available under existing treaties, which after all had allowed the Soviets to ring Moscow with a hundred fast defensive rockets, nuclear-tipped and still in place today.

The more ambitious specialists talked of war stars--great bunkers in the sky, able to knock down fleets of missiles. I doubted they could deal with the tens of thousands of warheads that could be launched in a full exchange. Still, to me that fact was a better argument against the existence of those thousands of warheads, rather than an argument against defense.

Finally, we settled on recommending a position claiming at least the moral high ground, if not high orbits. Defense was inevitably more stabilizing than relying on hair-trigger offense, we argued. It was also more principled. And eventually, the Soviet Union might not even be the enemy, we said--though we had no idea it would fade so fast. When that happened, defenses would still be useful against any attacker, especially rogue nations bent on a few terrorist attacks. There were plenty of science fiction stories, some many dacades old, dealing with that possibility.

The Advisory Council met in August of 1984 in a mood of high celebration. Their pioneering work had yielded fruits unimaginable in 1982--Reagan himself had proposed the Strategic Defense Initiative, suggesting that nuclear weapons be made "impotent and obsolete." The Soviets were clearly staggered by the prospect. (Years later I heard straight from a senior Soviet advisor that the US SDI had been the straw that broke the back of the military's hold on foreign policy. That seems to be the consensus now among the diplomatic community, though politically SDI is a common whipping boy, its funding cut.)

None of this was really unusual in the history of politics, policy and science fiction. H.G. Wells had visited with both presidents Roosevelt, Stalin, Churchill and other major figures. In 1906 Theodore Roosevelt was so dismayed by the Wellsian portrait of a dark future that he asked him to the White House for a long talk about how to avoid drifting that way. Wells's attention to war as the principal problem of the modern era found a ready audience among world leaders. Jules Verne had not commanded such respect in the corridors of power, and no writer since Wells has, but in the late twentieth century it seemed that science fiction's grasp of possibilities was once more called forth, this time by the same government which had fretted over Cleve Cartmill.

In the summer of 1984 all things seemed possible. I was not surprised that Robert Heinlein attended the Advisory Council meetings, dapper and sharp-witted. And out of the summer heat came a surprise visitor -- Arthur C. Clarke, in town to promote the opening of the film made from his novel,*2010* . Clarke had testified before congress against the Strategic Defense Initiative, and regarded the pollution of space by weapons, even defensive ones, as a violation of his life's vision.

Heinlein attacked as soon as Clarke settled into Larry Niven's living room. The conversation swirled around technical issues. Could SDI satellites be destroyed by putting into orbit a waiting flock of "smart rocks" (conventional explosives with small rockets attached)? Would SDI lead to further offensive weapons in space?

Behind all this lay a clear clash of personalities. Clarke was taken aback. His old friend Heinlein regarded Clarke's statements as both wrong-headed and rude. Foreigners on our soil should step softly in discussions of our self-defense policies, he said. It was, at best, bad manners. Perhaps Clarke was guilty of "British arrogance."

Clarke had not expected this level of feeling among old comrades. They had all believed in the High Church of Space, as one writer present put it. Surely getting away from the planet would diminish our rivalries?

Now each side regarded the other as betraying that vision, of imposing unwarranted assumptions on the future of mankind. It was a sad moment for many when Clarke said a quiet goodbye, slipped out and disappeared into his limousine, stunned.

In that moment I saw the dangers of mingling the visionary elements of sf with the hard-nosed. The field welcomed both, of course, but the world chewed up those of such ample spirit.

Behind much of this was Teller, close advisor to Reagan. He got involved with exotica such as x-ray lasers, which I thought beside the point. The answer lay not in vastly different, new technology, but using tried-and-true methods with a different strategic vision.

I was quite naive about what would follow. While the Soviets got the message quite clearly -- because they watched what we did, and didn't merely listen to the public debate -- and began thinking about throwing in the towel altogether. Meanwhile, over the Strategic Defense Initiative issue Nobel laureates ground their axes, techno-patter rained down, politicians played to the gallery -- ships passing in the night, their fog horns bellowing.

Our present had become, for that sf fan reading a newspaper report of Sputnik, completely science fictional. Even in the 1980s, though, I did not know how deep the science and science fiction connection went.

Old Legends

I had always wondered about Teller's effectiveness at influencing policy. In the 1940s, as James Gleick remarks in Genius, a biography of Richard Feynman, Teller was as imaginative and respected as Feynman. He was the great idea man of the Manhattan Project. So it was natural for me to ask him finally about science fiction's connection with both scientific discovery (tachyons) and science policy (the Manhattan Project).

"For long range thinking I trust in the real visionaries--the ones I prefer to read, at least. The science fiction writers. I haf always liked Mr. Heinlein, Mr. Asimov, of course Mr Clarke --they are much more important in the long run than any Secretary of Defense."

So we talked on about how he had read magazines in the 1940s Los Alamos, bought similar hardbacks as they began to appear in the 1950s, and eventually from the press of events kept up with only a few favorites--the hard sf types, mostly but not exclusively.

He pointed out to me an interesting paragraph in an old paperback.

We were searching...for a way to use U 235 in a controlled explosion. We had a vision of a one-ton bomb that would be a whole air raid in itself, a single explosion that would flatten out an entire industrial center... If we could devise a really practical rocket fuel at the same time, one capable of driving a war rocket at a thousand miles an hour, or more, then we would be in a position to make almost anybody say 'uncle' to Uncle Sam.

We fiddled around with it all the rest of 1943 and well into 1944. The war in Europe and the troubles in Asia dragged on. After Italy folded up...

That was Robert A. Heinlein as "Anson MacDonald" in "Solution Unsatisfactory," in the May 1941 *Astounding* . It even gets the principal events in the war in the right order.

"I found that remarkable," Teller said, describing how Manhattan Project physicists would sometimes talk at lunch about sf stories they had read. Someone had thought that Heinlein's ideas were uncannily accurate. Not in its details, of course, because he described not a bomb, but rather using radioactive dust as an ultimate weapon. Spread over a country, it could be decisive.

I recalled thinking in the 1950s that in a way Heinlein had been proved right. The fallout from nuclear bursts can kill many more than the blast. Luckily, Hiroshima and Nagasaki were air bursts, which scooped up little topsoil and so yielded very low fallout. For hydrogen bombs, fallout is usually much more deadly.

In Heinlein's description of the strategic situation, Teller said, the physicists found a sobering warning. Ultimate weapons lead to a strategic standoff with no way back--a solution unsatisfactory. How to avoid this, and the whole general problem of nuclear weapons in the hands of brutal states, preoccupied the physicists laboring to make them. Nowhere in literature had anyone else confronted such a Faustian dilemma as directly, concretely.

Coming three years later in the same magazine, Cleve Cartmill's "Deadline" provoked astonishment in the lunch table discussions at Los Alamos. It really did describe isotope separation and the bomb itself in detail, and raised as its principal plot pivot the issue the physicists were then debating among themselves: should the Allies use it? To the physicists from many countries clustered in the high mountain strangeness of New Mexico, cut off from their familiar sources of humanist learning, it must have seemed particularly striking that Cartmill described an allied effort, a joint responsibility laid upon many nations.

Discussion of Cartmill's "Deadline" was significant. The story's detail was remarkable, its sentiments even moreso. Did this rather obscure story hint at what the American public really thought about such a super-weapon, or would think if they only knew?

Talk attracts attention. Teller recalled a security officer who took a decided interest, making notes, saying little. In retrospect, it was easy to see what a wartime intelligence monitor would make of the physicists' conversations. Who was this guy Cartmill, anyway? Where did he get these details? Who tipped him to the isotope separation problem? "And that is vhy Mr. Campbell received his visitors."

So the great, resonant legend of early hard sf was, in fact, triggered by the quiet, distant "fan" community among the scientists themselves. For me, closing the connection in this fundamental fable of the field completed my own quizzical thinking about the link between the science I practice, and the fiction I deploy in order to think about the larger implications of my work, and of others. Events tinged with fable have an odd quality, looping back on themselves to bring us messages more tangled and subtle than we sometimes guess.

I am sure that the writers of that era, and perhaps of this one as well, would be pleased to hear this footnote to history. Somebody really was listening out there. I suspect today is no different. Perhaps the sf writers are indeed the unacknowledged legislators of tomorrow.

GREGORY BENFORD and DAVID BRIN

PARIS CONQUERS ALL

* The second of our War of the Worlds stories is the third story in the issue by a columnist. Gregory Benford collaborated with award-winner David Brin in this tale of yet another writer, Jules Verne, and his encounter with the Martians.

I commence this account with a prosaic stroll at eventide -- a saunter down the avenues of la Ville Lumiere, during which the ordinary swiftly gave way to the extraordinary. I was in Paris to consult with my publisher, as well as to visit old companions and partake of the exquisite cuisine, which my provincial home in Amiens cannot boast. Though I am now a gentleman of advanced age, nearing my 70th year, I am still quite able to favor the savories, and it remains a treat to survey the lovely demoiselles as they exhibit the latest fashions on the boulevards, enticing smitten young men and breaking their hearts at the same time.

I had come to town that day believing -- as did most others -- that there still remained weeks, or days at least, before the alien terror ravaging southern France finally reached the valley of the Seine. Ile de France would be defended at all costs, we were assured. So it came to pass that, tricked by this false complaisance, I was in the capital the very afternoon that the crisis struck.

Paris! It still shone as the most splendid exemplar of our progressive age -- all the more so in that troubled hour, as tense anxiety seemed only to add to the city's loveliness -- shimmering at night with both gas and electric lights, and humming by day with new electric trams, whose marvelous wires crisscrossed above the avenues like gossamer heralds of a new era.

I had begun here long ago as a young attorney, having followed into my father's profession. Yet that same head of our family had also accepted my urge to strike out on a literary road, in the theater and later down expansive voyages of prose. "Drink your fill of Paris, my son!" the good man said, seeing me off from the Nantes railway station. "Devour these wondrous times. Your senses are keen. Share your insights. The world will change because of it."

Without such help and support, would I ever have found within myself the will, the daring, to explore the many pathways of the future, with all their wonders and perils? Ever since the Martian invasion began, I had found myself reflecting on an extraordinary life filled with such good fortune, especially now that all human luck seemed about to be revoked. Now, with terror looming from the south and west, would it all soon come to nought? All that I had achieved? Everything humanity had accomplished, after so many centuries climbing upward from ignorance?

It was in such an uncharacteristically dour mood that I strolled in the company of M. Beauchamp, a gentleman scientist, that pale afternoon less than an hour before I had my first contact with the horrible Martian machines. Naturally, I had been following the eye-witness accounts which first told of plunging fireballs, striking the Earth with violence that sent gouts of soil and rock spitting upward, like miniature versions of the outburst at Krakatau. These impacts had soon proved to be far more than mere meteoritic phenomena, since there soon emerged, like insects from a subterranean lair, three-legged beings bearing incredible malevolence toward the life of this planet. Riding gigantic tripod mechanisms, these unwelcome guests soon set forth with one sole purpose in mind -- destructive conquest!

The ensuing carnage, the raking fire, the sweeping flames -- none of these horrors had yet reached the fair country above the river Loire . . . not yet. But reports all too vividly told of villages trampled, farmlands seared black, and hordes of refugees cut down as they fled.

Invasion. The word came to mind all too easily remembered. We of northern France knew the pain just twenty-eight years back, when Sedan fell and this sweet land trembled under an attacker's boot. Several Paris quarters still bear scars where Prussian firing squads tore moonlike craters out of plaster walls, mingling there the ochre life blood of communards, royalists and bourgeois alike.

Now Paris trembled before advancing powers so malign that, in contrast, those Prussians of 1870 were like beloved cousins, welcome to town for a picnic!

All of this I pondered while taking leave, with Beauchamp, of the Ecole Militaire, the national military academy, where a briefing had just been given to assembled dignitaries, such as ourselves. From the stone portico we gazed toward the Seine, past the encampment of the Seventeenth Corps of Volunteers, their tents arrayed across trampled grass and smashed flower beds of the ironically named Champ-de-Mars. The meadow of the god of war.

Towering over this scene of intense (and ultimately futile) martial activity stood the tower of M. Eiffel, built for the recent exhibition, that marvelously fashioned testimonial to metal and ingenuity . . . and also target of so much vitriol.

"The public's regard for it may improve with time," I ventured, observing that Beauchamp's gaze lay fixed on the same magnificent spire.

My companion snorted with derision at the curving steel flanks. "An eyesore, of no enduring value," he countered, and for some time we distracted ourselves from more somber thoughts by arguing the relative merits of Eiffel's work, while turning east to walk toward the Sorbonne. Of late, experiments in the transmission of radio-tension waves had wrought unexpected pragmatic benefits, using the great tower as an antenna. I wagered Beauchamp there would be other advantages, in time.

Alas, even this topic proved no lasting diversion from thoughts of danger to the south. Fresh in our minds were reports from the wine districts. The latest outrage -- that the home of Vouvray was now smashed, trampled and burning. This was my favorite of all the crisp, light vintages--better, even, than a fresh Sancerre. Somehow, that loss seemed to strike home more vividly than dry casualty counts, already climbing to the millions.

"There must be a method!" I proclaimed, as we approached the domed brilliance of Les Invalides. "There has to be a scientific approach to destroying the invaders."

"The military is surely doing its best," Beauchamp said.

"Buffoons!"

"But you heard of their losses. The regimants and divisions decimated --" Beauchamp stuttered. "The army dies for France! For humanity -- of which France is surely the best example."

I turned to face him, aware of an acute paradox -- that the greatest martial mind of all time lay entombed in the domed citadel nearby. Yet even he would have been helpless before a power that was not of this world.

"I do not condemn the army's courage," I assured.

"Then how can you speak --"

"No no! I condemn their lack of imagination!"

"To defeat the incredible takes --"

"Vision!"

Timidly, for he knew my views, he advanced, "I saw in the Match that the British have consulted with the fantasist, Mr. Wells."

To this I could only cock an eye. "He will give them no aid, only imaginings."

"But you just said --"

"Vision is not the same as dreaming."

At that moment the cutting smell of sulfuric acid waited on a breeze from the reducing works near the river. (Even in the most beautiful of cities, rode work has its place.) Beauchamp mistook my expression of disgust for commentary upon the Englishman, Wells.

"He is quite successful. Many compare him to you."

"An unhappy analogy. His stories do not repose on a scientific basis. I make use of physics. He invents."

"In this crisis --"

"I go to the moon in a cannon ball. He goes in an airship, which he constructs of a metal which does away with the law of gravitation. Ca c'est tres joli! -- but show me this metal. Let him produce it!"

Beauchamp blinked. "I quite agree -- but, then, is not our present science woefully inadequate to the task at hand -- defending ourselves against monstrous invaders?"

We resumed our walk. Leaving behind the crowds paying homage at Napoleon's Tomb, we made good progress along rue de Varenne, with the Petite Palais now visible across the river, just ahead.

"We lag technologically behind these foul beings, that I grant. But only by perhaps a century or two."

"Oh surely, more than that! To fly between the worlds --"

"Can be accomplished several ways, all within our comprehension, if not our grasp."

"What of the reports by astronomers of great explosions, seen earlier this year on the surface of the distant roddy planet? They now think these were signs of the Martian invasion fleet being launched. Surely we could not expend such forces!"

I waved away his objection. "Those are nothing more than I have already foreseen in From the Earth to the Moon. which I would remind you I published thirty-three years ago, at the conclusion of the American Civil War."

"You think the observers witnessed the belching of great Martian cannon ?"

"Of course! I had to make adjustments, engineering alterations, while designing my moon vessel. The shell could not be of steel, like one of Eiffel's bridges. So I conjectured that the means of making light projectiles of aluminum will come to pass. These are not basic limitations, you see --" I waved them away -- "but mere details."

The wind had shifted, and with relief I now drew in a heady breath redolent with the smells of cookery rising from the city of cuisine. Garlic, roasting vegetables, the dark aromas of warming meats -- such a contrast with the terror which advanced on the city, and on our minds. Along rue St. Grenelle, I glanced into one of the innumerable tiny cafes. Worried faces stared moodily at their reflections in the broad zinc bars, stained by spilled absinthe. Wine coursed down anxious throats. Murmurs floated on the fitful air.

"So the Martians come by cannon, the workhorse of battle," Beauchamp murmured.

"There are other methods," I allowed.

"Your dirigibles?"

"Come come, Beauchamp! You know well that no air permeates the realm between the worlds."

"Then what methods do they employ to maneuver? They fall upon Asia, Africa, the Americans, the deserving British -- all with such control, such intricate planning."

"Rockets! Though perhaps there are flaws in my original cannon ideas --I am aware that passengers would be squashed to jelly by the firing of such a great gun -- nothing similar condemns the use of cylinders of slowly exploding chemicals."

"To steer between planets? Such control!"

"Once the concept is grasped, it is but a matter of ingenuity to bring it to pass. Within a century, Beauchamp, we shall see rockets of our own rise from this ponderous planet, into the heavens. I promise you that!"

"Assuming we survive the fortnight," Beauchamp remarked gloomily. "Not to mention a century."

"To live, we must think. Our thoughts must encompass the entire range of possibility."

I waved my furled umbrella at the sky, sweeping it around and down rue de Rennes, toward the southern eminence of Montparnasse. By chance my gaze followed the pointing tip -- and so it I was among the first to spy one of the Martian machines, like a monstrous insect, cresting that ill-fated hill.

There is something in the human species which abhors oddity, the unnatural. We are double in arms, legs, eyes, ears, even nipples (if I may venture such an indelicate comparison; but remember, I am a man of science at all times). Two-ness is fundamental to us, except when Nature dictates singularity -- we have but one mouth, and one organ of regeneration. Such biological matters are fundamental. Thus, the instantaneous feelings horror at first sight of the three-ness of the invaders -- which was apparent even in the external design of their machinery. I need not explain the revulsion to any denizen of our world. These were alien beings, in the worst sense of the word.

"They have broken through!" I cried. "The front must have collapsed."

Around us crowds now took note of the same dread vision, looming over the sooty Montparnasse railway station. Men began to run, women to wail. Yet, some courageous ones of both sexes ran the other way, to help bolster the city's slim, final bulwark, a line from which rose vollies of crackling rifle fire.

By unspoken assent, Beauchamp and I refrained from joining the general fury. Two old men, wealthier in dignity than physical stamina, we had more to offer with our experience and seasoned minds than with the frail strength of our arms.

"Note the rays," I said dispassionately, as for the first time we witnessed the fearful lashing of that horrid heat, smiting the helpless trains, igniting rail cars and exploding locomotives at a mere touch. I admit I was struggling to hold both reason and resolve, fastening upon details as a drowning man might cling to flotsam.

"Could they be like Hertzian waves?" Beauchamp asked in wavering tones.

We had been excited by the marvelous German discovery, and its early application to experiments in wireless signaling Still, even I had to blink at Beauchamp's idea -- for the first time envisioning the concentration of such waves into searing beams. "Possibly," I allowed. "Legends say that Archimedes concentrated light to beat back Roman ships, at Syracuse. . . . But the waves Hertz found were meters long, and of less energy than a fly's wingbeat. These --"

I jumped, despite my efforts at self control, as another, much larger machine appeared to the west of the first, towering majestically, also spouting bright red torrents of destruction. It set fires on the far southern horizon, the beam playing over city blocks, much as a cat licks a mouse.

"We shall never defeat such power," Beauchamp said morosely.

"Certainly we do not have much time," I allowed. "But you put my mind into harness, my friend."

Around us people now openly bolted. Carriages rushed past without regard to panicked figures who dashed across the avenues. Horses clopped madly by, whipped by their masters. I stopped to unroll the paper from a Colombian cigar. Such times demand clear thinking. It was up to the higher minds and classes to display character and resolve.

"No, we must seize upon some technology closer to hand," I said. "Not the Hertzian waves, but perhaps something allied . . . "

Beauchamp glanced back at the destructive tripods with lines of worry creasing his brow. "If rifle and cannon prove useless against these marching machines --"

"Then we must apply another science, not mere mechanics."

"Biology? There are the followers of Pasteur, of course." Beauchamp was plainly struggling to stretch his mind. "If we could somehow get these Martians -- has anyone yet seen one? -- to drink contaminated milk . . . "

I had to chuckle. "Too literal, my friend. Would you serve it to them on a silver plate?"

Beauchamp drew himself up. "I was only attempting --"

"No matter. The point is now moot. Can you not see where the second machine stands, atop the very site of Pasteur's now ruined Institute?"

Although biology is a lesser cousin in the family of science, I nevertheless imagined with chagrin those fine collections of bottled specimens, now kicked and scattered under splayed tripod feet, tossing the remnants to the swirling winds. No help there, alas.

"Nor are the ideas of the Englishman, Darwin, of much use, for they take thousands of years to have force. No, I have in mind physics, but rather more recent work."

I had been speaking from the airy spot wherein my head makes words before thought has yet taken form, as often happens when a concept lumbers upward from the mind's depths, coming, coming . . .

Around us lay the most beautiful city in the world, already flickering with gas lamps, lining the prominent avenues. Might that serve as inspiration? Poison gas? But no, the Martians had already proved invulnerable to even the foul clouds which the Army tried to deploy.

But then what? I have always believed that the solution to tomorrow's problems usually lies in plain sight, in materials and concepts already at hand -- just as the essential ideas for submarines, airships, and even interplanetary craft, have been apparent for decades. The trick lies in formulating the right combinations.

As that thought coursed through my mind, a noise erupted so cacophonously as to over-ride even the commotion further south. A rattling roar (accompanied by the plaint of already-frightened horses) approached from the opposite direction! Even as I turned round toward the river, I recognized the clatter of an explosive-combustion engine, of the type invented not long ago by Herr Benz, now propelling a wagon bearing several men and a pile of glittering apparatus! At once I observed one unforeseen advantage of horseless transportation -- to allow human beings to ride toward danger that no horse on Earth would ever approach.

The hissing contraption ground to a halt not far from Beauchamp and me. Then a shout burst forth in that most penetrating of human accents --one habituated to open spaces and vast expanses.

"Come on, you Gol-durned piece of junk! Fire on up, or I'll turn ya into scrap b'fore the Martians do!"

The speaker was dressed as a workman, with bandoliers of tools arrayed across his broad, sturdy frame. A shock of reddish hair escaped under the rim of a large, curve-brimmed hat, of the type affected by the troupe of Buffalo Bill, when that showman's carnival was the sensation of Europe, some years back.

"Come now, Ernst," answered the man beside him, in a voice both more cultured and sardonic. "There's no purpose in berating a machine. Perhaps we are already near enough to acquire the data we seek."

An uneasy alliance of distant cousins, I realized. Although I have always admired users of the English language for their boundless ingenuity, it can be hard to see the countrymen of Edgar Allan Poe as related to those of Walter Scott.

"What do you say, Fraunhoffer?" asked the Englishman of a third gentleman with the portly bearing of one who dearly loves his schnitzel, now peering through an array of lenses toward the battling tripods. "Can you get a good reading from here?"

"Bah!" The bald-pated German cursed. "From ze exploding buildings and fiery desolation, I get plenty of lines, those typical of combustion. But ze rays zemselves are absurd. Utterly absurd!"

I surmised that here were scientists at work, even as I had prescribed in my discourse to Beauchamp, doing the labor of sixty battalions. In such efforts by luminous minds lay our entire hope.

"Absurd how?" A fourth head emerged, that of a dark young man, wearing objects over his ears that resembled muffs for protection against cold weather, only these were made of wood, linked by black cord to a machine covered with dials. I at once recognized miniature speaker-phones, for presenting faint sounds directly to the ears. The young man's accent was Italian, and curiously calm. "What is absurd about the spectrum of-a the rays, Professor?"

"There iss no spectrum!" the German expounded. "My device shows just the one hue of red light we see with our naked eyes, when the rays lash destructive force. There are no absorption lines, just a single hue of brilliant red!"

The Italian pursed his lips in thought. "One frequency, perhaps. . . ?"

"If you insist on comparing light to your vulgar Hertzlan waves --"

So entranced was I by the discussion that I was almost knocked down by Beauchamp's frantic effort to gain my attention. I knew just one thing could bring him to behave so -- the Martians must nearly be upon us! With this supposition in mind, I turned, expecting to see a disk-like foot of a leviathan preparing to crush us.

Instead, Beauchamp, white as a ghost, stammered and pointed with a palsied hand. "Verne, regardez!"

To my amazement, the invaders had abruptly changed course, swerving from the direct route to the Seine. Instead they turned left and were stomping swiftly toward the part of town that Beauchamp and I had only just left, crushing buildings to dust as they hurried ahead. At the time, we shared a single thought. The commanders of the battle tripods must have spied the military camp on the

Champ-de-Mars. Or else they planned to wipe out the nearby military academy. It even crossed my mind that their objective might be the tomb of humanity's greatest general, to destroy that shrine, and with it our spirit to resist.

But no. Only much later did we realize the truth.

Here in Paris, our vanquishers suddenly had another kind of conquest in mind.

Flames spread as evening fell. Although the Martian rampage seemed to have slackened somewhat, the city's attitude of sang-froid was melting rapidly into frothy panic. The broad boulevards that Baron Haussmann gave the city during the Second Empire proved their worth as aisles of escape while buildings burned.

But not for all. By nightfall, Beauchamp and I found ourselves across the river at the new army headquarters, in the tree-lined Tuileries, just west of the Louvre -as if the military had decided to make its last stand in front of the great museum, delaying the invaders in order to give the curators more time to rescue treasures.

A great crowd surrounded a cage wherein, some said, several captured Martians cowered. Beauchamp rushed off to see, but I had learned to heed my subconscious -- (to use the terminology of the Austrian alienist, Freud) -- and wandered about the camp instead. Letting the spectacle play in my mind.

While a colonel with a sooty face drew arrows on a map, I found my gaze wandering to the trampled gardens, backlit by fire, and wondered what the painter, Camille Pissaro, would make of such a hellish scene. Just a month ago I had visited his apartment at 2.04 rue de Rivoli, to see a series of impressions he had undertaken to portray the peaceful Tuileries. Now, what a parody fate had decreed for these same gardens!

The colonel had explained that invader tripods came in two sizes, with the larger ones appearing to control the smaller. There were many of the latter kind, still rampaging the city suburbs, but all three of the great ones reported to be in Northern France had converged on the same site before nightfall, trampling back and forth across the Champ.de-Mars, presenting a series of strange behaviors that as yet had no lucid explanation. I did not need a military expert to tell me what I had seen with my own eyes . . . three titanic metal leviathans, twisting arid capering as if in a languid dance, round and round the same object of their fierce attention.

I wandered away from the briefing, and peered for a while at the foreign scientists. The Italian and the German were arguing vehemently, invoking the name of the physicist Boltzmann, with his heretical theories of "atomic matter," trying to explain why the heat ray of the aliens should emerge as just a single, narrow color. But the discussion was over my head, so I moved on.

The American and the Englishman seemed more pragmatic, consulting with French munitions experts about a type of fulminating bomb that might be attached to a Martian machine's kneecap -- if only some way could be found to carry it there . . . and to get the machine to stand still while it was attached. I doubted any explosive device devised overnight would suffice, since artillery had been next to useless, but I envied the adventure of the volunteer bomber, whoever it might be.

Adventure. I had spent decades writing about it, nearly always in the form of extraordinary voyages, with my heroes bound intrepidly across foaming seas, or under the waves, or over icecaps, or to the shimmering moon. Millions read my works to escape the tedium of daily life, and perhaps to catch a glimpse of the near future. Only now the future had arrived, containing enough excitement for anybody.

We did not have to seek adventure far away. It had come to us. Right to our homes.

The crowd had ebbed somewhat, in the area surrounding the prisoners' enclosure, so I went over to join Beauchamp. He had been standing there for hours, staring at the captives, our only prizes in this horrid war, lying caged within stout iron bars, a dismal set of figures, limp yet atrociously fascinating.

"Have they any new ideas?" Beauchamp asked in a distracted voice, while keeping his eyes focused toward the four beings from Mars. "What new plans from the military geniuses?"

The last was spoken with thick sarcasm. His attitude had changed since noon, most clearly.

"They think the key is to be found in the master tripods, those that are right now stomping flat the region near Eiffel's Spire. Never have all three of the Master Machines been seen so close together. Experts suggest that the Martians may use movement to communicate. The dance they are now performing may represent a conference on strategy. Perhaps they are planning their next move, now that they have taken Paris."

Beauchamp grunted. It seemed to make as much sense as any other proposal to explain the aliens' sudden, strange behavior. While smaller tripods roamed about, dealing destruction almost randomly, the three great ones hopped and flopped like horons in a marsh, gesticulating wildly with their flailing legs, all this in marked contrast to the demure solidity of Eiffel's needle.

For a time we stared in silence at the prisoners, whose projectile had hurtled across unimaginable space only to shatter when it struck an unlucky hard place on the Earth, shattering open and leaving its occupants helpless, at our mercy. Locked inside iron, these captives did not look impressive, as if this world weighed heavy on their limbs. Or had another kind of languor invaded their beings. A depression of spirits, perhaps?

"I have pondered one thing, while standing here," Beauchamp mumbled. "An oddity about these creatures. We had been told that everything about them came in threes . . . note the trio of legs, and of arms, and of eyes --"

"As we have seen in newspaper sketches, for weeks," I replied.

"Indeed: But regard the one in the center. The one around which the others arrayed themselves, as if protectively . . . or perhaps in mutual competition.?"

I saw the one he meant. Slightly larger than the rest, with a narrower aspect in the region of the conical head.

"Yes, it does seem different, somehow . . . but I don't see --"

I stopped, for just then I did see . . . and thoughts passed through my brain in a pell mell rush.

"Its legs and arms . . . there are four! Its symmetry is different! Can it be of another race ? A servant species, perhaps? Or something superior? Or else . . . "

My next cry was of excited elation.

"Beauchamp! The master tripods . . . I believe I know what they are doing!

"Moreover, I believe this beckons us with opportunity."

The bridges were sheer madness, while the river flowing underneath seemed chock-a-block with corpses. It took our party two hours to fight our way against the stream of panicky human refugees, before the makeshift expedition finally arrived close enough to make out how the dance progressed.

"They are closer, are they not.?" I asked the lieutenant assigned to guide us. "Have they been spiraling inward at a steady rate?"

The young officer nodded. "Oui, Monsieur. It now seems clear that all three are converging on Eiffel's Tower. Though for what reason, and whether it will continue --"

I laughed, remembering the thought that had struck me earlier -- a mental image of herons dancing in a swamp. The comparison renewed when I next looked upward in awe at the stomping, whirlinggyrations of the mighty battle machines, shattering buildings and making the earth shake with each hammer blow of their mincing feet. Steam hissed from broken mains. Basements and ossuaries collapsed, but the dance went on. Three monstrous things, wheeling ever closer to their chosen goal . . . which waited quietly, demurely, like a giant metal ingenue.

"Oh, they will converge all right, lieutenant. The question is-- shall we be ready when they do?"

My mind churned.

The essential task in envisioning the future is a capacity for wonder. I had said as much to journalists. These Martians lived in a future of technological effects we could but imagine. Only through such visualization could we glimpse their Achilles heel.

Now was the crucial moment when wonder, so long merely encased in idle talk, should spring forth to action.

Wonder . . . a fine word, but what did it mean? Summoning up an inner eye, which could scale up the present, pregnant with possibility, into . . . into . . .

What, then? Hertz, his waves, circuits, capacitors, wires --

Beauchamp glanced nervously around. "Even if you could get the attention of the military --"

"For such tasks the army is useless. I am thinking of something else." I said suddenly, filled with an assurance I could not explain. "The Martians will soon converge at the center of their obsession. And when they do, we shall be ready."

"Ready with what?"

"With what lies within our--" and here I thought of the pun, a glittering word soaring up from the shadowy subconscious "-- within our capacitance. "

The events of that long night compressed for me. I had hit upon the kernel of the idea, but the implementation loomed like an insuperable barrier.

Fortunately, I had not taken into account the skills of other men, especially the great leadership ability of my friend, M. Beauchamp. He had commanded a battalion against the Prussians, dominating his comer of the battlefield without runners. With more like him, Sedan would never have fallen. His voice rose above the streaming crowds, and plucked forth from that torrent those who still had a will to contest the pillage of their city. He pointed to my figure, whom many seemed to know. My heart swelled at the thought that Frenchmen -- and Frenchwomen! -- would muster to a hasty cause upon the mention of my name, encouraged solely by the thought that I might offer a way to fight back.

I tried to describe my ideas as briskly as possible . . . but alas, brevity has never been my chief virtue. So I suppressed a flash of pique when the brash American, following the impulsive nature of his race, leaped up and shouted --

"Of course! Verne, you clever old frog. You've got it!"

-- and then, in vulgar but concise French, he proceeded to lay it all out in a matter of moments, conveying the practical essentials amid growing excitement from the crowd.

With an excited roar, our makeshift army set at once to work.

I am not a man of many particulars. But craftsmen and workers and simple men of manual dexterity stepped in while engineers, led by the Italian and the American, took charge of the practical details, charging about with the gusto of youth, unstoppable in their enthusiasm. In fevered haste, bands of patriots ripped the zinc sheets from bars. They scavenged the homes of the rich in search of silver. No time to beat it into proper electrodes -- they connected decanters and candlesticks into makeshift assortments. These they linked with copper wires, fetched from the cabling of the new electrical tramways.

The electropotentials of the silver with the copper, in the proper conducting medium, would be monstrously reminiscent of the original "voltaic" pile of Alessandro Volta. In such a battery, shape does not matter so much as surface area, and proper wiring. Working through the smoky night, teams took these rode pieces and made a miracle of rare design. The metals they immersed in a salty solution, emptying the wine vats of the district to make room, spilling the streets red, and giving any true Frenchman even greater cause to think only of vengeance!

These impromptu batteries, duplicated throughout the arrondissement, the quick engineers soon webbed together in a vast parallel circuit. Amid the preparations, M. Beauchamp and the English scientist inquired into my underlying logic.

"Consider the simple equations of planetary motion," I said. "Even though shot from the Martian surface with great speed, the time to reach Earth must be many months, perhaps a year."

"One can endure space for such a time?" Beauchamp frowned.

"Space, yes. It is mere vacuum. Tanks of their air-- thin stuff, Professor Lowell assures us from his observations -- could sustain them. But think! These Martians, they must have intelligence of our rank. They left their kind to venture forth and do battle. Several years without the comforts of home, until they have subdued our world and can send for more of their kind."

The Englishman seemed perplexed. "For more?"

"Specifically, for their families, their mates . . . dare I say their wives! Though it would seem that not all were left behind. At least one came along in the first wave, out of need for her expertise, perhaps, or possibly she was smuggled along on the ill-fated missile that our forces captured."

Beauchamp bellowed. "Zut! The four-legged one. There are reports of no others. You are right, Verne. It must be rare to bring one of that kind so close to battle!"

The Englishman shook his head. "Even if this is so, I do not follow how it applies to this situation." He gestured toward where the three terrible machines were nearing the tower, their gyrations now tight, their dance more languorous. Carefully, reverentially, yet with a clear longing they reached out to the great spire that Paris had almost voted to tear down, just a few years after the Grand Exhibition ended. Now all our hopes were founded in the city's wise decision to let M. Eiffel's masterpiece stand.

The Martians stroked its base, clasped the thick parts of the tower's curving thigh -- and commenced slowly to climb.

Beauchamp smirked at the English scholar, perhaps with a light touch of malice. "I expect you would not understand, sir. It is not in your national character to fathom this, ah, ritual."

"Humph!" Unwisely, the Englishman used Beauchamp's teasing as cause to take offense. "I'll wager that we give these Martians a whipping before your lot does!"

"Ah yes," Beauchamp remarked. "Whipping is more along the lines of the English, I believe."

With a glance, I chided my dear friend. After all, our work was now done. The young, the skilled, and the brave had the task well in hand. Like generals who have unleashed their regiments beyond recall, we had only to observe, awaiting either triumph or blame.

At dawn, an array of dozens and dozens of Volta batteries lay scattered across the south bank of the Seine. Some fell prey to rampages by smaller Martian machines, while others melted under hasty application of fuming acids. Cabling wound through streets where buildings burned and women wept. Despite all obstacles of flame, rubble, and burning rays, all now terminated at Eiffel's tower.

The Martians' ardent climb grew manifestly amorous as the sun rose in piercing brilliance; warming our chilled bones: I was near the end of my endurance, sustained only by the excitement of observing Frenchmen and women fighting back with ingenuity and rare unity. But as the Martians scaled the tower-- driven by urges we can guess by analogy alone -- I began to doubt. My scheme was simple, but could it work?

I conferred with the dark Italian who supervised the connections.

"Potentials? Voltages?" He screwed up his face. "Who has had-a time to calculate. All I know, M'sewer, iz that we got-a plenty juice. You want-a fry a fish, use a hot flame."

I took his point. Even at comparatively low voltages, high currents can destroy any organism. A mere fraction of an Ampere can kill a man, if his skin is made a reasonable conductor by application of water, for example. Thus, we took it as a sign of a higher power at work, when the bright sun fell behind a glowering black cloud, and an early mist rolled in from the north. It made the tower slick beneath the orange lamps we had festooned about it.

And still the Martians climbed.

It was necessary to coordinate the discharge of so many batteries in one powerful jolt, a mustering of beta rays. Pyrotechnicians had taken up positions beside our command post, within sight of the giant, spectral figures which now had mounted a third of the way up the tower.

"Hey Verne!" The American shouted, with well-meant impudence. "You're on !"

I turned to see that a crowd had gathered. Their expressions of tense hope touched this old man's heart. Hope and faith in my idea. There would be no higher point in the life of a fabulist.

"Connect!" I cried. "Loose the hounds of electrodynamics!"

A skyrocket leaped forth, trailing sooty smoke-- a makeshift signal, but sufficient.

Down by the river and underneath a hundred ruins, scores of gaps and switches closed. Capacitors arced. A crackling rose from around the city as stored energy rushed along the copper cabling. I imagined for an instant the onrushing mob of beta rays, converging on --

The invaders suddenly shuddered, and soon there emerged thin, high cries, screams that were the first sign of how much like us they were, for their wails rose in hopeless agony, shrieks of despair from mouths which breathed lighter air than we, but knew the same depths of woe.

They toppled one by one, tumbling in the morning mist, crashing to shatter on the trampled lawns and cobblestones of the ironically named Champ-de-Mars . . . marshaling ground of the god of war, and now graveyard of his planetary champions.

The lesser machines, deprived of guidance, soon reeled away, some falling into the river, and many others destroyed by artillery, or even enraged mobs. So the threat ebbed from its horrid peak . . . at least for the time being.

As my reward for these services, I would ask that the site be renamed, for it was not the arts of battle which turned the metal monsters into burning slag. Nor even Zeus's lightning, which we had unleashed. In the final analysis, it was Aphrodite who had come to the aid of her favorite city.

What a fitting way for our uninvited guests to meet their end -- to die passionately in Paris, from a fatal love.

SELFNESS

By Gregory Benford

I am a clone.

Or rather, I am better than one. Or so any identical twin surely must see the matter.

The recent media feeding frenzy about a cloned sheep, Dolly, showed us journalism in its fullest modern form. Many of those writing about this genuine watershed moment in techno-culture followed current journalist practice: their foremost research instrument was the telephone. Of those who called me--an unlikely authority, since I am not a biologist--none realized that DNA does not solely determine the heritage a child gets from its parents.

My brother, Jim, and I shared a womb without a view for nine months. (Though not always restfully, our mother reports.) Genetically identical, we also enjoyed the same currents and chemicals of our mother. After a rather traumatic birth--both had our appendixes removed within days--we were brought up in the same house, with constant attentive parents, and even wore matching clothes until our late teens. (How much trauma this clothing ritual induced in our personalities I leave to others to decide; suffice to say that being seen as sugary-cute has left me with a decided prejudice against sweets in any form.)

True twins share womb chemistry and endure many fateful slings and arrows together. The fabled connection between twins is true, in my case. We are distantly dismissive of mere fraternal twins (different DNA) and regard all others as "singletons," those condemned by birth to endure the isolation of never truly sharing the intuitive grasp that we enjoy without paying a price.

Or nearly so. There is mild statistical evidence that identicals have slightly lower IQ. This might be plausibly so; the comfort of ready communication may well lead to a certain mental laziness.

Jim and I felt the opposite. Reared in rural southern Alabama, we enjoyed an idyllic Huck Finn boyhood. But education there was casual at best. Our mother and father were high school teachers, and challenged the pervasive easy-going ignorance. We attended a one- room schoolhouse, with each row of seats a separate grade. Against this my brother and I united, reading widely and enjoying the clash of cultures which paraded by. After we were 9 our father became a career Army officer, whisking us to Japan for three years, Germany for another three, and further isolating the twins from a continuity that might have sucked us into the conventional.

So we are an odd pair even among twins. Jim got his doctorate from the same institution as I, UC San Diego, in the same area (plasma physics) and now lives a few kilometers from where I once lived, in northern California. Such correlations appear often among twins. We grow up in a culture of sameness, so have a sense of self always shared.

Among singletons, interest in twins is enduring. Do we feel some mystical sense of connection? Of course; but whether it is mystical or not begs description. I am writing this at 35,000 feet over Greenland, on the way back to UC Irvine from Lapland. I know without thinking about it that my brother is probably body surfing on a beach near La Jolla, though I have not spoken to him for ten days. I remember his itinerary and without conscious deliberation feel where he is likely to be. This is processing at the unconscious level, and as an experiment, when I see him in two days I shall check with him and let you know the outcome. [Later: my estimate was right to within the hour.]

But this is scarcely mystical. Instead, I attribute the innumerable similar incidents in our lives to a lot of automatic thinking, based on intuitions cooked up through more than five decades. To singletons this can look uncanny.

Speaking as a twin, clones seem a lesser form. They grow up in a later era than their genetic duplicates, with different upbringings. Would knowing that they were genetic duplicates trouble them? Surely such people would not be inherently more mentally fragile; Siamese twins are far more like each other than ordinary twins, yet suffer no higher incidence of mental illness than is usual, suggesting that even extreme parallels in nature and nurturer are not damaging.

The furor over Dolly puzzled me by the emotional level of debate. Reasonable people like political commentator George Will asked, "What if the great given--a human being is a product of the union of a man and a woman--is no longer a given?" This issue properly comes from a broader issue in biotechnology, the entire field of artificial birth in all forms, for there are no precise boundaries in this new territory.

Certainly I see no reason why society should prevent grieving parents from having a baby cloned from the cells of a dead child, if they wish. Beyond such emotionally wrenching cases, where should we erect walls? Oxford biologist Richard Dawkins asserted that he could see purely intellectual issues intriguing enough to justify cloning himself: "I think it would be mind-boggingly fascinating to watch a younger edition of myself growing up in the twenty-first century instead of the 1940s."

Many no doubt find his position puzzling or even immoral or disgusting. Even so, why should Dawkins be prevented from having a cloned child? What is society's mandate?

The Dolly debate produced several claims that cloning violated the fundamental principle of individual dignity. Twins certainly belie that argument. Fears of interchangeable people armies, usually marching robotically onward, come from a simple-minded genetic determinism. And the grounds for a principle of uniqueness seem vague at best.

After all, why treat clones differently?--we twins and clones are all "monozygotes", as the biologists put it. In fact, clones necessarily separate in outside influences from their first moments in the womb, for the wombs are different. Another's DNA inserted into a host egg will acquire "maternal factors" from the proteins of that egg, affecting later development. The womb's complex chemical mix varies with each mother, so nine months of different "weather" will change the outcome in the fetus; the baby will not be a photocopy of its older original.

And clones will be full-fledged people with all rights attendant to that status. Nobody forces twins to serve as organ farms for their other twin; clones would have the same legal status.

The true first use of cloning will undoubtedly be in the "copying" of highly selected farm animals. These could first be excellent milk cows or racing horses. More futuristically, we shall see--and quite soon-- the cloning of "pharm" animals which yield biotech products of use to us, such as insulin-rich milk from cows, and a whole array of therapeutic hormones, enzymes and proteins.

Plants have already been extensively engineered. More than three-quarters of the cotton grown in Alabama last year was genetically tuned to kill predatory insects. Already scientists are experimenting with cotton plants that contain polyester fibers, too, surely a boon for fans of leisure suits.

Still, cloning should indeed furrow the brow of long- perspective thinkers. We believe sexual reproduction holds sway over much of the kingdom of life because it provides ever-new gene mixes, allowing a species to build fresh defenses against the ever-mutating pathogens that infest the natural world. The perpetual arms race between prey and predator favors sex as a defense. Seen this way, we are men and women because the primary predator on humans have always been microbes, not tigers.

So "pharm" animals cloned over and over will face the very real threat of infectious diseases which wipe out a herd overnight. But surely nobody will clone huge numbers of humans, so such plagues will be quite unlikely. The breeds of influenza that regularly attack us genetically diverse humans will do far more damage.

As I write this, a presidential panel seems about to recommend a uniform federal ban on human cloning experiments. I believe this will be a mistake, generally, and an ineffective move anyway. The technology is fairly simple; others will pick it up. In Latin American countries or on offshore islands, clinics will offer the service at a hefty charge. Underground, without legal oversight, we will indeed see some tragedies and even horrors.

Bioethics is a field with many practitioners but few obviously qualified savants. Often the bans which spring from such federal committees prove ill-advised, their only long-term effects negative. This was the case with the two-year moratorium on recombinant DNA, which simply slowed the field without deciding anything. So did similar bans on selling organs or blood, and I predict, so shall the recent Clinton prohibition on using human embryos in federally backed medical research. The ultimate price for these momentary interruptions -- and so far they have always been momentary -- is lives lost because the resultant technology arrives too late for some patients.

Bioethicists tend to see problems everywhere, and saying no gives them visible power. Letting technology evolve willy-nilly, responding to what people want -- maybe even people without advanced degrees! -- gives bioethicists no perks or prominence; unsurprising, then, that they seldom go that route. They aren't the patients clinging to life, or infertile, or stunted in some potentially fixable way.

They also tend to think collectively, omitting the inconvenient needs of real people. Bioethics professor George Annas of Boston University flatly demands, "I want to put the burden of proof on scientists to show us why society needs this before society permits them to go ahead and [do] it." Note that he does not require this rule in his own work, including testing the above sentence by its own standards. Instead, Virginia Postrel has noted of Annas and many others, "We will hear the natural equated with the good, and fatalism lauded as maturity. That is a sentiment about which both green romantics and pious conservatives agree."

Indeed. We would save ourselves much trouble if we could agree that the proper place for most bioethical thought lies in counseling those affected, not in dictating the spectrum of possibilities.

#

Cloning arouses anxieties stemming from a general uncertainty with the very concept of the self. Legally, even the mind-body unity seems shaky. In 1991 the California Supreme Court decided that a cancer patient did not have a right to share in the profits from UCLA's use of his diseased cells to produce new drugs. This meant that a patient does not even own his own body, and so his integral self is not simply bodily.

Consciousness seems to us to be slippery and yet intuitively obvious. We feel ourselves to be the same person all along our life- trajectory, unique and self-contained. Just as an ant colony or a baseball game has an integrity even as its insects or players change, we have an irreducible selfness.

Of course, such assertions are hard to prove. (Indeed, proving who you are is done by showing a partial copy of yourself-- fingerprints, or a drivers' license.) We all readily assent to knowing that we experience a continuous self.

Yet we fall asleep every day, a loss of conscious continuity. People who lapse into year-long comas can emerge again with the same personality. Still better, patients in brain operations who have their heads chilled down until they are legally brain dead, with no alpha and beta rhythms at all, are still themselves when they are warmed back up and revived. Their memories and mannerisms come through intact.

Over what spans of time and condition can we keep our sense of selfness unbroken?

The bedrock issue of preserving one's selfness then intersects the increasing interest in prolonging life--if necessary by either freezing oneself after death, or even "uploading" into computers.

Making yourself into a computer file and programs fits one present picture of our Self: the mind is software running on the hardware of the brain. The Self, then, is whatever program is running on your customized operating system, one developed by the rubs and rituals of your upbringing.

Of course, such an analogy is suspect, for our brains self- program themselves, laying down memories in chemical pathways that are not simply erased, and aren't under our conscious control.

But the uploader's central point is that one can copy a mind much as a tape copies a piece of music, without knowing how music is made. The brain, they say, is the same.

Minds are self-organizing, evolving systems, however, unlike fixed musical works; but the image is striking, still. Where does it lead us?

The first novel about uploading, Charles Platt's 1991 The Silicon Man, does not directly confront a basic problem of copying, Levinson's Paradox: To the degree that a copy approaches perfection, it defeats itself. In being an absolutely perfect copy --so that no one can tell it from the original--it transforms the original into a duplicate. This means the perfect copy is no longer a perfect copy, because it has obliterated, rather than preserved, the uniqueness of the original--and thus failed to copy a central aspect of the original.

A perfect, artificial human intelligence would inevitably have this effect on its natural original. Sf author Paul Levinson pointed out this feature, hinting that it portended even deeper problems, in the 1980s. While the paradox may seem a mere logical quibble, it underlines how little we know of how much fidelity to the original truly implies that the self has been preserved.

No mere technological improvement can remove this logical difficulty. Given enough memory maintenance, we could maintain numerical versions of ourselves, assuming that the recording process would not destroy our fleshy originals.

This raises great troubles, though. Termed variously Dittos, Duplicates or Copies, these digital entities lead a tenuous existence. Real, fleshy folk would decisively reject the Copy Fallacy: the belief that a digital Self was identical to the Original, and that an Original should feel that a Ditto itself somehow carried them forward into immortality. (As long as nobody pulls the plug, of course.)

Refuting this Copy Fallacy is straightforward. Imagine yourself promised that you will be resurrected digitally, immediately after your death. Assign a price tag you will pay for that, insurance of a sort. Then imagine the guy who sells you on this notion saying that, uh, well, maybe it would not be started right away, but sometime in future...we promise. As that date recedes, people's enthusiasm for paying for Self Copies dims -- demonstrating that it is the hope of continuity they unconsciously relish.

As an identical twin, I have never bought the Copy Fallacy in any form. Though my brother and I have diverged in personality and appearance, due to differing environments and histories, for the first twenty years of our lives few could tell us apart. He and I could, though, and that's the nub of the argument: the Self is defined internally, not externally.

In the end, Copies benefit themselves, not the dead; machine immortality is more like having your twin live on, not yourself.

Some thinkers about computer identities, in the years since publication of The Silicon Man, have begun to push an agenda of Copy rights -- the expansion of classical liberty into the digital wilderness. Dittos still will be people, the argument goes, with different skills and drawbacks, rather like the "differently abled."

The freedom to change your own clock speed, morph into anything, or even remake your own mind, goes along with the admitted liability of not being physically real. Unable to literally walk the streets, they will be like amputated souls.

Platt envisioned tele-presencing and some digital prosthetics that might reach in limited fashion into the concrete universe, but these would be re-creations; if a Ditto feared for its life, why lurk fully in the dangerous real world?

Also, "rights" for Dittos also get tied up with our own deep- seated fears -- of digital immortals who amass wealth and like fungus reach into every avenue of natural, real lives; parasites, nothing less. Platt plainly foresees issues looming over the horizon, as soon as the digital world amasses financial power. Tycoon Dittos!

Running a Ditto of your Self, then giving it autonomy, means it could get rich and also change itself. Your Ditto could shape its own motivations, goals, habits, edit away memories and tastes. It then stops mimicking your own evolution. Your Ditto could erase any liking for Impressionist Opera and overlay instead a passion for rap, enjoying rhythms that would have bored the true Self into a coma. The easy access of a Ditto to his entire underpinning -- unlike ourselves, with much of our personality lying in our subconscious and not consciously fixable -- implies constant change, personality tinkering, perhaps worse.

#

Is consciousness just a property of special algorithms, sliding sheets of information, digital packets jumping through conceptual hoops? How we envision our selfness depends on this huge question, now a hot topic.

Does a model simulating watching a sunset have to feel the same way its Original did? Why doubt simulated consciousness, when nobody asked the same question of programs that balance checkbooks? Such issues perplex many philosophers today, but I think feeling one's way through them in fiction is a rather more revealing path than abstract argument.

Consider that a Ditto is forcefully reminded that he is not the Original, but a mere fog of digits. All that gives him a sense of Self as continuity is the endless stepping forward of pattern. In people, the "real algorithm", computes itself by firing synapses, ringing nerves, getting the feel of continuity from the dance of cause and effect.

Dittos on the other hand are simply time-stepped forward, in processes that could just as easily run backward without the Ditto even noticing. Even time is fragile, a convention, in a digital universe.

Dittos surely would stand on shaky metaphysical ground here. Would we find that a Ditto fidgeted out of pure self-anxiety? His digital stress chem shoots up, metabolics lurch, heart-sims hammer, lungs flutter in intense uneasiness? Would typical Dittos talk incessantly, acutely uncomfortable, and make odd demands of their keepers?--that they be edited, truncated, improved, perhaps finally killed?

The dream of bodiless existence does not imply the end of the human condition, if we are still truly simulating humans.

Consider how well one would have to describe what our everyday life is like. Making a Ditto's body seem right to its critical intelligence demands sets of overlapping rules. After all, the Ditto remembers what a pleasure eating, say, used to be, back there in the gritty, real world.

As he (or she) chews, teeth have to thunk down on food, saliva squirt to greet the munched mass, enzymes started to work to extract the right nutrient ratios. The program can bypass the involved stomach and colon processes, simplifying into a satisfying concentration of blood sugars, giving him a carbohydrate lift, a pleasant electrolyte balance, hormones and stabilizers all calculated with patchwork templates for the appropriate emotional levels.

The body becomes a set of recipes for seeming like oneself. No underlying physics or biology at work, just a good-enough fake, put in by hand--the unseen hand of some Programmer God. So emerges an existential angst as profound as anything Camus felt, surely.

All other detail can be discarded, once the subroutines got right effect, simulating the tingling of nerve endings. All this is to ground a visceral sense of Self, seemingly rock-solid, though really just a patched-in slug of digits, orchestrated by a mosaic of ten thousand ad hoc rules, running together.

So much effort, just to approximate what we get for free every day!

But of course, digital selves need not age or die, as long as somebody pays the power bill and doesn't pull the plug on us. Ordinary fear of mortal death will become a fear of being cut off, your Self never run again. Each interruption in running the Self will come to a Ditto as a possible final end, for he cannot act in the world while not running.

Indeed, when booted up again, he might not be able to tell he had suffered a hesitation-death, or whether it was a mere second or a hundred years of real time. This is a kind of heavenly eternity, to some. To me it seems like a hell of existential anxiety. If to us twins, singletons have to go through life with rather rickety mental identities, think of a Ditto's lot!

But the possibilities! proclaim some of the uploading Digiterati.

With enough computing space and speed, one could be King Me the Magnanimous, endowing many proto-Michelangelos with creative time...or perhaps becoming Michelangelo oneself, with time. What if genius is just a matter or accumulating greater computing capacity?

Rebuilding yourself from the ground up then emerges as at least a hope. That which is buried in the digits might be harvested, changed. Learn to freezeframe your own emotional states, like painting a self portrait for study later. Perhaps that could help understand oneself, like a botanist putting himself on a slide and under a microscope. Could slices of the Self, multiplied, be the Self? With even emotions as programs?

Such ideas run through Platt's seminal book. They provoked later writers like Greg Egan, who in Permutation City sees a special SelfHood Suite menu, eerie in its temptations. With it one could present interior-configurations as separate subroutines, elements in the modeled brain. Here, grouped under headings--Qualms, Anxieties, Aversions, Likes, Habits, Unconscious Appeals--could rest items he could edit, improve, erase entirely. Not knowing what the Self is, which irreducible kernel of menu items define oneself, for oneself, suggests that Dittos will be tempted into rapt navel gazing.

Given the chance, which would you choose in pursuit of "immortality" -- uploading or cryonics? Forget about the probabilities of success -- each seems fraught with peril. (In an earlier column I estimated that the probability of being successfully frozen and later revived by future technology was at best one percent. A small chance, but infinitely larger than plain, flat zero...)

Uploading gives a pure Copy; cryonics yields your own brain, no doubt altered by much chemistry and microengineering necessary to pull your consciousness back out of the ice.

Which is truer? As far as I know, sf has yet to confront this question.

My intuitive choice is cryonics. At least in its perfect form, you recover the true you, the original synapses and holistic organization of the hopelessly complex brain. With uploading, you at best get a model of yourself, a rendering in 0s and 1s which reproduces for an outside audience--though not including you, the true best critic--your basic personality and memories.

Of course, having your brain frozen leaves out much: your physiology, your body instincts, will have to come from some body grown from your own cells (the reproductive ones, probably) to accompany the revival of your brain.

Here the cloning of humans is essential. Current cryonics organizations (I know of four) routinely preserve not just the head of their patients, but the reproductive organs and other body samples.

The idea is to send forward in time as much information as possible. While some patients elect to have their entire bodies frozen in liquid nitrogen, a far more expensive proposition, most take the head-only route.

They anticipate that a body can be cloned for them at some far future date when it will not only be technically possible, but even fairly inexpensive. Even more, they trust that no medical prohibitions will have halted cloning research. Further, cryonicists hope that cloning technology will have avoided the clear dangers.

But if a body is grown for a defrosted and repaired head, what becomes of the body's head? Was it deliberately stunted from "birth", so that it never developed as a conscious human? It seems unlikely that anyone could grow a body in some chemical vat, no matter how sophisticated, without using the many complex functions that the brain provides for that body.

So even to envision cryonics proceeding, one must require that future society has solved both scientific and moral questions about selfness and its implications. This is not an easy future to foresee, not at all.

But remember that the future is infinite, or at least very long indeed. Note how primitive medicine was a mere century ago. A few more centuries of steady growth could yield a social and philosophical landscape beyond our present comprehension.

Suppose cryonics could work. You would have grabbed back from time's maw the pure raw stuff of Self. Cybernetics gives a digital model, one always suspect because it has to choose how to configure the myriad data points of any brain-readout.

Choice begets the particular, and to have the whole Self, you must have the true, full general Self, in whatever deep labyrinths it lies.

A collection of essays by Gregory Benford

+ a few extras…

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Compiled byNamtillaku

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GREGORY BENFORD

THE FAR FUTURE

Little science fiction deals with truly grand perspectives in time. Most stories and novels envision people much like ourselves, immersed in cultures that quite resemble ours, and inhabiting worlds which are foreseeable extensions of the places we now know.

Such landscapes are, of course, easier to envision, more comfortable to the reader, and simpler for the writer; one can simply mention everyday objects and let them set the interior stage of the reader's mind.

Yet some of our field's greatest works concern vast perspectives. Most of Olaf Stapledon's novels (Star Maker, Last And First Men) are set against such immense backdrops. Arthur C. Clarke's Against the Fall of Night opens over a billion years in our future. These works have remained in print many decades, partly because they are rare attempts to "look long" -- to see ourselves against the scale of evolution itself.

Indeed, H.G. Wells wrote The Time Machine in part as a reaction to the Darwinian ideas which had swept the intellectual world of comfortable England. He conflated evolution with a Marxist imagery of racial class separation, notions that could only play out on the scale of millions of years. His doomed crab scuttling on a reddened beach was the first great image of the far future.

Similarly, Stapledon and Clarke wrote in the dawn of modern cosmology, shortly after Hubble's discovery of universal expansion implied a startlingly large age of the universe. Cosmologists believed this to be about two billion years then. From better measurements, we now think it to be at least five times that. In any case, it was so enormous a time that pretensions of human importance seemed grotesque. We have been around less than a thousandth of the universe's age. Much has gone before us, and even more will follow.

In recent decades there have been conspicuously few attempts to approach such perspectives in literature. This is curious, for such dimensions afford sweeping vistas, genuine awe. Probably most writers find the severe demands too daunting. One must understand biological evolution, the physical sciences, and much else -- all the while shaping a moving human story, which may not even involve humans as we now know them. Yet there is a continuing audience for such towering perspectives.

"Thinking long" means "thinking big." Fiction typically focuses on the local and personal, gaining its power by unities of time and setting. Fashioning intense stories against huge backdrops is difficult. And humans are special and idiosyncratic, while the sweep of time is broad, general and uncaring.

We are tied to time, immense stretches of it. Our DNA differs from that of chimps by only 1.6 percent; we lords of creation are but a hair's breadth from the jungle. We are the third variety of chimp, and a zoologist from Alpha Centauri would classify us without hesitation along with the common chimp of tropical Africa and the pygmy chimp of Zaire. Most of that 1.6 percent may well be junk, too, of no genetic importance, so the significant differences are even smaller.

We carry genetic baggage from far back in lost time. We diverged genetically from the Old World monkeys about 30 million years ago, from gorillas about ten million years ago, and from the other chimps about seven million years ago. Only 40 thousand years ago did we wondrous creatures appear -- meaning our present form, which differs in shape and style greatly from our ancestor Neanderthals. We roved further, made finer tools, and when we moved into Neanderthal territory, the outcome was clear; within a short while, no more Neanderthals.

No other large animal is native to all continents and breeds in all habitats, from rainforests to deserts to the poles. Among our unique abilities which we proudly believe led to our success, we seldom credit our propensity to kill each other, and to destroy our environment--yet there are evolutionary arguments that these were valuable to us once, leading to pruning of our genes and ready use of resources.

These same traits now threaten our existence. They also imply that, if we last into the far future, those deep elements in us will make for high drama, rueful laughter, triumph and tragedy.

While we have surely been shaped by our environment, our escape from bondage to our natural world is the great theme of civilization. How will this play out on the immense scale of many millennia? The environment will surely change, both locally on the surface of the Earth, and among the heavens. We shall change with it.

We shall probably meet competition from other worlds, and may fall from competition to a Darwinian doom. We could erect immense empires and play Godlike games with vast populations. And surely we could tinker with the universe in ingenious ways, the inquisitive chimpanzee wrestling whole worlds to suit his desires. Once we gain great powers, we can confront challenges undreamed of by Darwin. The universe as a whole is our ultimate opponent.

In the very long run, the astrologers may turn out to be right: our fates may be determined by the stars. For they are doomed.

Stars are immense reservoirs of energy, dissipating their energy stores into light as quickly as their bulk allows. Our own star is 4.3 billion years old, almost halfway through its eleven billion year life span. After that, it shall begin to burn heavier and heavier elements at its core, growing hotter. Its atmospheric envelope of already incandescent gas shall heat and swell. From a mild-mannered, yellow-white star it shall bloat into a reddened giant, swallowing first Mercury, then Venus, then Earth and perhaps Mars.

H.G. Wells foresaw in The Time Machine a dim sun, with a giant crablike thing scuttling across a barren beach. While evocative, this isn't what astrophysics now tells us. But as imagery, it remains a striking reflection upon the deep problem that the far future holds -- the eventual meaning of human action.

About 4.5 billion years from now, our sun will rage a hundred times brighter. Half a billion years further on, it will be between 500 and a thousand times more luminous, and seventy percent larger in radius. The Earth's temperature depends only slowly on the sun's luminosity (varying as the one fourth root), so by then our crust will roast at about 1400 degrees Kelvin, room temperature is 300 Kelvin. The oceans and air will have boiled away, leaving barren plains beneath an angry sun which covers thirty-five degrees of the sky.

What might humanity -- however transformed by natural selection, or by its own hand -- do to save itself? Sitting further from the fire might work. Temperature drops inversely with the square of distance, so Jupiter will be cooler by a factor of 2.3, Saturn by 3.1. But for a sun 500 times more luminous than now, the Jovian moons will still be 600 degrees Kelvin (K), and Saturn's about 450 K. Uranus might work, 4.4 times cooler, a warm but reasonable 320 K. Neptune will be a brisk 255 K. What strange lives could transpire in the warmed, deep atmospheres of those gas giants?

Still, such havens will not last. When the sun begins helium burning in earnest it will fall in luminosity, and Uranus will become a chilly 200 K. Moving inward to Saturn would work, for it will then be at 300 K, balmy shirtsleeve weather -- if we have arms by then.

The bumpy slide downhill for our star will see the sun's luminosity fall to merely a hundred times the present value, when helium burning begins, and the Earth will simmer at 900 K. After another fifty million years --how loftily astrophysicists can toss off these immensities! -- as further reactions alter in the sun's core, it will swell into a red giant again. It will blow off its outer layers, unmasking the dense, brilliant core that will evolve into a white dwarf. Earth will be seared by the torrent of escaping gas, and bathed in piercing ultraviolet light. The white-hot core will then cool slowly.

As the sun eventually simmers down, it will sink to a hundredth of its present luminosity. Then even Mercury will be a frigid 160 K, and Earth will be a frozen corpse at 100 K. The solar system, once a grand stage, will be a black relic beside a guttering campfire.

To avoid this fate, intelligent life can tinker -- at least for a while -- with stellar burning. Our star will get into trouble because it will eventually pollute its core with the heavier elements that come from burning hydrogen. In a complex cycle, hydrogen fuses and leaves assorted helium, lithium, carbon and other elements. With all its hydrogen burned up at its core, where pressures and temperatures are highest, the sun will begin fusing helium. This takes higher temperatures, Which the star attains by compressing under gravity. Soon the helium runs out. The next heavier element fuses. Carbon bums until the star enters a complex, unstable regime leading to swelling. (For other stars than ours, there could even be explosions (supernovas) if its mass is great enough.)

To stave off this fate, a cosmic engineer need only note that at least ninety percent of the hydrogen in the star is still unburned, when the cycle turns in desperation to fusing helium. The star's oven lies at the core, and hydrogen is too light to sink down into it.

Envision a great spoon which can stir the elements in a star, mixing hydrogen into the nuclear ash at the core. The star could then return to its calmer, hydrogen-fusing reaction.

No spoon of matter could possibly survive the immense temperatures there, of course. But magnetic fields can move mass through their rubbery pressures. The sun's surface displays this, with its magnetic arches and loops which stretch for thousands of kilometers, tightly clasping hot plasma into tubes and strands.

If a huge magnetic paddle could reach down into the sun's core and stir it, the solar life span could extend to perhaps a hundred billion years. To do this requires immense currents, circulating over coils larger than the sun itself.

What "wires" could support such currents, and what battery would drive them? Such cosmic engineering is beyond our practical comprehension, but it violates no physical laws. Perhaps, with five billion years to plan, we can figure a way to do it. In return, we would extend the lifetime of our planet tenfold.

To fully use this extended stellar lifetime, we would need strategies for capturing more sunlight than a planet can. Freeman Dyson envisioned breaking up worlds into small asteroids, each orbiting its star in a shell of many billions of small worldlets. These could in principle capture nearly all the sunlight. We could conceivably do this to the Earth, then the rest of the planets.

Of course, the environmental impact report for such engineering would be rather hefty. This raises the entire problem of what happens to the Earth while all these stellar agonies go on. Even if we insure a mild, sunny climate, there are long term troubles with our atmosphere.

Current thinking holds that the big long term problem we face is loss of carbon dioxide from our air. This gas, the food of the plants, gets locked up in rocks. Photosynthetic organisms down at the very base of the food chain extract carbon from air, cutting the life chain.

We might fix this by bioengineering organisms that return carbon dioxide. Then we would need to worry about the slow brightening of our sun, which would make our surface temperature about 80 degrees Centigrade in 1.5 billion years. Compensating for this by increasing our cloud cover, say, would work for a while. A cooling cloud blanket will work for a while. Still, we continually lose hydrogen to space, evaporated away at the top of the atmosphere. Putting water clouds up to block the sunlight means that they, too, will get boiled away. Even with such measures, liquid water on Earth would evaporate in about 2.5 billion years from now. Without oceans, volcanoes would be the major source for new atmospheric elements, and we would evolve a climate much like that of Venus.

All this assumes that we don't find wholly new ways of getting around planetary problems. I suspect that we crafty chimpanzees probably shall, though. We like to tinker and we like to roam. Though some will stay to fiddle with the Earth, the sun and the planets, some will move elsewhere.

After all, smaller stars will live longer. The class called M dwarfs, dim and red and numerous, can burn steady and wan, for up to a hundred billion years, without any assistance. Then even they will gutter out. Planets around such stars will have a hard time supporting life, because any world close enough to the star to stay warm will also be tide locked, one side baked and the other freezing. Still, they might prove temporary abodes for wandering primates, or for others.

Eventually, no matter what stellar engine we harness, all the hydrogen gets burned. Similar pollution problems beset even the artificially aged star, now completely starved of hydrogen. It seethes, grows hotter, sears its planets, then swallows them.

There may be other adroit dodges available to advanced lifeforms, such as using the energy of supernovas. These are brute mechanisms, and later exploding stars can replenish the interstellar clouds of dust and gas, so that new stars can form -- but not many. On average, matter gets recycled in about four billion years in our galaxy. Our own planet's mass is partly recycled stellar debris from the first galactic supernova generation. This cycle can go on until about 20 billion years pass, when only a ten-thousandth of the interstellar medium will remain. Dim red stars will glow in the spiral arms, but the great dust banks will have been trapped into stellar corpses.

So unavoidably, the stars are as mortal as we. They take longer, but they die.

For its first fifty billion years, the universe will brim with light. Gas and dust will still fold into fresh suns. For an equal span the stars would linger. Beside reddening suns, planetary life will warm itself by the waning fires that herald stellar death.

Sheltering closer and closer to stellar warmth, life could take apart whole solar systems, galaxies, even the entire Virgo cluster of galaxies, all to capture light. In the long run, life must take everything apart and use it, to survive.

To ponder futures beyond that era, we must discuss the universe as a whole.

Modern cosmology is quite different from the physics of the Newtonian worldview, which dreamed uneasily of a universe that extended forever but was always threatened by collapse. Nothing countered the drawing-in of gravity except infinity itself. Though angular momentum will keep a galaxy going for a great while, collisions can cancel that. Objects hit each other and mutually plunge toward the gravitating center. Physicists of the Newtonian era thought that maybe there simply had not been enough time to bring about the final implosion. Newton, troubled by this, avoided cosmological issues.

Given enough time, matter will seek its own kind, stars smacking into each other, making greater and greater stars. This will go on even after the stars gutter out.

When a body meets a body, coming through the sky . . . Stars will inevitably collide, meet, merge. All the wisdom and order of planets and suns will finally compress into the marriage of many stars, plunging down the pit of gravity to become black holes. For the final fate of nearly all matter shall be the dark pyre of collapse.

Galaxies are as mortal as stars. In the sluggish slide of time, the spirals which had once gleamed with fresh brilliance will be devoured by ever-growing black holes. Inky masses will blot out whole spiral arms of dim red. The already massive holes at galactic centers will swell from their billion-stellar-mass sizes at present, to chew outward, gnawing without end.

From the corpses of stars, collisions will form either neutron stars or black holes, within about a thousand billion years (in exponential notation, 10[sup 12] years). Even the later and longest-lived stars cannot last beyond 10[sup 14] years. Collisions between stars will strip away all planets in 10[sup 15] years.

Blunt thermodynamics will still command, always seeking maximum disorder. In 10[sup 17] years, the last white dwarf stars will have cooled to be utterly black dwarfs, temperatures about 5 degrees Kelvin (Absolute). In time, even hell would freeze over.

Against an utterly black sky, shadowy cinders of stars will glide. Planets, their atmospheres frozen out into waveless lakes of oxygen, will glide in meaningless orbits, warmed by no ruby star glow. The universal clock would run down to the last tick of time.

But the universe is no static lattice of stars. It grows. The Big Bang would be better termed the Enormous Emergence, space-time snapping into existence intact and whole, of a piece. Then it grew, the fabric of space lengthening as time increased.

With the birth of space-time came its warping by matter, each wedded to the other until time eternal. An expanding universe cools, just as a gas does. The far future will freeze, even if somehow life manages to find fresh sources of power.

Could the expansion ever reverse? This is the crucial unanswered riddle in cosmology. If there is enough matter in our universe, eventually gravitation will win out over the expansion. The "dark matter" thought to infest the relatively rare, luminous stars we see could be dense enough to stop the universe's stretching of its own space-time. This density is related to how old the universe is.

We believe the universe is somewhere between 8 and 16 billion years old. The observed rate of expansion (the Hubble constant) gives 8 billion, in a simple, plausible model. The measured age of the oldest stars gives 16 billion.

This difference I believe arises from our crude knowledge of how to fit our mathematics to our cosmo-logical data; I don't think it's a serious problem. Personally I favor the higher end of the range, perhaps 12 to 14 billion. We also have rough measures of the deceleration rate of the universal expansion. These can give (depending on cosmological, mathematical models) estimates of how long a dense universe would take to expand, reverse, and collapse back to a point. At the extremes, this gives between 27 billion and at least 100 billion years before the Big Crunch. If we do indeed live in a universe which will collapse, then we are bounded by two singularities, at beginning and end. No structure will survive that future singularity. Freeman Dyson found this a pessimistic scenario and so refused to consider it.

A closed universe seems the ultimate doom. In all cosmological models, if the mass density of the universe exceeds the critical value, gravity inevitably wins. This is called a "closed" universe, because it has finite spatial volume, but no boundary. It is like a three dimensional analog of a sphere's surface. A bug on a ball can circumnavigate it, exploring all its surface and coming back to home, having crossed no barrier. So a starship could cruise around the universe and come home, having found no edge.

A closed universe stars with a big bang (an initial singularity) and expands. Separation between galaxies grows linearly with time. Eventually the universal expansion of space-time will slow to a halt. Then a contraction will begin, accelerating as it goes, pressing galaxies closer together. The photons rattling around in this universe will increase in frequency, the opposite of the red shift we see now. Their blue shift means the sky gets brighter in time. Contraction of space-time shortens wavelengths, which increases light energy.

Though stars will still age and die as the closed universe contracts, the background light will blue shift. No matter if life burrows into deep caverns, in time the heat of this light will fry it. Freeman Dyson remarked that the closed universe gave him "a feeling of claustrophobia, to imagine our whole existence confined within a box." He asked, "Is it conceivable that by intelligent intervention, converting matter into radiation to flow purposefully on a cosmic scale, we could break open a closed universe and change the topology of spacetime so that only a part of it would collapse and another would expand forever? I do not know the answer to this question."

The answer seems to be that once collapse begins, a deterministic universe allows no escape for pockets of spacetime. Life cannot stop the squeezing.

Some have embraced this searing death, when all implodes toward a point of infinite temperature. Frank Tipler of Tulane University sees it as a great opportunity. In those last seconds, collapse will not occur at the same rate in all directions. Chaos in the system will produce "gravitational shear" which drives temperature differences. Drawing between these temperature differences, life can harness power for its own use.

Of course, such life will have to change its form to use such potentials; they will need hardier stuff than blood and bone. Ceramic-based forms could endure, or vibrant, self-contained plasma clouds --any tougher structure might work, as long as it can code information.

This most basic definition of life, the ability to retain and manipulate information, means that the substrate supporting this does not matter, in the end. Of course, the style of thought of a silicon web feasting on the slopes of a volcano won't be that of a shrewd primate fresh from the veldt, but certain common patterns can transfer.

Such life forms might be able to harness the compressive, final energies at that distant end, the Omega Point. Frank Tipler's The Physics of Immortality makes a case that a universal intelligence at the Omega Point will then confer a sort of immortality, by carrying out the computer simulation of all possible past intelligences. All possible earlier "people" will be resurrected, he thinks. This bizarre notion shows how cosmology blends into eschatology, the study of the ultimate fate of things, particularly of souls.

I, too, find this scenario of final catastrophe daunting. Suppose, then, the universe is not so dense that it will ever reverse its expansion. Then we can foresee a long toiling twilight.

Life based on solid matter will struggle to survive. To find energy, it will have to ride herd on and merge black holes themselves, force them to emit bursts of gravitational waves. In principle these waves can be harnessed, though of course we don't know how as yet. Only such fusions could yield fresh energy in a slumbering universe.

High civilizations will rise, no doubt, mounted on the carcass of matter itself -- the ever-spreading legions of black holes. Entire galaxies will turn from reddening lanes of stars, into swarms of utterly dark gravitational singularities, the holes. Only by moving such masses, by extracting power through magnetic forces and the slow gyre of dissipating orbits, could life rule the dwindling resources of the ever-enlarging universe. Staying warm shall become the one great Law.

Dyson has argued that in principle, the perceived time available to living forms can be made infinite. In this sense, immortality of a kind could mark the cold, stretching stages of the universal death.

This assumes that we know all the significant physics, of course. Almost certainly, we do not. Our chimpanzee worldview may simply be unable to comprehend events on such vast time scales. Equally, though, chimpanzees will try, and keep trying.

Since Dyson's pioneering work on these issues, yet more physics has emerged which we must take into account. About his vision of a swelling universe, its life force spent, hangs a great melancholy.

For matter itself is doomed, as well. Even the fraction which escapes the holes, and learns to use them, is mortal. Its basic building block, the proton, decays. This takes unimaginably long -- current measurements suggest a proton lifetime of more than 10[sup 33] years. But decay seems inevitable, the executioner's sword descending with languid grace.

Even so, something still survives. Not all matter dies, though with the proton gone everything we hold dear will disintegrate, atoms and animals alike. After the grand operas of mass and energy have played out their plots, the universal stage will clear to reveal the very smallest.

The tiniest of particles -- the electron and its anti-particle, the positron -- shall live on, current theory suggests. No process of decay can find purchase on their infinitesimal scales, lever them apart into smaller fragments. The electron shall dance with its anti-twin in swarms: the lightest of all possible plasmas.

By the time these are the sole players, the stage will have grown enormously. Each particle will find its nearest neighbor to be a full light-year away. They will have to bind together, sharing cooperatively, storing data in infinitesimally thin currents and charges. A single entity would have to be the size of a spiral arm, of a whole galaxy. Vaster than empires, and more slow.

Plasmas held together by magnetic and electric fields are incredibly difficult to manage, rather like building a cage for jello out of rubber bands. But in principle, physics allows such magnetic loops and glowing spheres. We can see them in the short-lived phenomenon of ball lightning. More spectacularly, they occur on the sun, in glowing magnetic arches which can endure for weeks, a thousand kilometers high.

Intelligence could conceivably dwell in such wispy magnetic consorts. Communication will take centuries . . . but to the slow thumping of the universal heart, that will be nothing.

If life born to brute matter can find a way to incorporate itself into the electron-positron plasma, then it can last forever. This would be the last step in a migration from the very early forms, like us: rickety assemblies of water in tiny compartment cells, hung on a lattice of moving calcium rods.

Life and intelligence will have to alter, remaking their basic structures from organic molecules to, say, animated crystalline sheets. Something like this may have happened before; some theorists believe Earthly life began in wet clay beds, and moved to organic molecules in a soupy sea only later.

While the customary view of evolution does not speak of progress, there has been generally an increase of information transmitted forward to the next generation. Complexity increases in a given genus, order, class, etc. Once intelligence appears, or invades a wholly different medium, such "cognitive creatures" can direct their own evolution. Patterns will persist, even thrive, independent of the substrate.

So perhaps this is the final answer to the significance of it all. In principle, life and structure, hopes and dreams and Shakespeare's Hamlet, can persist forever -- if life chooses to, and struggles. In that far future, dark beyond measure, plasma entities of immense size and torpid pace may drift through a supremely strange era, sure and serene, free at last of ancient enemies.

Neither the thermodynamic dread of heat death nor gravity's gullet could then swallow them. Cosmology would have done its work.

As the universe swells, energy lessens, and the plasma life need only slow its pace to match. Mathematically, there are difficulties involved in arguing, as Dyson does, that the perceived span of order can be made infinite. The issue hinges on how information and energy scale with time. Assuming that Dyson's scaling is right, there is hope.

By adjusting itself exactly to its ever-cooling environment, life -- of a sort -- can persist and dream fresh dreams. The Second Law of Thermodynamics says that disorder increases in every energy transaction. But the Second Law need not be not the Final Law.

Such eerie descendants will have much to think about. They will be able to remember and relive in sharp detail the glory of the brief Early Time -- that distant, legendary era when matter brewed energy from crushing suns together. When all space was furiously hot, overflowing with boundless energy. When life dwelled in solid states, breathed in chilly atoms, and mere paltry planets formed a stage.

Freeman Dyson once remarked to me, about these issues, that he felt the best possible universe was one of constant challenge. He preferred a future which made survival possible but not easy. We chimps, if coddled, get lazy and then stupid.

The true far future is shrouded and mysterious. Still, I expect that he shall get his wish, and we shall not be bored.

GREGORY BENFORD

THE FIRE THIS TIME

SCIENCE*was invented once, and only once.*

This is a singularly striking fact of human history. There were many opportunities for science to emerge, in the sense that we know it -- the reasonably dispassionate search for objective, checkable troths about the physical world. The Egyptians and Babylonians had lots of rule-of-thumb engineering and geometry. The Romans could build magnificently. The Chinese invented paper, gunpowder, rockets, the great sailing vessels of the Ming era.

Yet none devised the rather abstract rules which govern scientific discourse. No rival to Euclid's Elements. No deductive mathematics. No Chinese or Indian or African theorems or proofs before they learned from Euclid.

Indeed, truly modern science emerged only half a millennium ago. The term "science," from the Latin, "to know," is less than two centuries old. Before that science existed but was called "natural philosophy." Science as we know it came at the hands of William of Ockham, Francis Bacon, and then the great experimenters, Galileo and his contemporaries. The crowning jewel was the systematic, mathematical description of the most classically serene part of the world, celestial dynamics, by Newton.

They all built on the Greeks, who invented the basic idea of the method. Along the shore of that rough peninsula, over two thousand years ago, the methods of careful reasoning, always braced by consultation with the facts of the matter, evolved and won through.

Not that all Greeks held to it, of course. Aristotle lusted after the great intellectual leaps. He was impatient with facts and seldom checked his many assertions. Simple enough, one would think, to see if a heavy ball of the same size as a light one fell to earth at a different rate. But it was nearly two thousand years before Galileo looked to see, and found the truth.

I loved Greece and was immediately drawn to it. My first visit there led to an entire novel about Mycenean archeology, Artifact. I grew up on a warm sea's edge, and live in Laguna Beach, California now because I simply love the rub and scent of the sea. More, I admire the cutting clarity of the air--sharper than the Gulf coast where I grew up, but sharing a smell of brine and eternal organic consequence.

I sometimes think that the Greeks developed their Euclidean certainties, their sharp visions of cause and circumscribed effect, because they lived in an air of razor clarity. The dry, lucid accuracies of Athenian air may have kindled in the ancient mind some vision of a realm beyond the raw rub of the day, a province of the eternal which obeyed finer laws, more graceful dynamics.

I thought this particularly because I was preparing, in late October of 1993, the notes for a course in ethics which I would soon teach in the honors humanities program at the University of California, Irvine. (Usually ethics is strictly a matter for the humanists, but for the past five years I have served as the token scientist in the honors courses.) It struck me how strongly Plato believed in smooth certainties lying behind our rude world, the famous shadows on the cave wall analogy. Socrates believed in higher ethical laws, too, which men could but crudely glimpse and try to copy. Idealism emerged in the sharp air of civilization's morning.

Somehow that city-state of a quarter million population produced an immense flowering in art, literature, philosophy- and science. Many cultures yield up art, music, and higher thought generally. But only the Greeks put together science. I wondered why.

I saw the smoke as I went to my one PM lecture on a blustery Wednesday, October 27. The spire of oily black smoke was about seven miles inland, I judged, near the freeway, far from my home in Laguna Beach. Dry winds off the desert called the Santa Anas brought an eerie, skin-prick-ling apprehension to the sharp air.

By the time I had held forth on turbulence theory for an hour and a half, a dark cloud loomed across all the southern horizon. The brush fire had swept to the sea. On the telephone my wife Joan said the smell was already heavy and asked me to come home.

I tried to reach Laguna Beach by the Pacific Coast Highway, only to be turned back by a policeman at the campus edge. So I went south, looping the long way around, leaving the freeway and threading through surface streets. When I had bought my Mercedes 560 SL my son had deplored its excess power, quite ecologically unsound, and I had replied lightly that I wanted to "seize opportunities." Here was the chance: I cut through traffic, hoping to get ahead of the predictable wedge wanting the only access to town.

I failed, of course. Traffic was chaotic. I took two hours to reach Monarch Bay, the community immediately south of Laguna Beach. At Monarch Bay the police stopped everyone. Smoke glowered across the entire horizon now.

I left my car at 5:30 and hiked north, striking up a conversation with a man, Dave Adams, who was walking to his nearby home. I stopped there for a drink and heard that the high school had burned. Our house sits three hundred meters above the school. On the other hand, this was media wisdom, instantly discounted. I went on, hitchhiking and walking the five miles to central Laguna by seven PM. Police were turning everyone back but the acrid flavor in the air alarmed me, and the dark clouds blowing thickly out to sea seemed to come from our hill. The police stopped me several times. I always retreated, then worked my way around to another street and went on.

I knew that Joan must have evacuated by then, but I had set out to come home and just kept at it, through the gathering pall. Maybe there was something I could do -fight the fire, water down the yard, rescue some precious memories...

On Wendt Street, near the high school, a police car came cruising down, herding the few homeowners left. I ducked behind a stone wall. "Get out of my driveway!" a man wearing a headphone radio shouted at me. He waved a pistol wildly -- a part of me noted, .$2 revolver, finger on the trigger guard, probably knows how to handle it -- and I realized he perhaps mistook me for a looter. I ran behind the police car and down a street, following the narrow windings toward our hill. Night had fallen.

I sprinted on -- excited, oblivious to choking smoke, sirens and hoarse cries. At the high school -untouched, of course -- I met fire teams and more police. Chaos. Flames leapt from our hill, a steady popping roar. Homes exploded in orange as their roofs burst open. Yellows and reds traced out the dark discords of walls collapsing, brush crackling, cinders churning up in cyclonic winds, orange motes in a fountain of air -then falling, bright tumbling fireworks. Ash swept through the streets like gray snow. Above it all a cowl of black smoke poured out to sea.

I crossed the street and climbed up onto a high ledge and still could not see far enough up Mystic Canyon to make out our house. But all around it homes burned furiously. Our street, Skyline Drive, was a flaming artery both above and below our house.

A fire warden shouted at me to get out. I hesitated, he shouted again, and I realized it was all over. At last I gave up our house and turned away. I had been rushing forward for several hours, intent on reaching home. That was impossible. I could do nothing in this inferno. I had not gotten in anybody's way, but I hadn't done any good, either. Working my way this close to the fires was risky, if only from the smoke I inhaled. Slowly I realized that I had been running on automatic, and all this was quite foolish.

I retreated through deserted streets. I hitchhiked partway back out and a few miles south found a 7-Eleven open. An incongruous sight, bright beacon beside the exodus. I was parched, sagging. I went in and straight to the back to get a big container of cold tea.

The store owner was in a heated argument with two men who wanted to get gasoline. Police had come by and ordered the pumps closed. Excited, the owner started rattling off Korean and one of the men grabbed him by the shin collar and pulled him halfway across the counter. More shouting. The owner got free and backed away and the rest of us in the store yelled at the two men. They swore at the owner but made no more moves.

Plenty of talk then, accusations and retorts and barks of angry egos. I judged it was not going to get any worse so I left money on the counter and walked out with the tea. A block further south six motorcycle police from Newport Beach sat on their machines and watched people still leaving along the Coast Highway, their uniforms pressed and neat. They weren't interested in the 7-Eleven.

I finished the tea before I reached the Adams home. They all watched the television news and I drank some more. My thirst would not go away. I sat and listened to the announcer declare that all homes in the Mystic Hills were lost. All. Confirmation sent me into a daze.

I called friends, who reported that Joan had indeed evacuated town and come to them, and then went on to the refugee center. Dave Adams drove me to the center and I found Joan. She was in better shape mentally and physically than I. I sat on a curb and ate my first fast food burger ever, from a free canteen run by In 'n Out. It was improbably delicious.

Joan had evacuated as flames marched over the ridge line of the hill across the street, coming as fast as a person walks. She had stuffed her Volvo with financial documents, vital but small items like safety deposit keys, passports and telephone directories, plus our photo albums, the oldest of our Japanese woodblock prints, jewelry, and cherished oddments of our accumulated history.

She had been putting the pets in the car when a guy walked up and asked if she needed help loading things in the car. She suspected he was in fact interested in getting into the house, so said no thanks. He ambled away. Just as she was ready to slam the trunk closed, our postman pulled up, looking rather anxious. She took the day's mail, jumped into the car, and headed downhill. People were barreling down at high speed. The postman followed her out, stopping to deliver to homes which were soon to burn, flames approaching behind him. At the time, she said, it did not occur to her to laugh. Later, she did.

A police chaplain came by and we talked about losing the house. I couldn't seem to get my mind around the concept. We were leaving the center to go back to the friends when a neighbor called to us. He had lost his house, his classic car collection included. But he had seen our house standing at nine PM, he was pretty sure. It was hard to tell in the darkness, though, without street lights. This heartened us greatly but I had severe doubts that anything could have survived the furnace I had seen.

We reached friends, an Episcopal minister and wife, at midnight. We slept solidly until six PM. Up, talk, news on TV -- which I found oddly uninteresting, and distrusted. Breakfast out. I always eat a lot in the morning, having grown up in farm country, and this time ordered double. The restaurant seemed eerie in its calm. Pancakes and omelettes, the fire only a rank smell from distant hills.

Back to the center, where we wore away the day vainly seeking news. Nobody released any information on homes burned. News programs dwelt infuriatingly on the spectacular wasteland at the top of our hill, never letting the helicopter camera angle descend to take in lower Skyline Drive. Reports continued that everything had burned on Skyline. I was inclined to believe them, though I kept saying encouraging things to all I talked to, including our daughter Alyson, by cellular phones supplied free. I distracted myself by searching for clothes in the immense piles donated by charitable groups. I was still wearing the shorts and short-sleeved shirt I had been lecturing in, what seemed a year ago.

At four PM word came that since all fires were out we could go back into town. We left, I picked up my car, and we edged our way into Laguna. Behind me, out of my sight, Joan's Volvo overheated, stranding her for nearly two hours on Coast Highway.

Dusk fell as I reached the high school again, only to be blocked by police. Nobody allowed on the hill. Nope, not even residents. They were trying to prevent looting. Grim warnings.

I simply could not turn back. This was my neighborhood and I knew the short cuts. I slipped around the police lines, over ash-covered tennis courts, along a path and up through several burned homes, on to Skyline. Several news teams were arrayed among the ruins with portable gear, shooting interviews under their bright lights. Media okay, but homeowners keep out.

Melted cars and ashy gray debris littered Skyline. Cables down, charred palm trees. A heavy acrid stench made me cough. I walked uphill and around a curve. Amid the black ruins our house stood untouched. I approached in a daze. The battle to save it was visible only in fire hoses left in the street, boot prints in the yard and minor damage to plants.

Two doors were unlocked, one ajar. Inside, the smoky stink could not blanket my immediate reaction:

home. Safe. Numbly I collected some floppy disk backups from my study. Pointless, but automatic. Our fireproof safe stood with both drawers yawning open. I took it all in but wasn't thinking much.

I departed in the gathering gloom. The street outside was covered with ash and burnt scraps. Somehow I didn't want to leave the hill, even in the gloom. I could not comprehend the enormity of others' loss, and of our luck. A German TV crew interviewed me when they found I could speak German. Crisis surrealism; a foreign tongue that recalled war zone damage.

Still dazed, I wondered where Joan was. Turned out she had been exhausted by the overheated car and traffic, and stopped at a friend's. She was quite wrung out. We finally linked up again and spent the night at a nearby friend's house. The next day, Friday, we even got into our house. About eighty percent of the neighborhood was gone, 199 homes, probably $200 million lost. In the whole town over 350 burned, with losses around $500 million.

The water had run out again and again through the long fight. Fire-men had been forced to abandon whole blocks to the swift flames. Around our group of a dozen homes they had drawn a perimeter and defended, using the hydrant across the street from us, which had high pressure. They worked around the houses, trampled vegetation, got the job done. The flames had come down our hill and the firefighters had stopped them at the curb across the street from our house.

Then the fire worked south, burning all the homes downhill from us, and leaped Skyline. It burned a dozen more homes below and then crawled up our canyon to within thirty meters of our house. The fire-men hit the flames with a 500 gallon-per-minute, precision high-velocity cannon. After several hours that did it. Our canyon was a black pit.

Apparently the initial small fire far inland was set by someone, the media said. I didn't care much for these larger views; my focus had narrowed to the local, intense present. Time to clean up. Our unlocked doors apparently were the firemen's work, checking for people unable to get out. Joan had left our safe closed, but not locked. A looter had come through and checked it, finding only financial papers. He took nothing. That must have been while the police cordon kept out homeowners, but not entrepreneurs ready for the quick take.

Wildlife had suffered enormously. Dead birds littered the canyon. In the hills beyond a walk through the black slopes came to a twisted wire fence. Against it was a line of white bones, the lizards and rabbits and snakes and rats and deer that had run in blind panic into it and turned to face the onrushing wall of heat.

I trapped a two-pound rat in our tool shed, and saw rats the size of cats jumping between palm trees. From our deck we watched hawks diving at mice as they scampered for shelter on the bare hillsides. We put out seed and water and birds flocked -- gnatcatchers, hummingbirds, red-tailed hawks, crows, brilliantly hued mountain bluebirds.

Two Dalmatians were found roaming, having somehow escaped their burning house. Boaters three miles offshore saw an exhausted mule deer doe swimming out to sea, away from the blighted canyons where she usually foraged. They hauled her in and brought her back for care. On the canyons, gray tree frogs turned spontaneously black, closely matching the charred ground. Somewhere in their genes lies the memory of many other fires, and a honed response to give them protection from predators, somehow triggered by the sight or smell of the flames.

All this seemed very distant, in the immense relief at being among the survivors. Our house was not particularly expensive, but what really matters, I came to feel, was how much of yourself you had put into your home. Neighbors recently moved in walked away from their ruins with apparently some aplomb. Oldtimers were more devastated.

We both slept poorly for several nights, chased by phantom flames in repeating dream dramas. Those who had lost everything were forlorn, adrift. When the Santa Ana winds picked up again, one woman who had been evacuated in the fire began automatically loading her car with cherished photographs. Some elderly couples developed the habit of taking their dearest possessions with them everywhere they went.

Counselors at the Community Clinic spoke of "post traumatic stress disorder" and of conducting "critical incident stress debriefings" but the phenomena they tried to capture with such jargon was real. I kept going over how close it had been, with the unsettled mind of one who has been shot at and barely missed.

As a scientist I habitually saw cause and effect, but the random nature of the world had asserted itself here. Much of our culture devotes itself obsessively to the comfy human world, our gossip and relationships and destinies. Now we had all been reminded that the world itself neither likes nor dislikes us; worse, in a way, it is indifferent. The fire had no point, no target in itself-- though whoever started it probably did. However much I believed as a scientist in an objective, unconcerned universe out there, which we study to understand, my emotions veered away from that.

The calamity had missed us by a hair. We had fireproofed the roof with concrete tile five years before, recoated with thick fire-resistant paint in 1992, and the morning of the fire had a garden crew clearing out the volatile underbrush. They had fled only when the flames danced above the ridgeline, just behind Joan. We had been prepared, sure, but we were hugely lucky, too.

We had already been through the slide and burning in our little canyon in January 1993, which took out the three homes immediately below us. The immensely larger ferocity of this catastrophe was numbing. A week later, a sudden rain flooded out the five surviving homes across the street. Sandbags in our driveway deflected the ash-laden streams from us. The big storms of winter were worse.

I missed no classes and got back to research soon. But my thinking was unsettled and in reading Plato I found a curious dislocation.

An unbroken tradition stretches from Pythagoras and his theorems to Copernicus and his planetary circles. But for most of the 1300 years between them, astrology dominated civilization's attitude toward the heavens. Astrology takes a more warm, comfy view of the sky, makes it human-centered.

Greek geometry and deductive thought were unique inventions, never duplicated by other cultures. The very notion that the cosmos is ultimately open to reason comes naturally only to minds who see how general deductive reasoning is. Greek patterns of thinking barely escaped the turmoil of intervening millennia, and if lost would probably never have been reinvented.

Did Euclidean certainties come in part from an unconscious association with the clarity of air and sea and crisp, dry land? I had noted the similar feel to California and Greece, and to the Egyptian city of Alexandria, where Euclid wrote his Elements. Did they see sharp visions of cause and effect because they lived in air of razor clarity? Did it hint of a realm beyond the clutter of detail, accident, emotion? In a pristine world it is easier to imagine a province of the eternal which obeyed finer, more lofty and graceful laws.

The fire impressed me with the sheer raw power of nature. It disoriented my thinking and made difficult a return to the calculations I was doing in turbulence theory. Some part of me could not settle down to the neat, clean equations, precise markings for exact quantities; the world outside was too rife with emotion, friction, brutal forces, malicious intent. The universe seemed to be threatening, not standing at an abstract distance.

If science was such an unlikely event, one time only, perhaps we should be more mindful that its habits of mind persist in our own time. We cannot rely on clear air to insure our trust in abstract reasoning.

Further, think of the assumptions behind the Search for Extraterrestrial Intelligence. Will intelligent life develop deductive reasoning? And then build radios? If it was a singular event for us, how might the raw edge of alien environments blot out those analytical habits which have led us up from darkness? Unsettling thoughts.

There is great relief in this aftermath, of course. Still, sometimes it felt as if the world would keep trying until it got us. I suppose in a way it will.

GREGORY BENFORD

THE FOURTH DIMENSION

Suppose that next to you, right now, a pale gray sphere appeared. It grew from baseball-sized to a diameter as big as you -- grainy, gray, cool to the touch -- then shrank to a point . . . and disappeared.

You would probably interpret it as a balloon blown up, then deflated. But where did the flat balloon go?

Or you could realize that you had been visited by a denizen of a higher dimension -- a four dimensional sphere, or hypersphere. In three dimensions, it looks like a sphere, the most perfect of figures, just as a sphere projected in two dimensions makes a circle. The fact that this isn't an everyday occurrence implies that travel between dimensions is uncommon, but not that it is illogical.

Probably you would not have thought of such ideas before 1884. That is due to the Reverend Edwin Abbott Abbott, M.A., D.D., headmaster of the City of London School.

Respected, well liked, he led a strictly regular life, as proper as a parallelogram. He had published quite a few conventional books with titles like Through Nature to Christ, Parables for Children and How to Tell the Parts of Speech. These did not prepare the world for his sudden excursion into the fantastic, in 1884. Beneath his exterior he was a bit odd, and his short novel Hatland has proved his only hedge against oblivion, an astonishingly prescient fantasy of mathematics.

Abbott's oddity began with his repeated name, which a mathematical wit might see as A times A or A Squared, A[sup 2]. Abbott's protagonist is A Square, a much troubled spirit. Liberated into another character, Abbott seems to have broken out of his cover as a prim reverend, and poured out his feelings.

The book has a curiously obsessive quality, which perhaps accounts for its uneasy reception. Reviewers termed it "soporific," "prolix,"" mortally tedious," "desperately facetious, "while others found it "clever," "fascinating," "never been equaled for clarity of thought," and "mind broadening," and they even likened it to Gulliver's Travels. This last comparison is just, because beneath the math drolleries lurks a penetrating satire of Victorian society.

A Square's society is as constrained as were the prim Victorians. Women are not full figures but mere lines. Soldiers are triangles with sharp points, adept at stabbing. The more sides, the higher the status, so hexagons outrank squares, and the high priests are perfect circles.

In a delicious irony, the upper classes are polygons with equal sides --but their views certainly do not embrace equality. Mathematicians term equal-sided figures "regular," and in nineteenth century terms, proper upper class polygons are of the regular sort.

A Square learns that his view of the world is too narrow. There is a third dimension, grander and exciting. but his hidebound fellows cannot see it. This opening-out is the central imaginative event of the novel, Abbott echoing an emergent idea.

In the late nineteenth century higher dimensions were fashionable. Mathematicians had laid the foundations for rigorous work in higher-dimensional space, and physicists were about to begin using four-dimensional spacetime. Twenty centuries after Euclid, the mathematician Bernhard Riemann took a great leap in 1854, liberating the idea of dimensions from our spatial senses. He argued that ever since Rene Descartes had described spaces with algebra, the path to discussing higher dimensions had been dear, but unwalked.

Descartes' analytic geometry defined lines as things described by one set of coordinates, distances along one axis. A plane needed two independent coordinate sets, a solid took three. With coordinates one could map an object, defining it quantitatively: not "Chicago is over that hill." but "Chicago is fifteen miles that way." This appealed more to our logical capacity, and less to our sensory experience.

Riemann described worlds of equal logical possibility, with dimensions ranging from one to infinity. They were not spatial in the ordinary sense. Instead, Riemann took dimension to refer to conceptual spaces, which he named manifolds.

This wasn't merely a semantic change. Weather, for example, depends on several variables -- say, n -- like temperature, pressure, wind velocity, time of day, etc. One could represent the weather as a moving point in an n-dimensional space. A plausible model of everyday weather needs about a dozen variables, so to visualize it means seeing curves and surfaces in a twelve-dimensional world. No wonder we understand the motions of planets (which even Einstein only needed four dimensions to describe), but not the weather.

Riemann revolutionized mathematics and his general ideas diffused into our culture. By 1880, C.H. Hinton had pressed the issue by building elaborate models to further his extra-dimensional intuition, he tried to explain ghosts as higher-dimensional apparitions. Pursuing the analogy, he wrote of a fourth-dimensional God from whom nothing could be hidden. The afterlife, then, allowed spirits to move along the time dimension, reliving and reassessing moments of life. Spirits from hyper-space were the subject of J.K.F. Zollner's 1878 Transcendental Physics, which envisioned them moving everywhere by short-cut loops through the fourth dimension.

Mystics responded to the fashion by imagining that God, souls, angels and any other theological beings resided as literal beings of mass ("hypermatter") in four-space. This neatly explains why they can appear anywhere they like, and God can be everywhere simultaneously, the way we can look down on a Flatland and perceive it as a whole. Some found such transports of the imagination inspiring, while others thought them crass and far too literal. I am unaware of Abbott himself ever subscribing to such beliefs.

Still, Abbott and his adventure-some Square longed for the strange. More than any other writer, Abbott coined the literary currency of dimensional metaphor. By having a point of view which is literally above it all, surveying the follies of a two-dimensional plane, Abbott can adroitly satirize the staid rigidities of his Victorian world. (Perhaps this is why he first published Flatland under a pseudonym.)

"Irregulars" are cruelly executed, for example. Do they stand for foreigners? Gypsies? Cripples? We are left to fill in some blanks, but the overall shape of the plot is clear -- flights of fancy are punished, and A Square does not finish happily.

At a deeper level, the book harks toward deep scientific issues, and the difficulty of comprehending a physical reality beyond our immediate senses. This is the great theme of modem physics. The worlds of relativity and the quantum are beyond the rough-and-ready ideas we chimpanzees have built into us, from our distant ancestors' experience at throwing stones and poking sticks on African plains.

Still deeper, in this fanciful narrative the good Reverend tries to speak indirectly of intense spiritual experience. The trip into the higher realm of three dimensions is a fine metaphor for a mystical encounter.

The thrust of the deceptively simple narrative is to make us examine our basic assumptions. After all, our visual perceptions of the world are two-dimensional patterns, yet we somehow know how to see three-dimensionality. One knows instantly the difference between a ball and a fiat disk by their shading in available light. Objects move in front of each other, like a woman walking by a wall. We automatically discount a possible interpretation -- that the woman has somehow dissolved the wall for an instant as she passes. Instead, we see her in her three-dimensionality. The eye has learned the world's geometry and discards any other scheme.

A Square learns this lesson early as he first visits Lineland in a dream. The only distinction the natives can have is in their length. They see each other as points, since they move along the same universal straight line. They estimate how far away others are by their acute sense of hearing picking up the difference between a bass left voice and a tenor right; the time lag in arrival tells the distance. The king is longest, men next, then boys are stubby lines. Women are mere points, of lower status. Their views of each other are partial and instinctive. They never dream of how narrowly they see their world.

This sets the stage for A Square's conceptual blowout when a Sphere visits him and yanks him up into the hallucinogenic universe of three dimensions. Its realities are surrealistic. A Square straggles to fathom what for us is instinctive.

The reality of three dimensions we take for granted, but for us, what is the reality of two dimensions? Would flatlanders have physical presence in our world -- that is, could we perceive a two-dimensional universe embedded in our own? Could we yank them up into our world?

Flatlanders could be as immaterial as shadows, mere patterns in our view. If an isosceles triangle soldier cut your throat it would not hurt. Abbott did not consider this in his first edition, but in the second he says that A Square eventually believes that flatlanders have a small but real height in our universe. A Square discusses this with the ruler of Flatland:

* I tried to prove to him that he was "high," as well as long and broad, although he did not know it. But

what was his reply? "You say I am 'high'; measure my 'highness' and I will believe you." What could I do? I met his challenge!

If flatlanders were even quite thick, they would not be able to tell, if in that direction they had no ability to move or did not vary. Height as a concept would lie beyond their knowable range. Or if they did vary in height, but could not directly see this, they might ascribe the differences to qualitative features like charisma or character or "presence." There would be rather mysterious forces at work in their world, the Platonic shadows of a higher, finer reality.

If a flatlander soldier of genuine physical thickness attacked, it would cut us like a knife. Otherwise, it could not impinge upon us. We would remain oblivious to all events in the lesser dimensions.

In a sense, a truly two-dimensional flatlander faces a similar problem if it tries to digest food. A simple alimentary canal from stem to stem of, say, a circle would bisect it. To keep itself intact, a circle would have to digest by enclosing whatever it used for food in pockets, opening one and passing food to the next like a series of locks in a canal, until eventually it excreted at the far end.

This is typical of the problems engaged by thinking in another dimension. Not until 1910 did artists respond to non-Euclidean spaces, with Cubism and its theories. Mute image and poetic metaphor, they said, were ways of perceiving what scientists could only describe in abstractions and analogies.

They were right, and many, including Picasso and Braque, struggled with the problem. Looking downward at lower dimensions is easy. Looking up strains us.

Visualizing the fourth dimension preoccupied both mists and geometers. A cube in 4D is called a tesseract. One way to think of it is to open a cubical cardboard box and look in. By perspective, you see the far end as a square. Diagonals (the cube edges) lead to the outer "comers" of a larger square -- the cube face you're looking through. Now go to a 4D analogy. A hypercube is one small cube, sitting in the middle of a large cube, connected to it by diagonals. Or rather, that is how it would look to us, lowly 3D folk.

Cutting a hypercube in the right way allows one to unfold it and reform it into a 3D pattern of eight cubes, just as a 3D cube can be made up of six squares. One choice looks like a sort of 3D cross. Salvador Dali used this as a crucifix in his 1954 painting Christus Hypercubus. Not only does the hypercube suggest the presence of a higher reality; Dali deals with the problem of projecting into lower dimensions. On the floor beneath the suspended hypercube, and the crucified Christ, is a checkerboard pattern -- except directly below the hypercube. There, the hypercube's shadow forms a square cross. (Shadows are the only 2D things in our world; they have no thickness.) Comparing this simple cross with the reality of the hypercube which casts the shadow, we contemplate that our world is perhaps a pallid shadow of a higher reality, an implicit mystical message.

Robert Heinlein gave this a twist with "And He Built a Crooked House," in which a house built to this pattern folds back up, during an earthquake, into a true hypercube, trapping the inhabitants in four dimensions. Much panic ensues.

Rudy Rucker, mathematician and science fiction author, has taken A Square and Flatland into myriad fresh adventures. I met Rucker in the 1980s and found him much like his fictional narrators, inventive and wild, with a cerebral spin on the world, a place he found only apparently commonplace. His The Sex Sphere (1983) satirizes dimensional intrusions, many short stories develop ideas only latent in Flatland, and his short story "Message Found in a Copy of Flatland" details how a figure much like Rucker himself returns to Abbott's old haunts and finds the actual portal into that world in the basement of a Pakistani restaurant. He finds that the triangular soldiers can indeed cut intruders from higher dimensions, and flatlanders are tasty when he gets hungry. As a sendup of the original it is pointed and funny.

In science fiction there have been many stories about creatures from the fourth dimension invading ours, generally with horrific results. Greg Bear's "Tangents" describes luring 4D beings into our space using sound. While we puzzle over whether an unseen fourth dimension exists, modem physics has used the idea in the Riemannian manner, to expand our conceptual underpinnings. Riemann saw a mathematical theme of conceptual spaces, not merely geometrical ones. Physics has taken this idea and run with it.

Abbott's solving the problem of flatlander physical reality by adding a tiny height to them was strikingly prescient. Some of the latest quantum field theories of cosmology begin with extra dimensions beyond three, and then "roll up" the extras so that they are unobservably small --perhaps a billion billion billion times more tiny than an atom. Thus we are living in a universe only apparently spatially three-dimensional; infinitesimal but real dimensions lurk all about us. In some models there actually are eighteen dimensions in all!

Even worse, this rolling up occurs by what I call "wantum mechanics" --we want it, so it must happen. We know no mechanism which could achieve this, but without it we would end up with unworkable universes which could not support life. For example, in such field theories with more than three dimensions, which do not roll up, there could be no stable atoms, and thus no matter more complex than particles. Further, only in odd-numbered dimensions can waves propagate sharply, so 3D is favored over 2D. In this view, we live not only in the best of all possible worlds, but the only possible one.

How did this surrealistically bizarre idea come about? From considering the form and symmetries of abstruse equations. In such chilly realms, beauty is often our only guide. The embarrassment of dimensions in some theories arises from a clarity in starting with a theory which looks appealing, then hiding the extra dimensions from actually acting in our physical world. This may seem an odd way to proceed, but it has a history.

The greatest fundamental problem of physics in our time has been to unite the two great fundamental theories of the century, general relativity and quantum mechanics, into a whole, unified view of the world. In cosmology, where gravity dominates all forces, general relativity rules. In the realm of the atom, quantum processes call the tune.

They do not blend. General relativity is a "classical" theory in that it views matter as particles, with no quantum uncertainties built in. Similarly, quantum mechanics cannot include gravity in a "natural" way.

Here "natural" means in a fashion which does not violate our sense of how equations should look, their beauty. Aesthetic considerations are very important in science, not just in physics, and they are the kernel of many theories. The quantum theorist Paul Dirac was asked at Moscow University his philosophy of physics, and after a moment's thought wrote on the blackboard, "Physical laws should have mathematical beauty." The sentence has been preserved on the board to this day.

One can capture a theorist's imagination better with a "pretty" idea than with a practical one. There have even been quite attractive mathematical cosmologies which begin with a two-dimensional, expanding universe, and later jump to 3D, for unexplained reasons.

Einstein wove space and time together to produce the first true theory of the entire cosmos. He had first examined a spacetime which is "flat," that is, untroubled by curves and twists in the axes which determine coordinates. This was his 1905 special theory of relativity. He drew upon ideas which Abbott had already used.

The Eminent British journal Nature published in 1920 a comparison of Abbott's prophetic theme:

* (Dr. Abbott) asks the reader, who has consciousness of the third dimension, to imagine a sphere descending upon the plane of Flatland and passing through it. How will the inhabitants regard this phenomenon? . . . Their experience will be that of a circular obstacle gradually expanding or growing, and then contracting, and they will attribute to growth in time what the external observer in three dimensions assigns to motion in the third dimension. Transfer this analogy to a movement of the fourth dimension through three-dimensional space. Assume the past and future of the universe to be all depicted in four-dimensional space and visible to any being who has consciousness of the fourth dimension. If there is motion of our three-dimensional space relative to the fourth dimension, all the changes we experience and assign to the flow of time will be due is reply to this movement, the whole of the future as well as the part always existing in the fourth dimension.

In special relativity, distance in spacetime is not the simple result we know from rectangular geometry. In the ordinary Euclidean geometry everyone learns in school, if "d" means a small change and the coordinates of space are called x, y and z, then we find a small length (ds) in our space by adding the squares Of each length, so that

* (ds)[sup 2] = (dx)[sup 2] + (dy)[sup 2] + (dz[sup 2]

The symbol "d" really stands for differential, so this is a differential equation.

Contrast special relativity, in which a small distance in space-time adds a length given by dt, a small change in time, multiplied by the speed of light, c:

* (ds)[sup 2] = (dx)[sup 2] + (dy)[sup 2] + (dz)[sup 2] center dot (cdt)[sup 2]

The trick is that the extra length (cdt) is subtracted, not added. This simple difference leads to a whole restructuring of the basic geometry. The mathematician Minkowski showed this some years after Einstein formulated special relativity.

A thicket of confusions lurks here. Reflect that the total small (or differential, in mathematical language) length is (ds), found by taking the square root of the above equation. But if (cdt) is greater than the positive (first three) terms, then (ds) is an imaginary number! What can this mean? Physically, it means the rules for moving in this four-dimensional (4D) space are complex and contrary to our 3D intuitions. Different kinds of curves are called "spacelike" and "timelike," because they have very different physical properties.

Einstein was fond of saying that he viewed the world as 4D, with people existing in it simultaneously. This meant that in 4D the whole life of a person (their "world-line") was on view. Life was eternal, in a sense --a cosmic distancing available mostly to mathematicians and lovers of abstraction.

Einstein's was the first major scientific use of time as an added dimension, though literature had gotten there first. By 1895 the widespread use of dimensional imagery led H.G. Wells to depict time as just another axis of a space-like cosmos, so that one could move forward and back along it. In a sense Wells's use domesticated the fourth dimension, relieving it of genuinely jarring strangeness, and ignoring the possibility of time paradox, too.

Einstein's theory contrasts strongly with visions such as Wells' in The Time Machine, which treats motion along the (dt) axis as very much like taking a train to the future, then back. In Einstein's geometry, only portions of the space can be reached at all without violating causality (the "light cone" within which two points can be connected by a single beam of light). Paradoxes can abound.

Logical twists have inspired many science fiction stories. The issues are quite real; we have no solid theory which includes time in a satisfying manner, along with quantum mechanics, as a truly integrated fourth dimension. I spent a great deal of space in my novel Timescape wrestling with how to make this intuitively clear, but the struggle to think in four dimensions is perhaps beyond realistic fiction; perhaps it is more properly the ground of metaphor.

Physicists began envisioning higher dimensions because they got a simpler dynamic picture, at the price of apparent complication. More dimensions to deal with certainly strains the imagination, and is at first glance an unintuitive way to think. But they can lead to beauties which only a mathematician can love, abstruse elegances. Thus Einstein, in his 1916 theory of general relativity, invoked the simplicity that objects move in "geodesies" -undisturbed paths, the equivalent of a straight line in Euclidean, rectangular geometry, or a great circle on a sphere -in a four-dimensional space-time. The clarity of a single type of curve, in return for the complication of a higher dimension.

Einstein's general relativity said that matter curved the four-dimensional spacetime, an effect we see as gravity. Thus he replaced a classical idea, force, with a modem geometrical view, curvature of a 4D world. This led to a cosmology of the entire universe which was expanding and therefore pointed implicitly backward to an origin.

Einstein did not in fact like this feature of his theory, and in his first investigations of his own marvelously beautiful equations fixed up the solution until it was static, without beginning or end. His authority was so profound that his bias might have held for ages, but Edmund Hubble showed within a decade that the universe was expanding.

Even so, the concept of a beginning land perhaps an end) may be an artifact of our persistent 3D views. Implicitly, space and time separate in the Einstein universe. They are connected, but can be defined as ideas that stand alone.

The essence of talking about dimensions is that they can be separately described. But this may not be so. At least, not in the beginning.

Even Edwin Abbott did not foretell that in the hands of cosmologists like Stephen Hawking and James Hartle, time and space would blend. Though the universe remains 4D, definitions blur.

Following the universe back to its origins leads inevitably to an early instant when intense energies led to the breakdown of the very ideas of space and time. Quantum mechanics tells us that as we proceed to earlier and earlier instants, something peculiar begins to happen. Time begins to turn into space. The origin of everything is in spacetime, and the "quantum foam" of that primordial event is not separable into our familiar distances and seconds.

What is the shape of this spacetime? Theory permits a promiscuously infinite choice. Our usual view would be that space is one set of coordinates, and time another. But quantum uncertainty erupts through these intuitive definitions.

Begin with an image of a remorselessly shrinking space governed by a backward marching time, like a cone racing downward to a sharp point. Time is the length along the axis, space the circular area of a sidewise slice. Customarily, we think of the apex as the beginning of things, where time starts and space is of zero extent.

Now round off the cone's apex to a curve. There, length and duration smear. This rounded end permits no special time when things began. To see this, imagine the cone tilted. This model universe could be conceptually tilted this way or that, with no unique inclination of the cone seeming to be preferred. Now the "earliest" event is not at the center of the rounded end. It is some spot elsewhere on the rounded nub, a place where space and time blend. No particular spot is special.

Another way to say this is that in 4D, time and space emerge gradually from an earlier essence for which we have no name. They are ideas we now find quite handy, but they were not forever fundamental.

In the primordial Big Bang, there is no dear boundary between space and time. Rather than an image of an explosion, perhaps we should call this event the Great Emergence. There we are outside the conceptual space of precisely known space and well defined time. Yet there are still only four dimensions -- just not sharp ones.

Einstein's cosmology thus begins with a time that is limited in the past, but has no boundary as such. Neither does space. As Stephen Hawking remarked, "The boundary condition of the universe is that it has no boundary."

Perhaps Edwin Abbott would not like the theological ramifications of these ideas. He was of the straitlaced Church of England. (The American version is the Episcopal faith, which happens to be my own. As an boy I was an acolyte, charged with lighting candles and carrying forth the sacraments of holy communion, in red and white robes. The robes were intolerably hot in our Atlanta church, and once I fainted and collapsed in service -- overcome by the heat, not the ideas. I'm told it provoked a stir.) However, it is notable that members of that faith had a decided dimensionally imaginative bent, at least in the nineteenth century; Lewis Carroll and H.G. Wells come to mind.

No doubt, psychologically the sharp-cone cosmological picture, with its initial singular point suggests the idea of a unique Creator who sets the whole thing going. How? Physics has no mechanism. For now, it merely describes.

Here lurks a conceptual gap, for we have no model which tells us a mechanism for making universes, much less one in which such basics as space and time are illusions. We need a "God of the gaps" to explain how the original, defining event happened. These new theories seem to bridge this gap in a fashion, but at the price of abandoning still more of our basic intuitions.

Much of God's essence comes from our perceived necessity for a creator, since there was a creation. But if there is no sharp beginning, perhaps we need no sharp, clear creator. Without a singular origin in time, or in space for that matter, is there any need to appeal to a supernatural act of creation?

But does this mean we can regard the universe as entirely self-consistent, its 4D nature emerging with time, from an event which lies a finite time in our past but does not need any sort of infinite Creator? Can the universe be a closed system, containing the reason for its very existence within itself?

Perhaps -- to put it mildly. Theory stands mute. Yet this latest outcome of our wrestling with dimensions assumes that there are laws to this universe, mathematically expressed in a stew of coordinates and algebra and natural beauties.

But whence come the laws themselves? Is that where a Creator resides, making not merely spacetime but the laws? Of this mathematics can say nothing -- so far.

Edwin Abbott would no doubt be astonished at the twists and turns his Lewis Carroll-like narrative has taken us to, only a bit more than a century beyond his initial penning of Flatland. The questions still loom large.

So such matters progress, sharpening the questions without answering them in final fashion. We can only be sure that the future holds ideas which he, and we, would find stranger still.

About this Title