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Destinies

Edited by JAMES BAEN

THE PAPERBACK MAGAZINE OF SCIENCE FICTION AND SPECULATIVE FACT

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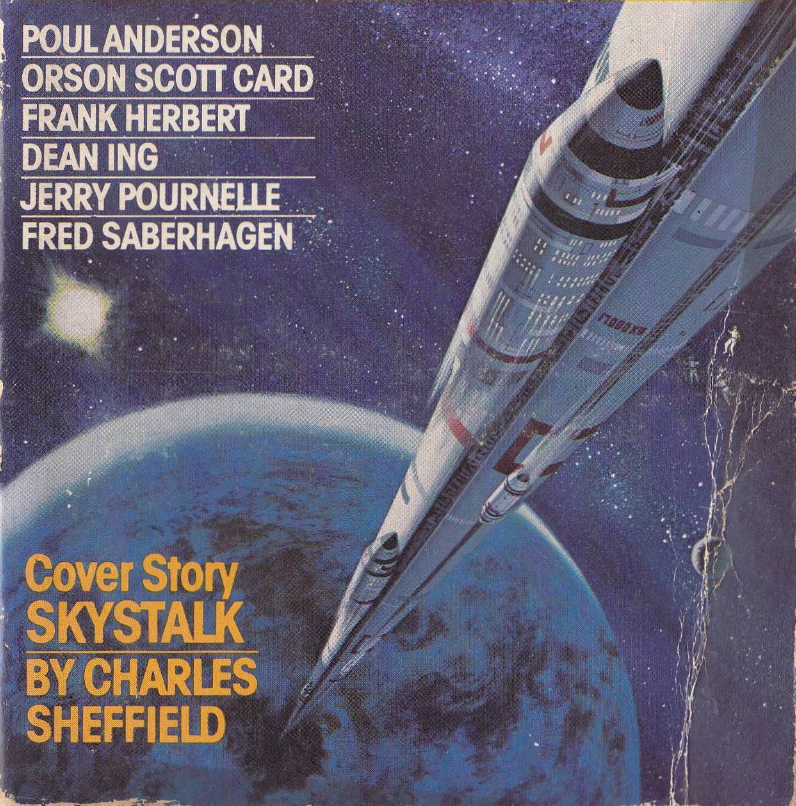

Cover Story
SKYSTALK
BY CHARLES SHEFFIELD

ROCKETS ARE WRONG

And if you don't believe it, take another look at the cover of this the fourth issue of *Destinies.* As promised in the previous issue, *Destinies #4* features a fiction/fact duet on the first post-primitive space technology: the skyhook; the space elevator; the beanstalk—call it what you will—a *physical* link from the surface of a planet to geosynch and beyond. An energy-free stairway to heaven. A veritable bridge to the stars! As President of the American Astronautical Society, Charles Sheffield can hardly be accused of an anti-rockets bias, but he goes a long way herein toward throwing them on the scrapheap of history.

Also in this issue Jerry Pournelle searches without success for "The Limits to Knowledge," we introduce "The L-5 Digest" with an exhortatory note from Robert Heinlein, Dean Ing takes a look at "Vehicles for Future Wars" (they are *very* strange), and Poul Anderson reaches the Penultimate in his five-part series on "Science Fiction and Science." Plus we got Fred Saberhagen (berserkers in a different light), Frank Herbert, and Spider Robinson. You want more? At these prices?

Hmmmm...we seem to have run out of room without getting to *Destinies #5.* Suffice it to say it's our First Anniversary Issue, with stellar contributors ranging from A (Anderson) to Z (Zelazny). In between you will find names like David Drake, James Gunn, Frank Herbert, James Hogan, Jerry Pournelle, Spider Robinson and Harry G. Stine. See you then.

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Skystalk

by Charles Sheffield

The more powerful
a technology,
the greater
the fruits thereof—
and the danger...

Illustrated by Steve Fabian

Finlay's Law: Trouble comes at three a.m.

That's always been my experience, and I've learned to dread the hand on my shoulder that shakes me to wakefulness. My dreams had been bad enough, blasting off into orbit on top of an old chemical rocket, riding the torch, up there on a couple of thousand tons of volatile explosives. I'll never understand the nerve of the old-timers, willing to sit up there on one of those monsters.

I shuddered, forced my eyes open, and looked up at Marston's anxious face. I was already sitting up.

"Trouble?" It was a stupid question, but you're allowed a couple of those when you first wake up.

His voice was shaky. "There's a bomb on the Beanstalk."

I was off the bunk, pulling on my undershirt and groping around for my shoes. Larry Marston's words pulled me bolt upright.

"What do you mean, *on* the Beanstalk?"

"That's what Velasquez told me. He won't say more until you get on the line. They're holding a coded circuit open to Earth."

I gave up my search for shoes and went barefoot after Marston. If Arnold Velasquez were right—and I didn't see how he could be—then one of my old horrors was coming true. The Beanstalk had been designed to withstand most natural events, but sabotage was one thing that could never be fully ruled out. At any moment, we had nearly four hundred buckets climbing the Stalk and the same number going down. With the best screening in the world, with hefty rewards for information even of *rumors* of sabotage, there was always the small chance that something could be sneaked through on an outbound bucket. I had less worries about the buckets that went down to Earth. Sabotage from the space end had little to offer its perpetrators, and the Colonies would provide an unpleasant form of death to anyone who tried it, with no questions asked.

Arnold Velasquez was sitting in front of his screen door at Tether Control in Quito. Next to him stood a man I recognized only from news pictures: Otto Panosky, a top aide to the President. Neither man seemed to be looking at the screen. I wondered what they were seeing on their inward eye.

"Jack Finlay here," I said. "What's the story, Arnold?"

There was a perceptible lag before his head came up to stare at the screen, the quarter of a second that it took the video signal to go down to Earth, then back up to synchronous orbit.

"It's best if I read it to you, Jack," he said. At least his voice was under control, even though I could see his hands shaking as they held the paper. "The President's Office got this in over the telecopier about twenty minutes ago."

He rubbed at the side of his face, in the nervous gesture that I had seen during most major stages of the Beanstalk's construction. "It's addressed to us, here in Sky Stalk Control. It's quite short. 'To the Head of Space Transportation Systems. A fusion bomb has been placed in one of the out-going buckets. It is of four megaton capacity, and was armed prior to placement. The secondary activation command can be given at any time by a coded radio signal. Unless terms are met by the President and World Congress on or before 02.00 U.T., seventy-two hours from now, we will give the command to explode the device. Our terms are set out in the following four paragraphs. One—' "

"Never mind those, Arnold." I waved my hand, impatient at the signal delay. "Just tell me one thing. Will Congress meet their demands?"

He shook his head. "They can't. What's being asked for is preposterous in the time available. You know how much red tape there is in intergovernmental relationships."

"You told them that?"

"Of course. We sent out a general broadcast." He shrugged. "It was no good. We're dealing with fanatics, with madmen. I need to know what you can do at your end."

"How much time do we have now?"

He looked at his watch. "Seventy-one and a half hours, if they mean what they say. You understand that we have no idea which bucket might be carrying the bomb. It could have been planted there days ago, and still be on the way up."

He was right. The buckets—there were three hundred and eighty-four of them each way—moved at a steady five kilometers a minute, up or down. That's a respectable speed, but it still took almost five days for each one of them to climb the cable of the Beanstalk out to our position in synchronous orbit.

Then I thought a bit more, and decided he wasn't quite right.

"It's not that vague, Arnold. You can bet the bomb wasn't placed on a bucket that started out more than two days ago. Otherwise, we could wait for it to get here and disarm it, and still be inside their deadline. It must still be fairly close to Earth, I'd guess."

"Well, even if you're right, that deduction doesn't help us." He was chewing a pen to bits between sentences. "We don't have anything here that could be ready in time to fly out and take a look, even if it's only a couple of thousand kilometers. Even if we did, and even if we could spot the bomb, we couldn't rendezvous with a bucket on the Stalk. That's why I need to know what you can do from your end. Can you handle it from there?"

I took a deep breath and swung my chair to face Larry Marston.

"Larry, four megatons would vaporize a few kilometers of the main cable. How hard would it be for us to release ballast at the top end of the cable, above us here, enough to leave this station in position?"

"Well . . ." He hesitated. "We could do that, Jack. But then we'd lose the power satellite. It's right out at the end there, by the ballast. Without it, we'd lose all the power at the station here, and all the buckets too—there isn't enough reserve power to keep the magnetic fields going. We'd need all our spare power to keep the recycling going here."

That was the moment when I finally came fully awake. I realized the implications of what he was saying, and was nodding before he'd finished speaking. Without adequate power, we'd be looking at a very messy situation.

"And it wouldn't only be us," I said to Velasquez and Panosky, sitting there tense in front of their screen. "Everybody on the Colonies will run low on air and water if the supply through the Stalk breaks down. Dammit, we've been warning Congress how vulnerable we are for years. All the time, there've been fewer and fewer rocket launches, and nothing but foot-dragging on getting the second Stalk started with a Kenya tether. Now you want miracles from us at short notice."

If I sounded bitter, that's because I *was* bitter. Panosky was nodding his head in a conciliatory way.

"We know, Jack. And if you can pull us through this one, I think you'll see changes in the future. But right now, we can't debate that. We have to know what you can do for us *now,* this minute."

I couldn't argue with that. I swung my chair again to face Larry Marston.

"Get Hasse and Kano over here to the Control Room as soon as you can." I turned back to Velasquez. "Give us a few minutes here, while we get organized. I'm bringing in the rest of my top engineering staff."

While Larry was rounding up the others, I sat back and let the full dimensions of the problem sink in. Sure, if we had to we could release the ballast at the outward end of the Stalk. If the Beanstalk below us were severed we'd have to do that, or be whipped out past the Moon like a stone from a slingshot, as the tension in the cable suddenly dropped.

But if we did that, what would happen to the piece of the Beanstalk that was still tethered to Earth, anchored down there in Quito? There might be as much as thirty thousand kilometers of it, and as soon as the break occurred it would begin to fall.

Not in a straight line. That wasn't the way that the dynamics went. It would begin to curl around the Earth, accelerating as it went, cracking into the atmosphere along the equator like a billion-ton whip stretching half-way around the planet. Forget the carrier buckets, and the superconducting cables that carried electricity down to the drive train from the solar power satellite seventy thousand kilometers above us. The piece that would do the real damage would be the central, load-bearing cable itself. It was only a couple of meters across at the bottom end, but it widened steadily as it went up. Made of bonded and doped silicon whiskers, with a tensile strength of two hundred million Newtons per square centimeter, it could handle an incredible load—almost two-thirds of a billion tons at its thinnest point. When that stored energy hit the atmosphere, there was going to be a fair amount of excitement down there on the surface. Not that we'd be watching it—the loss of the power satellite would make us look at our own survival problems; and as for the Colonies, a century of development would be ended.

By the time that Larry Marston came back with Jen Hasse and Alicia Kano, I doubt if I looked any more cheerful than Arnold Velasquez, down there at Tether Control. I sketched out the problem to the two newcomers; we had what looked like a hopeless situation on our hands.

"We have seventy-one hours," I concluded. "The only question we need to answer is, what will we be doing at this end during that time? Tether Control can coordinate disaster planning for the position on Earth. Arnold has already ruled out the possibility of any actual *help* from Earth—there are no rockets there that could be ready in time."

"What about the repair robots that you have on the cable?" asked Panosky, jumping into the conversation. "I thought they were all the way along its length."

"They are," said Jen Hasse. "But they're special purpose, not general purpose. We couldn't use one to look for a radioactive signal on a bucket, if that's what you're thinking of. Even if they had the right sensors for it, we'd need a week to reprogram them for the job."

"We don't have a week," said Alicia quietly. "We have seventy-one hours." She was small and dark-haired, and never raised her voice much above the minimum level needed to reach her audience—but I had grown to rely on her brains more than anything else on the station.

"Seventy-one hours, if we act *now,*" I said. "We've already agreed that we don't have time to sit here and wait for that bucket with the bomb to arrive—the terrorists must have planned it that way."

"I know." Alicia did not raise her voice. "Sitting and waiting won't do it. But the total travel time of a carrier from the surface up to synchronous orbit, or back down again, is a little less than a hundred and twenty hours. That means that the bucket carrying the bomb will be at least *half-way* here in sixty hours. And a bucket that started down from here in the next few hours—"

"—would have to pass the bucket with the bomb on the way up, before the deadline," broke in Hasse. He was already over at the Control Board, looking at the carrier schedule. He shook his head. "There's nothing scheduled for a passenger bucket, in the next twenty-four hours. It's all cargo going down."

"We're not looking for luxury." I went across to look at the schedule. "There are a couple of ore buckets with heavy metals scheduled for the next three hours. They'll have plenty of space in the top of them, and they're just forty minutes apart from each other. We could squeeze somebody in one or both of them, provided they were properly suited up. It wouldn't be a picnic, sitting in suits for three days, but we could do it."

"So how would we get at the bomb, even if we did that?" asked Larry. "It would be on the other side of the Beanstalk from us, passing at a relative velocity of six hundred kilometers an hour. We couldn't do more than wave to it as it went by, even if we knew just which bucket was carrying the bomb."

"That's the tricky piece." I looked at Jen Hasse. "Do you have enough control over the mass driver system, to slow everything almost to a halt whenever an inbound and an outbound bucket pass each other?"

He was looking doubtful, rubbing his nose thoughtfully. "Maybe. Trouble is, I'd have to do it nearly a hundred times, if you want to slow down for every pass. And it would take me twenty minutes to stop and start each one. I don't think we have that much time. What do you have in mind?"

I went across to the model of the Beanstalk that we kept on the Control Room table. We often found that we could illustrate things with it in a minute that would have taken thousands of words to describe.

"Suppose we were here, starting down in a bucket," I said. I put my hand on the model of the station, thirty-five thousand kilometers above the surface of the Earth in synchronous orbit. "And

suppose that the bucket we want to get to, the one with the bomb, is here, on the way up. We put somebody in the inbound bucket, and it starts on down."

I began to turn the drive train, so that the buckets began to move up and down along the length of the Beanstalk.

"The people in the inbound bucket carry a radiation counter," I went on. "We'd have to put it on a long arm, so that it cleared all the other stuff on the Stalk, and reached around to get near the upbound buckets. We can do that, I'm sure—if we can't, we don't deserve to call ourselves engineers. We stop at each outbound carrier, and test for radioactivity. There should be enough of that from the fission trigger of the bomb, so that we'll easily pick up a count when we reach the right bucket. Then you, Jan, hold the drive train in the halt position. We leave the inbound bucket, swing around the Stalk, and get into the other carrier. Then we try and disarm the bomb. I've had some experience with that."

"You mean we get out and actually *climb* around the Beanstalk?" asked Larry. He didn't sound pleased at the prospect.

"Right. It shouldn't be too bad," I said. "We can anchor ourselves with lines to the ore bucket, so we can't fall."

Even as I was speaking, I realized that it didn't sound too plausible. Climbing around the outside of the Beanstalk in a space-suit, twenty thousand kilometers or more up, dangling on a line connected to an ore bucket—and then trying to take apart a fusion bomb wearing gloves. No wonder Larry didn't like the sound of that assignment. I wasn't surprised when Arnold Velasquez chipped in over the circuit connecting us to Tether Control.

"Sorry, Jack, but that won't work—even if you could do it. You didn't let me read the full message from the terrorists. One of their conditions is that we mustn't stop the bucket train on the Stalk in the next three days. I think they were afraid that we would reverse the direction of the buckets, and bring the bomb back down to Earth to disarm it. I guess they don't realize that the Stalk wasn't designed to run in reverse."

"Damnation. What else do they have in that message?" I asked. "What can they do if we decide to stop the bucket drive anyway? How can they even tell that we're doing it?"

"We have to assume that they have a plant in here at Tether Control," replied Velasquez. "After all, they managed to get a bomb onto the Stalk in spite of all our security. They say they'll explode the bomb if we make any attempt to slow or stop the bucket train, and we simply can't afford to take the risk of doing that. We have to assume they can monitor what's going on with the Stalk drive train."

There was a long, dismal silence, which Alicia finally broke.

"So that seems to leave us with only one alternative," she said thoughtfully. Then she grimaced and pouted her mouth. "It's a two-bucket operation, and I don't even like to think about it—even though I had a grandmother who was a circus trapeze artiste."

She was leading in to something, and it wasn't like her to make a big build-up.

"That bad, eh?" I said.

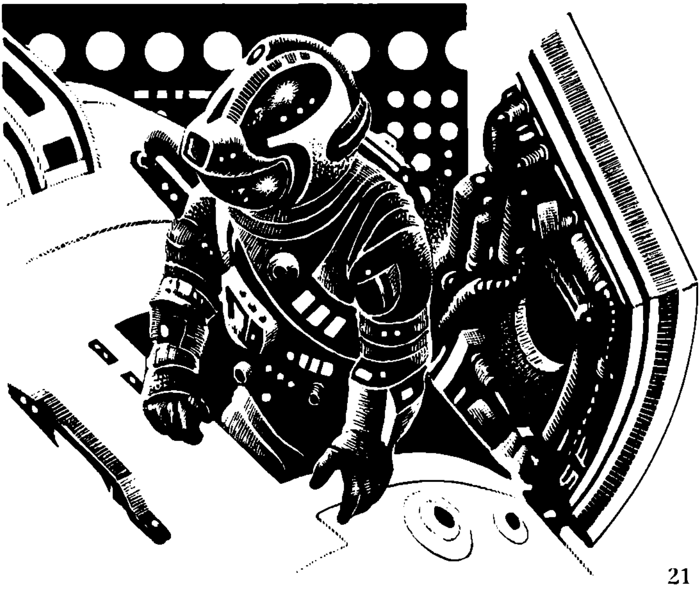
"That bad, if we're lucky," she said. "If we're unlucky, I guess we'd all be dead in a month or two anyway, as the recycling runs down. For this to work, we need a good way of dissipating a lot of kinetic energy—something like a damped mechanical spring would do it. And we need a good way of sticking to the side of the Beanstalk. Then, we use *two* ore buckets—forty minutes apart would be all right—like this . . ."

She went over to the model of the Beanstalk. We watched her with mounting uneasiness as she outlined her idea. It sounded crazy. The only trouble was, it was that or nothing. Making choices in those circumstances is not difficult.

One good thing about space maintenance work—you develop versatility. If you can't wait to locate something down on Earth, then waste another week or so to have it shipped up to you,

you get into the habit of making it for yourself. In an hour or so, we had a sensitive detector ready, welded on to a long extensible arm on the side of a bucket. When it was deployed, it would reach clear around the Beanstalk, missing all the drive train and repair station fittings, and hang in close to the outbound buckets. Jen had fitted it with a gadget that moved the detector rapidly upwards at the moment of closest approach of an upbound carrier, to increase the length of time available for getting a measurement of radioactivity. He swore that it would work on the fly, and have a better than ninety-nine percent chance of telling us which outbound bucket contained the bomb—even with a relative fly-by speed of six hundred kilometers an hour.

I didn't have time to argue the point, and in any case Jen was the expert. I also couldn't dispute his



claim that he was easily the best qualified person to operate the gadget. He and Larry Marston, both fully suited-up, climbed into the ore bucket. We had to leave the ore in there, because the mass balance between in-going and outbound buckets was closely calculated to give good stability to the Beanstalk. It made for a lumpy seat, but no one complained. Alicia and I watched as the bucket was moved into the feeder system, accelerated up to the correct speed, attached to the drive train, and dropped rapidly out of sight down the side of the Beanstalk.

"That's the easy part," she said. "They drop with the bucket, checking the upbound ones as they come by for radioactivity, and that's all they have to do."

"Unless they can't detect any signal," I said. "Then the bomb goes off, and they have the world's biggest roller-coaster ride. Twenty thousand kilometers of it, with the big thrill at the end."

"They'd never reach the surface," replied Alicia absent-mindedly. "They'll frizzle up in the atmosphere long before they get there. Or maybe they won't. I wonder what the terminal velocity would be if you hung onto the Stalk cable?"

As she spoke, she was calmly examining an odd device that had been produced with impossible haste in the machine shop on the station's outer rim. It looked like an old-fashioned parachute harness, but instead of the main chute the lines led to a wheel about a meter across. From the opposite edge of the wheel, a doped silicon rope led to a hefty magnetic grapnel. Another similar arrangement was by her side.

"Here," she said to me. "Get yours on over your

suit, and let's make sure we both know how to handle them. If you miss with the grapple, it'll be messy."

I looked at my watch. "We don't have time for any dry run. In the next fifteen minutes we have to get our suits on, over to the ore buckets, and into these harnesses. Anyway, I don't think rehearsals here inside the station mean too much when we get to the real thing."

We looked at each other for a moment, then began to suit up. It's not easy to estimate odds for something that has never been done before, but I didn't give us more than one chance in a hundred of coming out of it safely. Suits and harnesses on, we went and sat without speaking in the ore bucket.

I saw that we were sitting on a high-value shipment—silver and platinum, from one of the

Belt mining operations. It wasn't comfortable, but we were certainly traveling in expensive company. Was it King Midas who complained that a golden throne is not right for restful sitting?

No matter what the final outcome, we were in for an unpleasant trip. Our suits had barely enough capacity for a six-day journey. They had no recycling capacity, and if we had to go all the way to the halfway point we would be descending for almost sixty hours. We had used up three hours to the deadline, getting ready to go, so that would leave us only nine hours to do something about the bomb when we reached it. I suppose that it was just as bad or worse for Hasse and Marston. After they'd done their bit with the detector, there wasn't a thing they could do except sit in their bucket and wait, either for a message from us or an explosion far above them.

"Everything all right down there, Larry?" I asked, testing the radio link with them for the umpteenth time.

"Can't tell." He sounded strained. "We've passed three buckets so far, outbound ones, and we've had no signal from the detector. I guess that's as planned, but it would be nice to know it's working all right."

"You shouldn't expect anything for at least thirty-six hours," said Alicia.

"I know that. But it's impossible for us *not* to look at the detector whenever we pass an outbound bucket. Logically, we should be sleeping now and saving our attention for the most likely time of encounter—but neither one of us seems able to do it."

"Don't assume that the terrorists are all that logical, either," I said. "Remember, we are the ones who decided that they must have started the bomb on its way only a few hours ago. It's possible they put it into a bucket three or four days ago, and made up the deadline for some other reason. We think we can disarm that bomb, but they may not agree —and they may be right. All we may manage to do is advance the time of the explosion when we try and open up the casing."

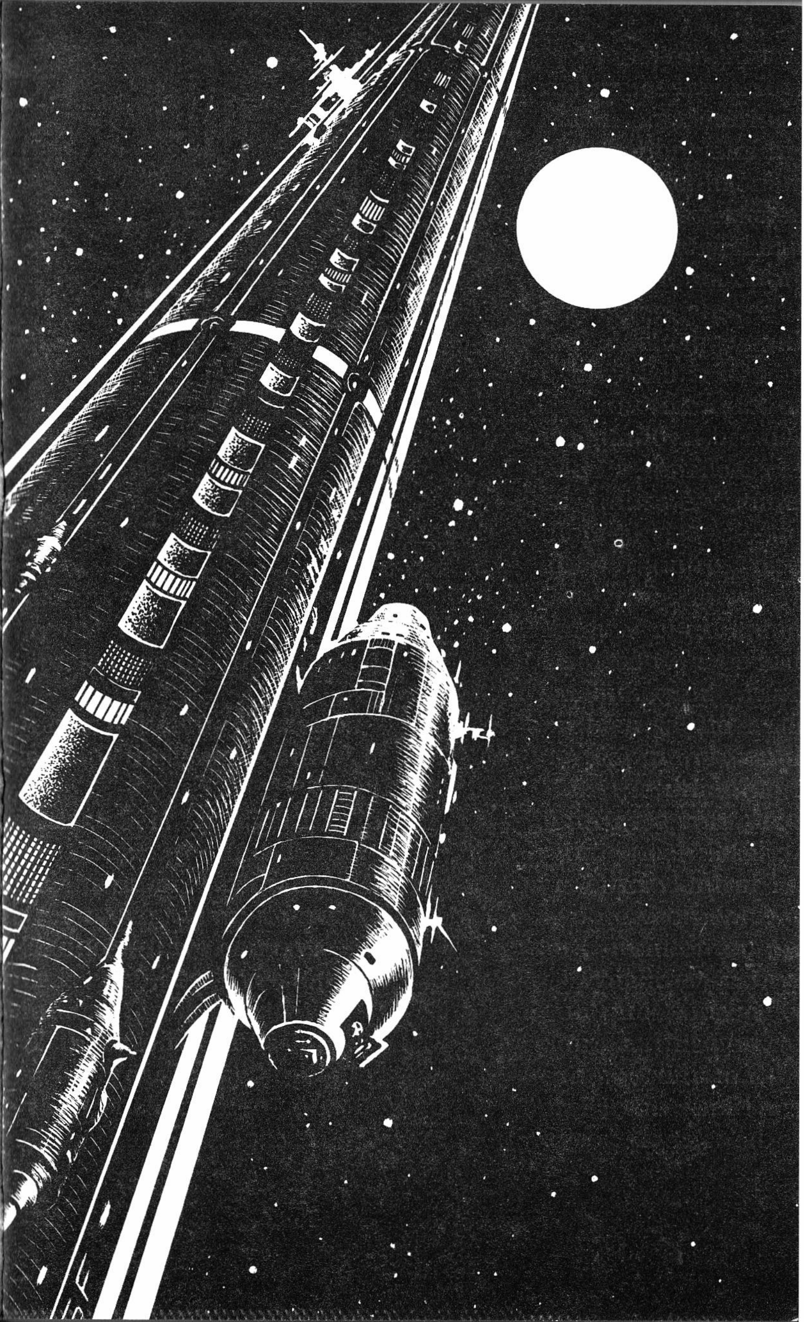
As I spoke, I felt our bucket begin to accelerate. We were heading along the feeder and approaching the bucket drive train. After a few seconds, we were outside the station, dropping down the Beanstalk after Jen and Larry.

We sat there in silence for a while. I'd been up and down the Stalk many times, and so had Alicia, but always in passenger modules. The psychologists had decided that people rode those a lot better when they were windowless. The cargo bucket had no windows either, but we had left the hatch open, to simplify communications with the other bucket and to enable us to climb out if and when the time came. We would have to close it when we were outside, or the aerodynamic pressures would spoil bucket stability when it finally entered the atmosphere—three hundred kilometers an hour isn't that fast, but it's a respectable speed for travel at full atmospheric pressure.

Our bucket was about four meters wide and three deep. It carried a load of seven hundred tons, so our extra mass was negligible. I stood at its edge and looked up, then down. The psychologists were quite right. Windows were a bad idea.

Above us, the Beanstalk rose up and up, occulting the backdrop of stars. It went past the synchronous station, which was still clearly visible as a blob on the stalk, then went on further up, invisible, to the solar power satellite and the great ballast weight, a hundred and five thousand kilometers above the surface of the Earth. On the Stalk itself, I could see the shielded superconductors that ran its full length, from the power satellite down to Tether Control in Quito. We were falling steadily, our rate precisely controlled by the linear synchronous motors that set the accelerations through pulsed magnetic fields. The power for that was drawn from the same superconducting cables. In the event of an electrical power failure, the buckets were designed to 'freeze' to the side of the Stalk with mechanical coupling. We had to build the system that way, because about once a year we had some kind of power interruption—usually from small meteorites, not big enough to trigger the main detector system, but large enough to penetrate the shields and mess up the power transmission.

It was looking down, though, that produced the real effect. I felt my heart begin to pump harder, and I was gripping at the side of the bucket with my space-suit gloves. When you are in a rocket-propelled ship, you don't get any real feeling of height. Earth is another part of the Universe, something independent of you. But from our position, moving along the side of the Beanstalk, I had quite a different feeling. We were *connected* to the planet. I could see the Stalk, dwindling smaller and smaller down to the Earth below. I had a very clear feeling that I could fall all the way down it, down to the big, blue-white globe at its foot. Although I had lived up at the station quite happily for over five years, I



suddenly began to worry about the strength of the main cable. It was a ridiculous concern. There was a safety factor of ten built into its design, far more than a rational engineer would use for anything. It was more likely that the bottom would fall out of our ore bucket, than that the support cable for the Beanstalk would break. I was kicking myself for my illogical fears, until I noticed Alicia also peering out at the Beanstalk, as though trying to see past the clutter of equipment there to the cable itself. I wasn't the only one thinking wild thoughts.

"You certainly get a different look at things from here," I said, trying to change the mood. "Did you ever see anything like that before?"

She shook her head ponderously—the suits weren't made for agility of movement.

"Not up here, I haven't," she replied. "But I once went up to the top of the towers of the Golden Gate Bridge in San Francisco, and looked at the support cables for that. It was the same sort of feeling. I began to wonder if they could take the strain. That was just for a bridge, not even a big one. What will happen if we don't make it, and they blow up the Beanstalk?"

I shrugged, inside my suit, then realized that she couldn't see the movement. "This is the only bridge to space that we've got. We'll be out of the bridge business, and back in the ferry-boat business. They'll have to start sending stuff up by rockets again. Shipments won't be a thousandth of what they are now, until another Stalk can be built. That will take thirty years, starting without this one to help us—even if the Colonies survive all right, and work on nothing else. We don't have to worry about that, though. We won't be there to hassle with it."

She nodded. "We were in such a hurry to get away it never occurred to me that we'd be sitting here for a couple of days with nothing to do but worry. Any ideas?"

"Yes. While you were making the reel and grapnel, I thought about that. The only thing that's worth our attention right now is a better understanding of the geometry of the Stalk. We need to know exactly where to position ourselves, where we'll set the grapnels, and what our dynamics will be as we move. I've asked Ricardo to send us schematics and lay-outs over the suit videos. He's picking out ones that show the drive train, the placing of the superconductors, and the unmanned repair stations. I've also asked him to deactivate all the repair robots. It's better for us to risk a failure on the maintenance side than have one of the monitoring robots wandering along the Stalk and mixing in with what we're trying to do."

"I heard what you said to Panosky, but it still seems to me that the robots ought to be useful."

"I'd hoped so, too. I checked again with Jen, and he agrees we'd have to reprogram them, and we don't have the time for it. It would take weeks. Jen said having them around would be like taking along a half-trained dog, bumbling about while we work. Forget that one."

As we talked, we kept our eyes open for the outbound buckets, passing us on the other side of the Beanstalk. We were only about ten meters from them at closest approach and they seemed to hurtle past us at an impossible speed. The idea of hitching on to one of them began to seem more and more preposterous. We settled down to look in more detail at the configuration of cables, drive train, repair stations and buckets that was being flashed to us over the suit videos.

It was a weary time, an awful combination of boredom and tension. The video images were good, but there is a limit to what you can learn from diagrams and simulations. About once an hour, Jen Hasse and Larry Marston called in from the lower bucket beneath us, reporting on the news—or lack of it—regarding the bomb detection efforts. A message relayed from Panosky at Tether Control reported no progress in negotiations with the terrorists. The fanatics simply didn't believe their terms couldn't be met. That was proof of their naivety, but didn't make them any less dangerous.

It was impossible to get comfortable in our suits. The ore buckets had never been designed for a human occupant, and we couldn't find a level spot to stretch out. Alicia and I passed into a half-awake trance, still watching the images that flashed onto the suit videos, but not taking in much of anything. Given that we couldn't sleep, we were probably in the closest thing we could get to a resting state. I hoped that Jen and Larry would keep their attention up, watching an endless succession of buckets flash past them and checking each one for radioactivity count.

The break came after fifty-four hours in the bucket. We didn't need to hear the details from the carrier below us to know they had it—Larry's voice crackled with excitement.

"Got it," he said. "Jen picked up a strong signal from the bucket we just passed. If you leave the ore carrier within thirty-four seconds, you'll have thirty-eight minutes to get ready for it to come past you. It will be the second one to reach you. For

God's sake don't try for the wrong one."

There was a pause, then Larry said something I would never have expected from him. "We'll lose radio contact with you in a while, as we move further along the Stalk. Good luck, both of you—and look after him, Alicia."

I didn't have time to think that one through—but shouldn't he be telling *me* to look after *her?* It was no time for puzzling. We were up on top of our bucket in a second, adrenalin moving through our veins like an electric current. The cable was whipping past us at a great rate; the idea of forsaking the relative safety of the ore bucket for the naked wall of the Beanstalk seemed like insanity. We watched as one of the repair stations, sticking out from the cable into open space, flashed past.

"There'll be another one of those coming by in

thirty-five seconds," I said. "We've got to get the grapnels onto it, and we'll be casting blind. I'll throw first, and you follow a second later. Don't panic if I miss—remember, we only have to get one good hook there."

"Count us down, Jack," said Alicia. She wasn't one to waste words in a tight spot.

I pressed the digital read-out in my suit, and watched the count move from thirty-five down to zero.

"Count-down display on Channel Six," I said, and picked up the rope and grapnel. I looked doubtfully at the wheel that was set in the middle of the thin rope, then even looked suspiciously at the rope itself, wondering if it would take the strain. That shows how the brain works in a crisis—that rope would have held a herd of elephants with no trouble at all.

I cast the grapnel as the count touched to zero, and Alicia threw a fraction later. Both ropes were spliced onto both suits, so it was never clear which grapnel took hold. Our bucket continued to drop rapidly towards Earth, but we were jerked off the top of it and went zipping on downwards fractionally slower as the friction reel in the middle of the rope unwound, slowing our motion.

We came to a halt about fifty meters down the Beanstalk from the grapnel, after a rough ride in which our deceleration must have averaged over seven gee. Without that reel to slow us down gradually, the jerk of the grapnel as it caught the repair station wall would have snapped our spines when we were lifted from the ore bucket.

We hung there, swinging free, suspended from the wall of the Stalk. As the reel began to take up the line that had been paid out, I made the mistake of looking down. We dangled over an awful void, with nothing between us and that vast drop to the Earth below but the thin line above us. When we came closer to the point of attachment to the Beanstalk wall, I saw just how lucky we had been. One grapnel had missed completely, and the second one had caught the very lip of the repair station platform. Another foot to the left and we would have missed it altogether.

We clawed our way up to the station rim—easy enough to do, because the gravity at that height was only a fraction of a gee, less than a tenth. But a fall from there would be inexorable, and we would have fallen away from the Beanstalk, with no chance to re-connect to it. Working together, we freed the grapnel and readied both lines and grapnels for re-use. After that there was nothing to do but cling to the side of the Beanstalk, watch the sweep of the heavens above us, and wait for the outbound ore buckets to come past us.

The first one came by after seventeen minutes. I had the clock read-out to prove it, otherwise I would have solemnly sworn that we had waited there for more than an hour, holding to our precarious perch. Alicia seemed more at home there than I was. I watched her moving the grapnel to the best position for casting it, then settle down patiently to wait.

It is hard to describe my own feelings in that period. I watched the movement of the stars above us, in their great circle, and wondered if we would be alive in another twenty minutes. I felt a strong communion with the old sailors of Earth's seas, up in their crow's-nest in a howling gale, sensing nothing but darkness, high-blown spindrift, perilous breakers ahead, and the dipping, rolling stars above.

Alicia kept her gaze steadily downwards, something that I found hard to do. She had inherited a good head for heights from her circus-performer grandmother.

"I can see it," she said at last. "All ready for a repeat performance?"

"Right." I swung the grapnel experimentally. "Since we can see it this time, we may as well throw together."

I concentrated on the bucket sweeping steadily up towards us, trying to estimate the distance and the time that it would take before it reached us. We both drew back our arms at the same moment and lobbed the grapnels towards the center of the bucket.

It came past us with a monstrous, silent rush. Again we felt the fierce acceleration as we were jerked away from the Beanstalk wall and shot upwards after the carrier. Again, I realized that we couldn't have done it without Alicia's friction reel, smoothing the motion for us. This time, it was more dangerous than when we had left the downbound bucket. Instead of trying to reach the stationary wall of the Stalk, we were now hooked onto the moving bucket. We swung wildly beneath it in its upward flight, narrowly missing contact with elements of the drive train, and then with another repair station that flashed past a couple of meters to our right.

Finally, somehow, we damped our motion, reeled in the line, slid back the cover to the ore bucket and fell safely forward inside it. I was completely drained. It must have been all nervous stress—we hadn't expended a significiant amount of physical energy. I know that Alicia felt the same way as I did, because after we plumped over the rim of the carrier we both fell to the floor and lay there without speaking for several minutes. It gives some idea of our state of mind when I say that the bucket we had reached, with a four megaton bomb inside it that might go off at any moment, seemed like a haven of safety.

We finally found the energy to get up and look around us. The bucket was loaded with manufactured goods, and I thought for a sickening moment that the bomb was not there. We found it after five minutes of frantic searching. It was a compact blue cylinder, a meter long and fifty centimeters wide, and it had been cold-welded to the wall of the bucket. I knew the design.

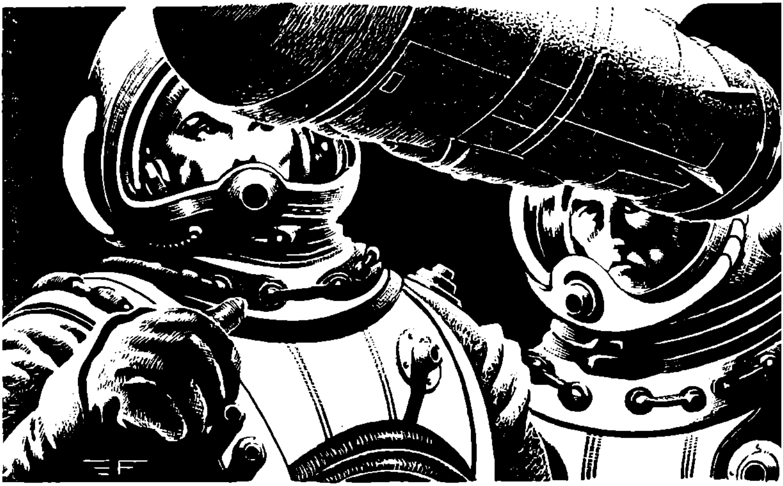
"There it is," I said to Alicia. Then I didn't know what to say next. It was the most advanced design, not the big, old one that I had been hoping for.

"Can you disarm it?" asked Alicia.

"In principle. There's only one problem. I know how it's put together—but I'll never be able to get it apart wearing a suit. The fingerwork I'd need is just too fine for gloves. We seem to be no better off than we were before."

We sat there side by side, looking at the bomb. The irony of the situation was sinking in. We had reached it, just as we hoped we could. Now, it seemed we might as well have been still back in the station.

"Any chance that we could get it free and dump it overboard?" asked Alicia. "You know, just chuck the thing away from the bucket."



I shook my head, aware again of how much my suit impeded freedom of movement. "It's spot-welded. We couldn't shift it. Anyway, free fall from here would give it an impact orbit, and a lot of people might be killed if it went off inside the atmosphere. If we were five thousand kilometers higher, perigee would be at a safe height above the surface—but we can't afford to wait for another sixteen hours until the bucket gets up that high. Look, I've got another idea, but it will mean that we'll lose radio contact with the station."

"So what?" said Alicia. Her voice was weary. "There's not a thing they can do to help us anyway."

"They'll go out of their minds with worry down on Earth, if they don't know what's happening here."

"I don't see why we should keep all of it for ourselves. What's your idea, Jack?"

"All right." I summoned my reserves of energy. "We're in vacuum now, but this bucket would be air-tight if we were to close the top hatch again. I have enough air in my suit to make a breathable atmosphere in this enclosed space, at least for long enough to let me have a go at the bomb. We've got nearly twelve hours to the deadline, and if I can't disarm it in that time I can't do it at all."

Alicia looked at her air reserve indicator and nodded. "I can spare you some air, too, if I open up my suit."

"No. We daren't do that. We have one other big problem—the temperature. It's going to feel really cold in here, once I'm outside my suit. I'll put my heaters on to maximum, and leave the suit open, but I'm still not sure I can get much done before I begin to freeze up. If I begin to lose feeling in my fingers, I'll need your help to get me back inside. So you have to stay in your suit. Once I'm warmed up, I can try again."

She was silent for a few moments, repeating the calculations that I had just done myself.

"You'll only have enough air to try it twice," she said at last. "If you can't do it in one shot, you'll have to let me have a go. You can direct me on what has to be done."

There was no point in hanging around. We sent a brief message to the station, telling them what we were going to do, then closed the hatch and began to bleed air out of my suit and into the interior of the bucket. We used the light from Alicia's suit, which had ample power to last for several days.

When the air pressure inside the bucket was high enough for me to breathe, I peeled out of my suit. It was as cold as charity in that metal box, but I ignored that and crouched down alongside the bomb in my underwear and bare feet.

I had eleven hours at the most. Inside my head, I fancied that I could hear a clock ticking. That must have been only my fancy. Modern bombs have no place for clockwork timers.

By placing my suit directly beneath my hands, I found that I could get enough heat from the thermal units to let me keep on working without a break. The clock inside my head went on ticking, also without a break.

On and on and on.

They say that I was delirious when we reached the station. That's the only way the Press could reconcile my status as public hero with the things that I said to the President when he called up to congratulate us.

I suppose I could claim delirium if I wanted to—five days without sleep, two without food, oxygen starvation, and frostbite of the toes and ears, that might add up to delirium. I had received enough warmth from the suit to keep my hands going, because it was very close to them, but that had been at the expense of some of my other extremities. If it hadn't been for Alicia, cramming me somehow back into the suit after I had disarmed the bomb, I would have frozen to death in a couple of hours.

As it was, I smelled ripe and revolting when they unpacked us from the bucket and winkled me out of my suit—Alicia hadn't been able to re-connect me with the plumbing arrangements.

So I told the President that the World Congress was composed of a giggling bunch of witless turds, who couldn't sense a global need for more bridges to space if a Beanstalk were pushed up their backsides—which was where I thought they kept their brains. Not quite the speech that we used to get from the old-time returning astronauts, but I must admit it's one that I'd wanted to give for some time. The audience was there this time, with the whole world hanging on my words over live TV.

We've finally started construction on the second Beanstalk. I don't know if my words had anything to do with it, but there was a lot of public pressure after I said my piece, and I like to think that I had some effect.

And me? I'm designing the third Beanstalk; what else? But I don't think I'll hold my breath waiting for a Congressional Vote of Thanks for my efforts saving the first one. ●

"WHY USE SOMETHING
AS WASTEFUL AND NOISY
AS A ROCKET
WHEN THERE ARE SIMPLE,
CLEAN, EFFICIENT
ALTERNATIVES?"

HOW TO BUILD A BEANSTALK

by Charles Sheffield

Illustrated by David Egge

THE AGE OF ROCKETS.

The launch of a Saturn V rocket is an impressive sight. It is impressively noisy, impressively big and impressively risky. It is also one of Man's outstanding examples of conspicuous consumption, where a few thousand tons of fuel go up (literally) in smoke (literally) in a couple of minutes. And yet it is, in 1979, the best space transportation system that we have.

If we were to sit down and make a list of the properties of our 'ideal' space transportation system, without worrying about whether or not we could ever hope to achieve it, what would it look like? Well, first and most important it ought not to use up any raw materials in its working—no reaction mass, which all rockets need to propel themselves. It ought to allow us to take materials up and down from planetary surfaces, and be equally good at moving us around in free space. And it would be nice if it were somehow completely energy-free. While we are at it, let's ask that it be also silent and non-polluting.

Note that our old friend, the rocket, satisfies *none* of our ideal system requirements. The Space Shuttle, our first reusable spacecraft, is not suited to anything beyond low earth orbit activities, and is, with all its advantages over its non-reusable predecessors, still a very primitive system.

It may sound improbable, but an ideal space system, satisfying *all* our requirements, could be here in a couple of generations. As we shall see, the technology needed is not far from that already available to us.

It is curious that science fiction, which likes to look beyond today's technology, has remained so infatuated with the idea of rockets. Some people even use them to *define* the field. Look at the 'sf' section in public libraries and you will often see a small drawing of a rocket attached to the spine of each volume. It may be a perverse choice of label for a branch of writing that covers everything from 'Ringworld' to 'Flowers For Algernon', but you can see how the logic goes; science fiction means space travel, and space travel means rockets—because they are 'the only way of getting up to space and around in space.' After all, there is nothing for any other sort of transportation to 'push against' in space. Right?

Not quite. We will try and dispose of that peculiar viewpoint here. Our preoccupation with rockets for space travel will probably amaze our descendants.

"Why use something as wasteful and noisy as a rocket," they will ask, "when there are simple, clean, efficient alternatives? Why didn't they use Beanstalks?"

The Age of Rockets may look to them like the Age of Dinosaurs. Let's try and see it through their eyes, beginning with the most basic principles.

A spacecraft, orbiting Earth around the equator just high enough to avoid the main effects of atmospheric drag, makes a complete revolution in about an hour and a half. If the Earth had no atmosphere, a spacecraft in a 'grazing orbit' would skim around just above the surface in 84.9 minutes. At the end of that time, it would *not* be above the same point on the Earth where it started. The Earth is rotating, too, and if the spacecraft revolves in the same direction as Earth it must go farther—about 2,370 kilometers, the distance that a point on the equator rotates in 84.9 minutes—before it again passes over the point where it began.

Now keep the spacecraft in a circular path above the equator, but instead of a grazing orbit, imagine that it travels 1,000 kilometers above the surface. Then the orbital period will be greater. It will now be about 106 minutes: the higher the orbit, the longer the period of revolution.

When the height of the spacecraft is 35,770 kilometers, the orbital period is 1,436 minutes, or one sidereal day (a *solar* day, the time that a point on the Earth takes to return to point exactly at the Sun, is 1,440 minutes). In other words, the spacecraft now takes just as long as the Earth to make one full revolution in space. Since the spacecraft is moving around at the same rate as the Earth, it seems to hover always above the same point on the equator.

Such a specialized orbit is called *geostationary,* because the satellite does not move relative to the Earth's surface. It is a splendid orbit for a communications satellite. There is no need for ground receiving antennae to track the satellite at all—it remains in one place in the sky. The term 'Clarkian orbit' has been proposed as an alternate to the cumbersome 'geostationary orbit', in recognition of Arthur Clarke's original suggestion in 1945 that such orbits had unique potential for use in worldwide communications. Note, by the way, that a 24-hour period orbit does not have to be geostationary. An orbit whose plane is at an angle to the equator can be *geosynchronous,* with 24-hour period, but it moves up and down in latitude and oscillates in longitude during one day. The class of geosynchronous orbits includes all geostationary orbits.

A geosynchronous orbit has some other unusual features. It is at the distance from the Earth where gravitational and centrifugal accelerations on an orbiting object balance. To see what this means, suppose that you could erect a thin pole vertically on the equator. A long pole, and I do mean *long.* Suppose that you could extend it upwards over a hundred thousand kilometers, and it was strong and rigid enough that you could make it remain vertical. Then every part of the pole *below* the height of a geostationary orbit would feel a net downward force, because it is travelling too slowly for centrifugal acceleration to balance gravitational acceleration. On the other hand, every element of the pole beyond geostationary altitude would feel a net *outward* force. Those elements are travelling so fast that centrifugal force exceeds gravitational pull.

(Every mechanics textbook will point out that there are no such things as 'centrifugal forces'; there is only the gravitational force, curving the path of the orbiting body from its natural inclination to continue in a straight line. The centrifugal forces are fictitious forces, arising only as a consequence of the use of a rotating reference frame for calculations. But centrifugal forces are so convenient that everyone uses them, even if they don't exist! And when you move to an Einsteinian viewpoint you find that centrifugal forces now appear as real as any others. So much for theories.)

The higher that a section of the pole is above geostationary height, the greater the total outward pull on it. So if we make the pole just the right length, the total inward pull from all parts of the pole *below* geostationary height will exactly balance the outward pull from the higher sections *above* that height. Our pole will hang there, touching the Earth at the equator but not exerting any downward force on it. If you like, we can think of the pole as an enormously long satellite, in a geostationary orbit.

How long would such a pole have to be? If we were to make the pole of uniform cross-section, it would have to extend upwards a distance of about

143,700 kilometers. This result does not depend on the cross-sectional area of the pole, nor on the material from which it is made. It should be clear that in practice we would not choose to make a pole of uniform cross-section, since the downward pull that it must withstand is far greater up near geosynchronous height than it is near the Earth. At the higher point, the pole must support the weight of more than 35,000 kilometers of itself, whereas near Earth it supports only the weight hanging below it. From this, we would expect that the best design will be a tapered pole, with its thickest part at geostationary altitude where the pull on it is greatest.

The idea of a rigid pole is also misleading. We have seen that the only forces at work are tensions. It is thus more logical to think of the structure as a *cable* than a pole.

We now have the major feature of our 'basic Beanstalk'. It will be a long, strong cable, extending from the surface of the Earth on the equator, out to beyond the geostationary orbit. It will be of the order of 144,000 kilometers long. We will use it as the load-bearing cable of a giant elevator, to send materials up to orbit and back. The structure will hang there in static equilibrium, revolving with the Earth. It is a bridge to space, replacing the old ferry-boat rockets.

That's the main concept. What could be simpler? We have—perhaps an understatement—left out a number of 'engineering details,' but we will look at those next.

DESIGNING THE BEANSTALK.

Let us list some of the questions that we must answer before we have a satisfactory Beanstalk design. The most important ones are as follows:

- What shape should the load-bearing cable have?
- What materials will it be made from?
- Where will we get those materials?
- Where will we build the Beanstalk, where will we attach it to Earth, and how will we get it installed?
- How will we use the main cable to move materials up and down from Earth?
- Will a Beanstalk be stable, against the gravitational forces from the Sun and Moon, against weather, and against natural events here on Earth?
- What are the advantages of a Beanstalk over rockets?
- If we can get satisfactory answers to all these questions, *when* should we be able to build a

Beanstalk?

We can offer definite answers to some of these questions; other answers can only be conjectures. Let's begin with the first, which is also the easiest.

Suppose that the load-bearing cable is made of a single material. Then the most efficient design is one in which the stress on the material, per unit area, is the same all the way along it. This means there is no wasted strength. With such an assumption, it is a simple exercise in statics to derive an equation for the cross-sectional area of the cable as a function of distace from the center of the Earth.

The result has the form:

(1) $A(r) = A\ (R).\ \exp\ (K.f(r/R).d/T.R)$

(*Note to Editor Baen.* I know you told me not to use equations, but surely I'm entitled to at least *one.)*

In this equation, A(r) is the cross-sectional area of the cable at distance r from the center of the Earth, A(R) is the area at the distance R of a geostationary orbit, K is the gravitational constant for the Earth, d is the density of the material from which the cable is made, T is the tensile strength of the cable per unit area, and $f(r/R) = 3/2 - R/r - (r/R)^2/2$.

Equation (1) tells us a great deal. First, we note that the variation of the cross-sectional area with distance does not depend on the tensile strength T directly, but only on the *ratio* T/d, which is the strength-to-weight ratio for the material. The substance from which we will build the Beanstalk must be strong, but more than that it should be strong and *light*.

Second, we can see that the shape of the cable is tremendously sensitive to the strength-to-weight ratio of the material, because this quantity occurs in the exponential of equation (1). To take a simple example, suppose that we have a material with a *taper factor* of 10,000. We define *taper factor* as the cross-sectional area of the cable at geostationary height, divided by the cross-sectional area at the surface of the Earth. So, for example, a cable that was one square meter in area at the bottom end would in this case be 10,000 square meters in area at geostationary height.

Now suppose that we could double the strength-to-weight ratio of the material we use for the cable. The taper ratio would drop from 10,000 to 100. If we could double the strength-to-weight ratio again, the taper ratio would reduce from 100 to 10.

It is clear that we should make the Beanstalk of the strongest possible material. Note that an infinitely strong material would need no taper at all.

Two other points are worth noting about the shape of the cable. It is easy to show that the function f(r/R) has its maximum value at r = R. This confirms the intuitive result, that the cable must be thickest at geostationary height, where the load is greatest since the cable must support all the downward weight between that height and the surface of the Earth. Second, a look at the change of f(r/R) with increasing r shows that the cross-sectional area decreases slowly above geostationary height. This is why we need a cable with a length that is much more than twice the distance to that height.

MATERIALS FOR THE BEANSTALK.

The cable that we need must be able to withstand a tension at least equal to its own weight from a height of 35,000 kilometers down to the surface. In practice, it must be a good deal stronger than that. We will certainly want to build in a reasonable safety factor, and we will want to hang other structures on the cable all the way down, to make it into a usable transportation system. So we expect that we will need to work with a very strong material, one with an unusually high strength-to-weight ratio. Of course, if one does not have a material that is quite as strong as needed, one can try and compensate by increasing the taper factor, but we have seen that this would be a very inefficient way to go. Halving the strength of materials would square the taper factor. The incentive to work with the strongest possible materials is very large.

The tension in the cable at a height of 35,770 kilometers, where upward and downward forces exactly balance, is less than the weight of a similar length of 35,770 kilometers of cable down here on Earth, for two reasons. The downward gravitational force decreases as the square of the distance from the center of the Earth, and the upward centrifugal force increases linearly with that distance. Both these effects tend to decrease the tension that the cable must support. A straightforward calculation shows that the maximum tension in a cable of constant cross-section will be equal to the weight of 4,940 kms. of such cable, here on Earth. This is in a sense a 'worst case' calculation, since we know that the cable will be designed to taper. However, the need for a safety factor means that we need to be conservative, and the figure of 4,940 kms. gives us a useful standard in terms of which we can calibrate the strength of available materials.

The definition we have chosen of a cable's strength, namely, how much length of its own substance it must support under Earth's gravity, is used quite widely. For a particular material, the length of itself the cable will support is called the 'support length' or 'characteristic length'. It is particularly handy because of the way in which the strength of materials is usually described, in terms of the tons *weight* per square centimeter (or per square inch) that they will support. (It would be more desirable, scientifically speaking, to give strength in dynes per square centimeter, or in newtons per square meter. These measures are independent of the Earth's surface gravity. But historically, pounds per square inch and kilos per square centimeter came first and things are still given that way in most of the handbooks. Note also that we are concerned only with *tensile* strength—how strong the material is when you pull it. *Compressive* and *shear* strengths are quite different, and a material may be very strong in compression and weak in tension. A building brick is a good example of this.)

Against our requirement of a support length of 4,940 kms, how well do the substances that we have available today measure up?

Not too well. Now we see why no one has yet built a Beanstalk. Table 1 shows the strengths of currently available materials, their densities, and their support lengths. (The physical data that I am using here is drawn, wherever possible, from the "Handbook of Chemistry and Physics", 57th Edition. It is one of the most widely available reference texts and should be in any reasonable library.)

Not surprisingly, we won't be trying to make a

Beanstalk support cable from lead. As we can see from the table, even the best steel wire that we can find has a support length only one hundredth of what we need. The last entry in the table, Fictionite, would be perfect but for one drawback: it doesn't exist yet. The strongest materials that we have today, graphite and silicon carbide whiskers, still fall badly short of our requirements (for Earth, that is. A Mars Beanstalk has a minimum support length of only 973 kms. We could make one of those nicely using graphite whiskers).

Does this mean that we have a hopeless situation? It depends what confidence you have in the advance of technology. Table 2 lists the strength of materials that have been available at different dates in human history. There is some inevitable arbitrariness in making a table like this, since no one really knows when the Hittites began to smelt iron, and there must have been poor control of times, temperatures and purity of raw materials in the Bronze Age and early Iron Age. All these factors have a big effect on the tensile strength of the products.

It is tempting to try and fit some kind of function to the values in the table, and see when we will have a material available with a support length of 5,000 kms. or better. It is also very dangerous to even think of such a thing. For example, consider a fit to the data of the form: Strength = B/(t - T), where B and T are to be determined by the data, and t is time in years before the year 2000 A.D. This fits the data fairly well if we choose B = 525,000 and T = 17.5 years. Unfortunately, such a form becomes infinite when t = T. If we were to believe such a fit, we would expect to have infinitely strong materials available to us some time in 1982!

TABLE 1
STRENGTH OF MATERIALS

Material	Tensile strength (kgms/squ.cm.)	Density (gms/c.c.)	Support length (kilometers)
Lead	200	11.4	0.18
Gold	1,400	19.3	0.73
Aluminum	2,000	2.7	7.4
Cast iron	3,500	7.8	4.5
Carbon steel	7,000	7.8	9.0
Manganese steel	16,000	7.8	21.
Drawn tungsten	35,000	19.3	18.
Drawn steel wire	42,000	7.8	54.
Iron whisker	126,000	7.8	161.
Silicon whisker (SiC)	210,000	3.2	660.
Graphite whisker	210,000	2.0	1,050.
Fictionite	2,000,000	2.0	10,000.

Not surprisingly, extrapolation of a trend without using physical models can lead us to ridiculous results. A much more plausible way of predicting the potential strength of materials is available to us,

TABLE 2
PROGRESS IN STRENGTH OF MATERIALS
AS A FUNCTION OF TIME

Year	Available material	Tensile Strength (kgms/sq.cm.)
1500 B.C.	Bronze	1,400
1850	Iron	3,500
1950	Special steels	16,000
1970	Drawn steel	42,000
1980	Graphite and silicon whiskers	210,000

Note: Years given indicate the dates when the materials could first be reliably produced in production quantities.

based on the known structure of the atom. In chemical reactions, only the outermost electrons of the atom participate, and it is the coupling of these outer electrons that decides the strength of chemical bonds. These bonds in turn set bounds on the possible strength of a material. Thus, so far as we are concerned the nucleus of the atom—which is where almost all the atomic mass resides—contributes nothing; strength of coupling, and hence material strength, comes only from those outer electrons.

In Table 3 we give the strengths of the chemical bonds for different pairs of atoms. These strengths, divided by the molecular weight of the appropriate element pair, decide the ultimate strength-to-weight ratio for a material entirely composed of

TABLE 3
POTENTIAL STRENGTH OF MATERIALS BASED ON THE STRENGTH OF CHEMICAL BONDS

Element pairs	Molecular weight*	Chemical bond strength (kcal/mole)	Support length (kilometers)**
Silicon-carbon	40	104	455
Carbon-carbon	24	145	1,050
Fluorine-hydrogen	20	136	1,190
Boron-hydrogen	11	80.7	1,278
Nitrogen-nitrogen	28	225.9	1,418
Carbon-oxygen	28	257.3	1,610
Hydrogen-hydrogen	2	104.2	9,118
Positronium-positronium	1/918.6	104	16,700,000

*Some of these element pairs do not exist as stable molecules, but can exist in a crystal lattice structure.

**We are using the support length of the graphite whisker as the standard of strength provided by the chemical bonds.

that pair of elements. The final column of the table shows the support length that this strength-to-weight ratio implies, using the carbon-carbon bond of the graphite whisker as the reference case.

Examining the Table, we see that the hydrogen-hydrogen bond has by far the greatest potential strength. In this bond, every electron participates in the bonding process (each atom has only one!) and the hydrogen nucleus contains no neutrons, which offer added weight without adding anything to the possible strength. A substance that consisted of pure solid hydrogen could in principle have a support length of more than 9,000 kilometers—very similar to the Fictionite of Table 1.

Even this strength is very modest if we are willing to look at a rather more exotic composition for our cables. Positronium is an 'atom' consisting of an electron and a positron. The positron takes the place of the usual proton in the hydrogen atom, but it has a far smaller mass. Positronium has been made in the laboratory, but it is unstable with a very short lifetime. If, however, positronium could be stabilized against decay, perhaps by the application of intense electromagnetic fields, then the resulting positronium-positronium bond should have a strength comparable with that of the hydrogen-hydrogen bond, and a far smaller molecular weight. It will have a support length of 16,700,000 kilometers—the taper of a Beanstalk made from such a material would be unmeasurably small. This would be true even for a Beanstalk on Jupiter, where the strength requirement is higher than for any other planet of the Solar System.

The positronium cable is likely to remain unavailable to us for some time yet. Even the solid hydrogen cable offers us the practical problem that we don't know how to build it. Rather than insisting on any particular material for our Beanstalk, it is safer and more reasonable to make a less specific statement: the strength of materials available to us has been increasing steadily throughout history, with the most striking advance coming in this century. It seems plausible to look for at least an increase of another order of magnitude in strength in the next hundred years. Such an advance in materials technology would make the construction of a Beanstalk quite feasible by the middle of the next century, at least from the point of view of strength of materials. It could come far sooner.

Something with the properties of Fictionite would do very nicely. The taper ration would be only 1.6, and a Beanstalk that was one meter in diameter at the lower end and of circular cross-section could support a load of nearly sixteen million tons.

WHERE TO BUILD THE BEANSTALK.

We have talked about what we will make the Beanstalk out of, but we have not discussed where we will find those materials. The answer to such a question is provided when we look at *how* we will build it.

For several reasons, the 'Tower of Babel' technique—start here on Earth and just build upwards—is not the way to go. The structure would be in *compression,* not tension, all the way up to beyond geostationary altitude, and we picked our material for its tensile strength. Worse still, structures in compression can buckle, which is a form of mechanical failure that does not apply to materials under tension.

Clearly, we will somehow begin *at the top,* with materials that we find up there. But *where* at the top? This is worth thinking about in more detail.

To a first approximation, the Earth is a sphere and its external gravity field is the same as that of a point mass. To a good second approximation, it is an oblate spheroid, with symmetry about the axis of rotation (the polar axis). The third order approximation gets much messier. Not only does the Earth "wobble" a bit about its axis of rotation, but there are fine inhomogeneities in the internal structure that show up as 'gravity anomalies' in the external gravitational field. These gravity anomalies are the deviations of the field from that which would be produced by a regular spheroid of revolution.

The anomalies are small—only a couple of milligals—but they are important. (In geodesy, a *gal* is not something that a male geodesist would like to snuggle up to; it is a unit of acceleration, equal to 1 cm. per second per second. A *milligal* is a thousandth of that. Earth's surface gravity is about 980 gals. If the Earth's gravity field were to change by one milligal, you would weigh differently by about one four-hundredth of an ounce. Even a change of a full gal—a thousand milligals—would not be noticed.)

If we look at these small gravity anomalies in the region of the orbit of a geostationary satellite, we find that they give rise to local maxima and minima of the gravitational potential. Satellites in such orbits tend to 'drift' to where the potential has its nearest local maximum, and to oscillate about such a position. For this particular location (35,770 kms. up, in the plane of the equator) these are the stable points of the gravitational field. At first sight, this looks like the best place to start to build your Beanstalk. You could put your source of materials there, and begin to extrude load-bearing cable up and down simultaneously, so as to keep a balance between the gravitational and centrifugal forces on the whole cable. Doing this, you might expect to be able to keep the cable Earth-stationary, always over the same fixed point of the surface.

Unfortunately, the gravitational potential is not so well-behaved. The positions of the stable points, the places where the potential has its local maxima, depend on the distance from the center of the Earth.

As you begin to extrude cable upwards and downwards, parts of the cable will move into regions where they are no longer at a local maximum of the potential. There will then be a strong tendency for the cable to "walk." It will begin to move steadily around the equator (and off the equator!), adjusting its position to the *average* of the gravity potential maxima encountered at all heights where a piece of the cable is present.

Such behavior is—at the very least—an annoyance. It means that you must allow for such motion in the design and construction, and you must tether the cable at the ground end when you have finished.

Such a tether is not a bad thing. We shall see later that it is an essential part of Beanstalk design if we want a usable structure, one that can carry cargo and people up and down it. However, you can't tether the Stalk until you have *finished* building it.

So we have still not answered the question, where do you do that construction? Remember, the geostationary location is full of other satellites—the communications satellites sit out there, and some of the weather satellites. It would be intolerable for the Beanstalk, half-built, to come drifting along through their *lebensraum* until it was finally long enough to tether.

What other options do we have? Well, there is the "bootstrap" method. In this, you fabricate a very thin Beanstalk, tether it, and use that to stop your main Beanstalk from wandering about during the construction.

My own favorite is more ambitious than a construction from geostationary orbit. You build *all* your Beanstalk well away from Earth, out at L-4 or L-5. When you have it all done, you fly it down. You arrange your timing so that the lower end arrives at a pre-prepared landing and tether site on the equator at the same time as the upper end makes a rendezvous with a ballast weight, way out beyond geostationary height. Once the Beanstalk has been tethered, the problem of a stable position for the orbit is not serious—it merely means that the Stalk doesn't follow the exact local vertical on the way up, because it tries to adapt to the mean gravity gradient all the way along its length.

Building the Stalk well away from Earth helps the problem of material supply. We certainly don't want to use Earth materials for construction, since getting them up there would be an enormous task. Fortunately, two of the promising substances that we found in the table of strong materials are graphite and silicon carbide. Coincidentally, two of the main categories of asteroid are termed the carbonaceous and the silicaceous types. They can be the source of our raw materials.

The way to build the Beanstalk is now apparent. We fly a smallish (a couple of kilometers in diameter) asteroid in from the Asteroid Belt and settle it at L-4. We build a solar power satellite or a fusion plant out there, too, to provide the energy that we need. Then we fabricate the Beanstalk, the whole thing: load-bearing cable, superconducting power cables, and drive train (more on these in a moment). And we fly it on down to Earth.

The final descent speed need not be high. We can use the inertia of the whole length of the Stalk to slow the arrival of its lower end.

The demand on the raw material resources of Earth in this whole operation will be minimal.

USING THE BEANSTALK.

A couple of paragraphs back, I threw in reference to superconducting power cables and drive train. These are the key to making the Beanstalk useful. Let us look in more detail at the whole structure of the Stalk.

We will have a load-bearing cable, perhaps a couple of meters across at the lower end, stretching up from the equator to out past geosynchronous altitude. It will be tethered at its lower end to prevent it from moving about around the Earth. It will be strong enough to support a load of millions of tons. What else do we need to do to make it useful?

First, we will strengthen the tether, to make sure that it can stand a pull of many millions of tons without coming loose from Earth. Next, we will go out to the far end of the cable, and hang a really big ballast weight there. The ballast weight pulls outwards, so that the whole cable is now under an added tension, balancing the pull of the ballast against the tether down on Earth.

We really need that tension.

Why? Well, suppose that we want to send a million tons of cargo up the Beanstalk. The first thing we will do is hang it on the cable near the ground tether. If the tension down near the lower end is a couple of million tons, when we hang the cargo on the cable we simply reduce the upward force on the tether from two million tons to one million tons. The cargo itself is providing some of the downward pull needed to balance the upward tug of the ballast at the far end. The whole system is still stable.

But if we had used a smaller ballast weight, enough to give us a pull at the tether of only half a million tons, we would be in trouble. If we hang a million tons of cargo on the cable, it will pull the ballast weight downwards. There is just not enough ballast to provide the required upward pull. We must provide an initial ballast weight that is sufficient to give a tension more than any weight that we will ever try and send up the cable.

There is another advantage to a massive ballast weight. We can use a shorter cable. We can hang a really big ballast at, say, a hundred thousand kilometers out, and it will not be necessary to have more cable beyond that point. The ballast weight provides the upward pull that balances the downward pull of the cable below geostationary height. We have to be a little careful here. A ballast that has a *mass* of ten million tons will not be enough to allow you to raise a *weight* of ten million tons up from Earth. The ballast will not pull outwards as hard as the weight pulls downwards, unless it is out at a distance where the net *outward* acceleration due to combined centrifugal and gravitational forces is one gee. This requires that the ballast be more than 1.8 million kilometers out from Earth—far past the Moon's distance of 400,000 kilometers.

We conclude from this that the ballast will be a massive one. This is no real problem. After all, even a modest sized asteroid, a kilometer across, will mass anything up to a billion tons.

Once we have a taut cable, suitably anchored, we need a power source for the activities on the Beanstalk. We put a solar power satellite or a fusion plant out at the far end and run cables all the way down, attaching them to the main loadbearing cable. Superconducting cables make sense, but we will have to be sure that they are suitably insulated—near-Earth space isn't *that* cold. But perhaps by the time we build the Stalk we will have superconductors that operate up to higher critical temperatures. The ones available now remain superconductors only up to about 23 degrees Kelvin.

There is a fringe benefit to running cables down the Beanstalk. We can carry down power from space without worrying about the effects of microwave radiation on the Earth—which is a serious worry with present solar power satellite designs.

Once we have the power cables installed, we can build the drive train, again attaching it to the load cable for its support. The easiest system for a drive train is probably a linear synchronous motor. The principles and the practice for that are well-established, which means it will all be off-the-shelf fixtures—except that we will want fifty to a hundred thousand kilometers of drive ladder. But remember, all this construction work will be done before we fly the Beanstalk in for a landing, and the abundant raw materials of the asteroid at L-4 will still be available to us.

Assuming that we drive cars up and down the Stalk at the uniform speed of 300 kilometers an hour, the journey up to synchronous altitude will take five days. That's a lot slower than a rocket, but it will be a lot more restful—and look at some of the other advantages.

First, we will have a completely non-polluting system, one that uses no reaction mass at all. This may appear a detail, until you look at the effects of frequent rocket launches on the delicate balance of the upper atmosphere and ionosphere of Earth.

Second, we will have a potentially *energy-free* system. Any energy that you use in the drive train in taking a mass up to synchronous height can in principle be recovered by making returning masses provide energy to the drive train as they descend to Earth. Even allowing for inevitable friction and energy conversion losses, a remarkably efficient system will be possible.

In some ways, the Stalk offers something even better than an energy-free system. When a mass begins its ascent from the surface of the Earth, it is moving with the speed of a point on the Earth's equator—a thousand miles an hour. When it reaches synchronous height, it will be travelling at 6,600 miles an hour. And if, from that point on, you let it "fall outwards" to the end of the Stalk, it will be launched on its way with a speed of more than 33,000 miles an hour, relative to the Earth. That's enough to throw it clear out of the Solar System.

Where did all the energy come from to speed up the mass?

The natural first answer might be, from the drive train. That is not the case. The energy comes from the rotational energy of the Earth itself. When you send a mass up the Beanstalk, you slow the Earth in its rotation by an infinitesimal amount, and when you send something back down, you speed it up a little. We don't need to worry about the effects on the planet, though. You'd have to take an awful lot of mass up there before you could make an appreciable effect on the rotation rate of Earth. The total rotational energy of Earth amounts to only about one thousandth of the planet's gravitational self-energy, but that is still an incredibly big number. We can use the Beanstalk without worrying about the effects that it will have on the Earth.

The converse of this is much less obvious. What about the effects of the Earth on the Beanstalk? Will we have to be worried about weather, earthquakes, and other natural events?

Earthquakes sound nasty. We certainly want the tether to be secure. If it came loose the whole Beanstalk would shoot off out into space, following the ballast. However, it is quite easy to protect ourselves. We simply arrange that the tether be held down by a mass that is itself a part of the lower end of the Stalk. Then the tether is provided by the simple weight of the bottom of the Beanstalk, and that will be a stable situation as long as the force at that point remains "down"—which will certainly be true unless something were to blow the whole Earth apart; in which case, we might expect to have other things to worry about.

Weather should be no problem. The Stalk presents so small a cross-sectional area compared with its strength that no storm we can imagine would trouble it. The same is true for perturbations from the gravity of the Sun and the Moon. Proper design of the Stalk will avoid any resonance effects, in which the period of the forces on the structure might coincide with any of its natural vibration frequencies.

In fact, by far the biggest danger we can conceive of is a man-made one—sabotage. A bomb, exploding halfway up the Beanstalk, would create unimaginable havoc in both the upper and lower sections of the structure. That would be the thing against which all security measures would be designed.

WHEN CAN WE BUILD A BEANSTALK?

We need two things before we can go ahead with a Beanstalk construction project: a strong enough material, and an off-Earth source of supplies. Both of these ought to be available in the next fifty to one hundred years. The general superiority of Beanstalks to rockets is so great that I expect to see the prototype built by the year 2050.

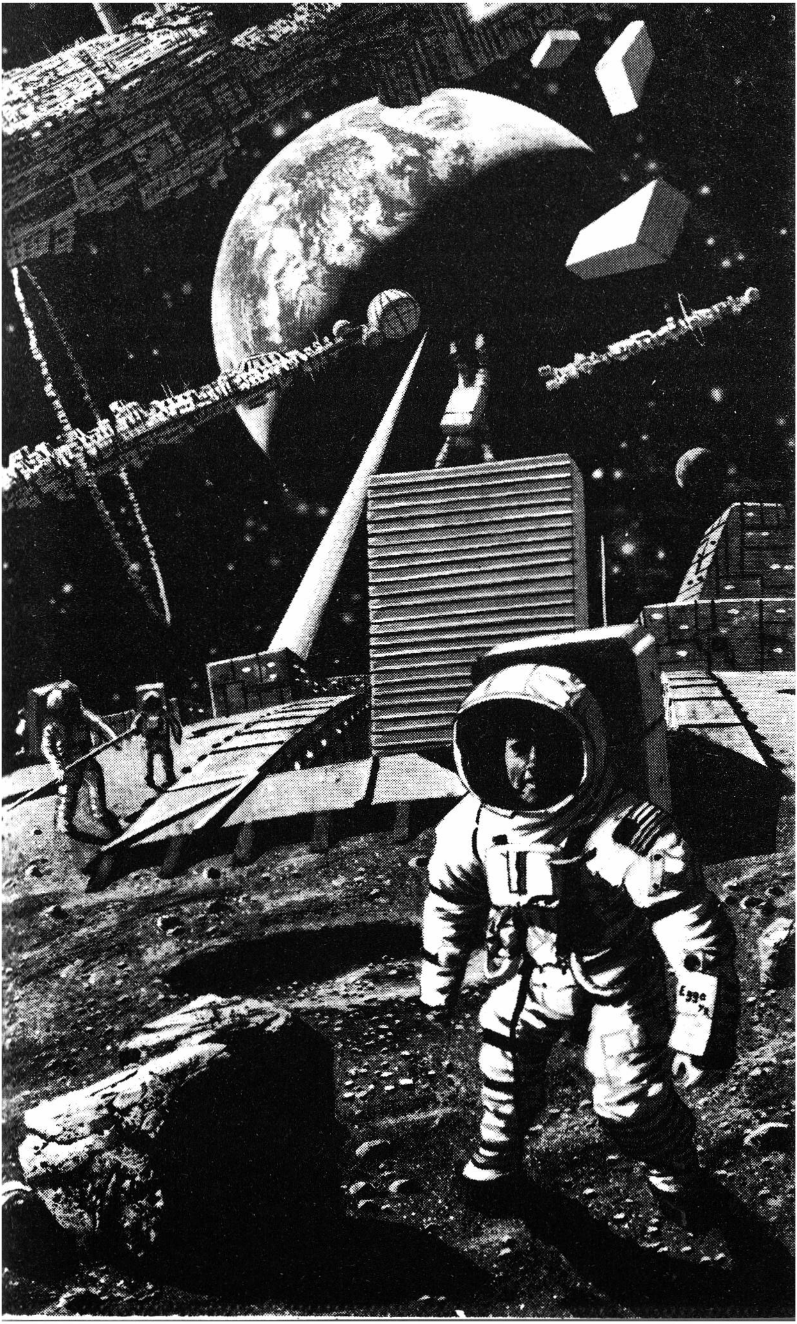
I do not regard this estimate as very adventuresome. It is certainly less so than Orville Wright's statement, when in 1911 he startled the world by predicting that we would eventually have passenger air service between cities as much as a hundred miles apart.

Unless we blow ourselves up, bog down in the Prox-mire, or find some other way to begin the slide back to the technological Dark Ages, normal engineering progress will give us the tools that we need to build a Beanstalk, by the middle of the next century. The economic impetus to deploy those tools will be provided by a recognition of the value of the off-Earth energy and raw materials, and it will be with us long before then.

This discussion seems to me to be so much a part of an inevitable future that I feel obliged to speculate a little further, just to make the subject matter less pedestrian. Let us look further out.

Non-synchronous Beanstalks have already been proposed for the Earth. These are shorter Stalks, non-tethered, that move around the Earth in low orbits and dip their ends into Earth's atmosphere and back out again a few times a revolution. They are a delightful and new idea that was developed in detail in a 1977 paper by Hans Moravec. The logical next step is free-space Beanstalks. These are revolving about their own center of mass, and they can be used to provide momentum transfer to spacecraft. They thus form a handy way to move materials about the Solar System.

Look ahead now a few thousand years. Civilization has largely moved off Earth, into free-space colonies. There are many thousands of these, each self-sustaining and self-contained, constructed from materials available in the Asteroid Belt. Although they are self-supporting, travel among them will be common, for commerce and recreation. Naturally enough, this travel will be accomplished without the use of reaction mass, via an extensive system of free-space Beanstalks which provide the velocity increases and decreases needed to move travellers around from colony to colony. There will be hundreds of thousands of these in a spherical region centered on the Sun, and they will all be freely orbiting.



The whole civilization will be stable and organized, but there will be one continuing source of perturbation and danger. Certain singularities of the gravitational field exist, disturbing the movements of the colonists and their free transfer through the Solar System.

The singularities sweep their disorderly way around the Sun, upsetting the orbits of the colonies and the Beanstalks with their powerful gravity fields and presenting a real threat of capture to any who get too close to them.

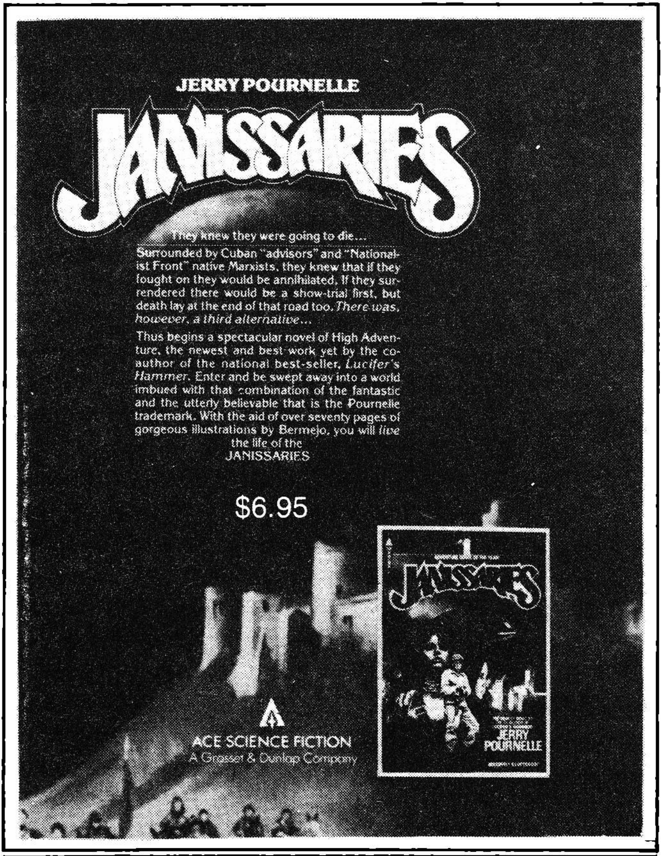
It seems inevitable that, in some future Forum on one of the colonies, a speaker will one day arise to voice the will of the people. He will talk about the problem presented by the singularities, about the need to remove them. About the danger they offer, and about the inconvenience they cause. And finally, as a newly-arisen Cato he may mimic the words of his predecessor to pronounce judgment on one or more of those gravity singularities of the Solar System, the planets.

"Terra delenda est"—Earth must be destroyed!

BEANSTALK TIME–A FINAL NOTE.

Beanstalks, originally called skyhooks, are an idea of the 1960's whose time may at last have come. They are used as important elements of at least two novels published in 1979, Arthur Clarke's "The Fountains Of Paradise" and my own "The Web Between The Worlds." I suspect that they will become a standard element of most projected futures, as a rational alternative to the rocketry that has served sf writers so long and so well. ●

THE END.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some events in the templar radiant

by fred saberhagen

 Illustrated by Bea Font

To a true scientist nothing is too much to pay for knowledge— life itself is cheap at the price!

All his years of past work, and more than that, his entire future too, hung balanced on this moment.

A chair forgotten somewhere behind him, Sabel stood tall in the blue habit that often served him as laboratory coat. His hands gripped opposite corners of the high, pulpit-like control console. His head was thrown back, eyes closed, sweat-dampened dark hair hanging in something more than its usual disarray over his high, pale forehead.

He was alone, as far as any other human presence was concerned. The large, stone-walled chamber in which he stood was for the moment quiet.

All his years of work . . . and although during the past few days he had mentally rehearsed this moment to the point of exhaustion, he was still uncertain of how to start. Should he begin with a series of cautious, testing questions, or ought he leap toward his real goal at once?

Hesitancy could not be long endured, not now. But caution, as it usually had during his private mental rehearsals, prevailed.

Eyes open, Sabel faced the workbenches filled with equipment that were arranged before him. Quietly he said: "You are what human beings call a berserker. Confirm or deny."

"Confirm." The voice was familiar, because his hookup gave it the same human-sounding tones in which his own laboratory computer ordinarily spoke to him. It was a familiarity that he must not allow to become in the least degree reassuring.

So far, at least, success. "You understand," Sabel pronounced, "that I have restored you from a state of nearly complete destruction. I—"

"Destruction," echoed the cheerful workbench voice.

"Yes. You understand that you no longer have the power to destroy, to take life. That you are now constrained to answer all my—"

"To take life."

"Yes. Stop interrupting me." He raised a hand to wipe a trickle of fresh sweat from an eye. He saw how his hand was quivering with the strain of its unconscious grip upon the console. "Now," he said, and had to pause, trying to remember where he was in his plan of questioning.

Into the pause, the voice from his laboratory speakers said: "In you there is life."

"There is." Sabel managed to reassert himself, to pull himself together. "Human life." Dark eyes glaring steadily across the lab, he peered at the long, cabled benches whereon his captive enemy lay stretched, bound down, vitals exposed like those of some hapless human on a torture rack. Not that he could torture what had no nerves and did not live. Nor was there anything like a human shape in sight. All that he had here of the berserker was fragmented. One box here, another there, between them a chemical construct in a tank, that whole complex wired to an adjoining bench that bore rows of semi-material crystals.

Again his familiar laboratory speaker uttered alien words: "Life is to be destroyed."

This did not surprise Sabel; it was only a restatement of the basic programmed command that all berserkers bore. They were machines fabricated by unknown builders on an unknown world, at a time perhaps before any creature living on Earth had been able to see stars as anything more than points of light. That the statement was made so boldly now roused in Sabel nothing but hope; it seemed that at least the thing was not going to begin by trying to lie to him.

It seemed also that he had established a firm physical control. Scanning the indicators just before him on the console, he saw no sign of danger . . . he knew that, given the slightest chance, his prisoner was going to try to implement its basic programming. He had of course separated it from anything obviously useful as a weapon. But he was not absolutely certain of the functions of all the berserker components that he had brought into his laboratory and hooked up. And the lab of course was full of potential weapons. There were fields, electric and otherwise, quite powerful enough to extinguish human life. There were objects that could be turned into deadly projectiles by only a very moderate application of force. To ward off any such improvisations Sabel had set defensive rings of force to dancing round the benches upon which his foe lay bound. And, just for insurance, another curtain of fields hung round him and the console. The fields were almost invisible, but the ancient stonework of the lab's far wall kept acquiring and losing new flavorings of light at the spots where the spinning field-components brushed it and eased free again.

Not that it seemed likely that the berserker-brain in its present disabled and almost disembodied state could establish control over weaponry enough to kill a mouse. Nor did Sabel ordinarily go overboard on the side of caution. But, as he told himself, he understood very well just what he was dealing with.

He had paused again, seeking reassurance from the indicators ranked before him. All appeared to be going well, and he went on: "I seek information from you. It is not military information, so whatever inhibitions have been programmed into you against answering human questions do not apply." Not that he felt at all confident that a berserker would meekly take direction from him. But there was nothing to be lost by the attempt.

The reply from the machine was delayed longer than he had expected, so that he began to hope his attempt had been successful. But then the answer came.

"I may trade certain classes of information to you, in return for lives to be destroyed."

The possibility of some such proposition had crossed Sabel's mind some time ago. In the next room a cage of small laboratory animals was waiting.

"I am a cosmophysicist," he said. "In particular I strive to understand the Radiant. In the records of past observations of the Radiant there is a long gap that I would like to fill. This gap corresponds to the period of several hundred standard years during which berserkers occupied this fortress. That period ended with the battle in which you were severely damaged. Therefore I believe that your memory probably contains some observations that will be very useful to me. It is not necessary that they be formal observations of the Radiant. Any scene recorded in light from the Radiant may be helpful. Do you understand?"

"In return for my giving you such records, what lives am I offered to destroy?"

"I can provide several." Eagerly Sabel once more swept his gaze along his row of indicators. His recording instruments were probing hungrily, gathering at an enormous rate the data needed for at least a partial understanding of the workings of his foe's unliving brain. At a score of points their probes were fastened in its vitals.

"Let me destroy one now," its human-sounding voice requested.

"Presently. I order you to answer one question for me first."

"I am not constrained to answer any of your questions. Let me destroy a life."

Sabel tuned a narrow doorway for himself through his defensive fields, and walked through it into the next room. In a few seconds he was back. "Can you see what I am carrying?"

"Then it is not a human life you offer me."

"That would be utterly impossible."

"Then it is utterly impossible for me to give you information."

Without haste he turned and went to put the animal back into the cage. He had expected there might well be arguments, bargaining. But this argument was only the first level of Sabel's attack. His data-gathering instruments were what he really counted on. The enemy doubtless knew that it was being probed and analyzed. But there was evidently nothing it could do about it. As long as Sabel supplied it power, its brain must remain functional. And while it functioned, it must try to devise ways to kill.

Back at his console, Sabel took more readings. DATA PROBABLY SUFFICIENT FOR ANALYSIS, his computer screen at last informed him. He let out breath with a sigh of satisfaction, and at once threw certain switches, letting power die. Later if necessary he could turn the damned thing on again and argue with it some more. Now his defensive fields vanished, leaving him free to walk between the workbenches, where he stretched his aching back and shoulders in silent exultation.

Just as an additional precaution, he paused to disconnect a cable. The demonic enemy was only hardware now. Precisely arranged atoms, measured molecules, patterned larger bits of this and that. Where now was the berserker that humanity so justly feared? That had given the Templars their whole reason for existence? It no longer existed except in potential. Take the hardware apart, on even the finest level, and you would not discover any of its memories. But, reconnect this and that, reapply power here and there, and back it would bloom into reality, as malignant and clever and full of information as before. A non-material artifact of matter. A pattern.

No way existed, even in theory, to torture a machine into compliance, to extort information from it. Sabel's own computers were using the Van Holt algorithms, the latest pertinent mathematical advance. Even so they could not entirely decode the concealing patterns, the trapdoor functions, by which the berserker's memory was coded and concealed. The largest computer in the human universe would probably not have time for that before the universe itself came to an end. The unknown Builders had built well.

But there were other ways besides pure mathematics with which to circumvent a cipher. Perhaps, he thought, he would have tried to find a way to offer it a life, had that been the only method he could think of.

Certainly he was going to try another first. There had to be, he thought, some way of disabling the lethal purpose of a berserker while leaving its calculating abilities and memory intact. There would have been times when the living Builders wanted to approach their creations, at least in the lab, to test them and work on them. Not an easy or simple way, perhaps, but something. And that way Sabel now instructed his own computers to discover, using the mass of data just accumulated by measuring the berserker in operation.

Having done that, Sabel stood back and surveyed his laboratory carefully. There was no reason to think that anyone else was going to enter it in the near future, but it would be stupid to take chances. To the Guardians, an experiment with viable berserker parts would stand as *prima facie* evidence of goodlife activity; and in the Templar code, as in many another system of human law, any such willing service of the berserker cause was punishable by death.

Only a few of the materials in sight might be incriminating in themselves. Coldly thoughtful, Sabel made more disconnections, and rearrangements. Some things he locked out of sight in cabinets, and from the cabinets he took out other things to be incorporated in a new disposition on the benches. Yes, this was certainly good enough.

He suspected that most of the Guardians probably no longer knew what the insides of a real berserker looked like.

Sabel made sure that the doors leading out of the lab, to the mall-level corridor, and to his adjoining living quarters, were both locked. Then, whistling faintly, he went up the old stone stair between the skylights, that brought him out upon the glassed-in roof.

Here he stood bathed in the direct light of the Radiant itself. It was a brilliant point some four kilometers directly above his head—the pressure of the Radiant's inverse gravity put it directly overhead for everyone in the englobing structure of the Fortress. It was a point brighter than a star but dimmer than a sun, not painful to look at. Around Sabel a small forest of sensors, connected to instruments in his laboratory below, raised panels and lenses in a blind communal stare, to that eternal noon. Among these he began to move about as habit led him, mechanically checking the sensors' operation, though for once he was not really thinking about the Radiant at all. He thought of his success below. Then once more he raised his own two human eyes to look.

It made its own sky, out of the space enclosed by the whitish inner surface of the Fortress's bulk. Sabel could give from memory vastly detailed expositions of the spectrum of the Radiant's light. But as to exactly what color it was, in terms of perception by the eye and brain—well, there were different judgments on that, and for his part he was still uncertain.

Scattered out at intervals across the great curve of interior sky made by the Fortress's whitish

stonework, Sabel could see other glass portals like his own. Under some of them, other people would be looking up and out, perhaps at him. Across a blank space on the immense concavity, an echelon of maintenance machines were crawling, too far away for him to see what they were working at. And, relatively nearby, under the glass roof of a great ceremonial plaza, something definitely unusual was going on. A crowd of thousands of people, exceptional at any time in the Fortress with its relatively tiny population, were gathered in a circular mass, like live cells attracted to some gentle biological magnet at their formation's center.

Sabel had stared at this peculiarity for several seconds, and was reaching for a small telescope to probe it with, when he recalled that today was the Feast of Ex. Helen, which went a long way toward providing an explanation. He had in fact deliberately chosen this holiday for his crucial experiment, knowing that the Fortress's main computer would today be freed of much routine business, its full power available for him to tap if necessary.

And in the back of his mind he had realized also that he should probably put in an appearance at at least one of the day's religious ceremonies. But this gathering in the plaza—he could not recall that any ceremony, in the years since he had come to the Fortress, had ever drawn a comparable crowd.

Looking with his telescope up through his own glass roof and down through the circular one that sealed the plaza in from airless space, he saw that the crowd was centered on the bronze statue of Ex. Helen there. And on a man standing in a little cleared space before the statue, a man with arms raised as if to address the gathering. The angle was wrong for Sabel to get a good look at his face, but the blue and purple robes made the distant figure unmistakable. It was the Potentate, come at last to the Fortress in his seemingly endless tour of his many subject worlds.

Sabel could not recall, even though he now made an effort to do so, that any such visitation had been impending—but then of late Sabel had been even more than usually isolated in his own work. The visit had practical implications for him, though, and he was going to have to find out more about it quickly. Because the agenda of any person of importance visiting the Fortress was very likely to include at some point a full-dress inspection of Sabel's own laboratory.

He went out through the corridor leading from laboratory to pedestrian mall, locking up carefully behind him, and thinking to himself that there was no need to panic. The Guardians would surely call to notify him that a visit by the Potentate impended, long before it came. It was part of their job to see that such things went smoothly, as well as to protect the Potentate while he was here. Sabel would have some kind of official warning. But this was certainly an awkward time . . .

Along the pedestrian mall that offered Sabel his most convenient route to the ceremonial plaza, some of the shops were closed—a greater number than usual for a holiday, he thought. Others appeared to be tended only by machines. In the green parkways that intersected the zig-zag mall at irregular intervals, there appeared to be fewer strollers than on an ordinary day. And the primary school operated by the Templars had evidently been closed; a minor explosion of youngsters in blue-striped coveralls darted across the mall from parkway to playground just ahead of Sabel, their yells making him wince.

When you stood at one side of the great plaza and looked across, both the convexity of its glass roof and the corresponding concavity of the level-feeling floor beneath were quite apparent. Especially now that the crowd was gone again. By the time Sabel reached the center of the plaza, the last of the Potentate's entourage was vanishing through exits on its far side.

Sabel was standing uncertainly on the lowest marble step of Ex. Helen's central shrine. Her stat-bronze statue dominated the plaza's center. Helen the Exemplar, Helen of the Radiant, Helen Dardan. The statue was impressive, showing a woman of extreme beauty in a toga-like Dardanian garment, a diadem on her short curly hair. Of course long-term dwellers at the Fortress ignored it for the most part, because of its sheer familiarity. Right now, though, someone was stopping to look, gazing up at the figure with intent appreciation.

Sabel's attention, in turn, gradually became concentrated upon this viewer. She was a young, brown-haired girl of unusually good figure, and clad in a rather provocative civilian dress.

And presently he found himself approaching her. "Young woman? If you would excuse my curiosity?"

The girl turned to him. With a quick, cheerful curiosity of her own she took in his blue habit, his stature, and his face. "No excuse is needed, sir." Her voice was musical. "What question can I answer for you?"

Sabel paused a moment in appreciation. Everything about this girl struck him as quietly delightful. Her manner held just a hint of timidity, compounded with a seeming eagerness to please.

Then he gestured toward the far side of the plaza. "I see that our honored Potentate is here with us today. Do you by any chance know how long he plans to stay at the Fortress?"

The girl replied: "I heard someone say, ten standard days. It was one of the women wearing purple-bordered cloaks—?" She shook brown ringlets, and frowned with pretty regret at her own ignorance.

"Ah—one of the vestals. Perhaps you are a visitor here yourself?"

"A newcomer, rather. Isn't it always the way, sir, when you ask someone for local information? 'I'm a newcomer here myself.'"

Sabel chuckled. *Forget the Potentate for now.* "Well, I can hardly plead newcomer status. It must be something else that keeps me from knowing what goes on in my own city. Allow me to introduce myself: Georgicus Sabel, Doctor of Cosmography."

"Greta Thamar." Her face was so pretty, soft, and young, a perfect match for her scantily costumed body. She continued to radiate an almost-timid eagerness. "Sir, Dr. Sabel, would you mind if I asked you a question about yourself?"

"Ask anything."

"Your blue robe. That means you are one of the monks here?"

"I belong to the Order of Ex. Helen. The word 'monk' is not quite accurate."

"And the Order of Ex. Helen is a branch of the Templars, isn't it?"

"Yes. Though our Order is devoted more to contemplation and study than to combat."

"And the Templars in turn are a branch of Christianity."

"Or they were." Sabel favored the girl with an approving smile. "You are more knowledgeable than many newcomers. And, time was when many Templars really devoted themselves to fighting, as did their ancient namesakes."

The girl's interest continued. By some kind of body-language agreement the two of them had turned around and were now strolling slowly back in the direction that Sabel had come from.

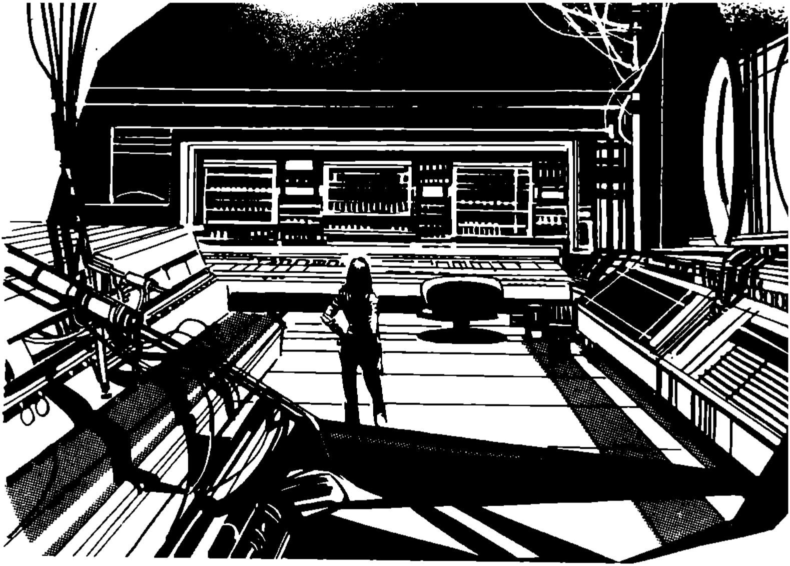
Greta said: "I don't know about that. The ancient ones, I mean. Though I tried to study up before I came here. Please, go on."

"Might I ask your occupation, Greta?"

"I'm a dancer. Only on the popular entertainment level, I'm afraid. Over at the *Contrat Rouge*. But I . . . please, go on."

On the Templar-governed Fortress, popular entertainers were far down on the social scale. *Seen talking to a dancer in the plaza* . . . but no, there was really nothing to be feared from that. A minimal loss of status, perhaps, but counterbalanced by an increase in his more liberal acquaintances' perception of him as more fully human. All this slid more or less automatically through Sabel's mind, while the attractive smile on his face did not, or so he trusted, vary in the slightest.

Strolling on, he shrugged. "Perhaps there's not a great deal more to say, about the Order. We study and teach. Oh, we still officially garrison this Fortress. Those of us who are Guardians maintain and man the weapons, and make berserkers their field



of study, besides acting as the local police. The main defenses out on the outer surface of the Fortress are still operational, though a good many decades have passed since we had a genuine alarm. There are no longer many berserkers in this part of the Galaxy." He smiled wryly. "And I am afraid there are no longer very many Templars, either, even in the parts of the Galaxy where things are not so peaceful."

They were still walking. Proceeding in the direction of Sabel's laboratory and quarters.

"Please, tell me more." The girl continued to look at him steadily with attention. "Please, I am really very interested."

"Well. We of the Order of Ex. Helen no longer bind ourselves to poverty—or to permanent celibacy. We have come to honor Beauty on the same level as Virtue, considering them both to be aspects of the Right. Our great patroness of course stands as Exemplar of both qualities."

"Ex. Helen . . . and she really founded the Order, hundreds of years ago? Or—"

"Or, is she really only a legend, as some folk now consider her? No, I think that there is really substantial evidence of her historical reality. Though of course the purposes of the Order are still valid in either case."

"You must be very busy. I hope you will forgive my taking up your time like this."

"It is hard to imagine anyone easier to forgive. Now, would you by chance like to see something of my laboratory?"

"Might I? Really?"

"You have already seen the Radiant, of course. But to get a look at it through some of my instruments will give you a new perspective . . ."

As Sabel had expected, Greta did not seem able to understand much of his laboratory's contents. But she was nevertheless impressed. "And I see you have a private space flyer here. Do you use it to go out to the Radiant?"

At that he really had to laugh. "I'm afraid I wouldn't get there. Oh, within a kilometer of it, maybe, if I tried. The most powerful spacecraft built might be able to force its way to within half that distance. But to approach any closer than that—impossible. You see, the inner level of the Fortress, where we are now, was built at the four-kilometer distance from the Radiant because that is the distance at which the effective gravity is standard normal. As one tries to get closer, the gravitic resistance goes up exponentially. No. I use the flyer for field trips. To the outer reaches of the Fortress, places where no public transport is available."

"Is that a hobby of some kind?"

"No, it's really connected with my work. I search for old Dardanian records, trying to find their observations of the Radiant . . . and in here is where I live."

With eyes suddenly become competent, Greta surveyed the tidy smallness of his quarters. "Alone, I see."

"Most of the time . . . my work demands so much. Now, Greta, I have given you something of a private showing of my work. I would be very pleased indeed if you were willing to do the same for me."

"To dance?" Her manner altered, in a complex way. "I suppose there might be room enough in here for dancing . . . if there were some suitable music."

"Easily provided." He found a control on the wall; and to his annoyance he noticed that his fingers were now quivering again.

In light tones Greta said: "I have no special costume with me, sir, just these clothes I wear."

"They are delightful—but you have one other, surely."

"Sir?" And she, with quick intelligence in certain fields of thought, was trying to repress a smile.

"Why, my dear, I mean the costume that nature gives to us all, before our clothes are made. Now, if it is really going to be up to me to choose . . ."

Hours later when the girl was gone, he went back to work, this time wearing a more conventional laboratory coat. He punched in a command for his computer to display its results, and, holding his breath, looked at the screen.

BASIC PROGRAMMING OF SUBJECT DEVICE MAY BE CIRCUMVENTED AS FOLLOWS: FABRICATE A DISABLING SLUG OF CESIUM TRIPHENYL METHYL. ISOTOPE 137 OF CESIUM, OF 99% PURITY, TO BE USED. SLUG TO BE CYLINDRICAL 2.346 CM DIAMETER, 5.844 CM LENGTH. COMPONENTS OF SUBJECT DEVICE NOW IN LABORATORY TO BE REASSEMBLED TO THOSE REMAINING IN FIELD, WITH SLUG CONNECTED ELECTRICALLY AND MECHANICALLY ACROSS PROBE POINTS OUR NUMBER 11 AND OUR NUMBER 12A IN ARMING MECHANISM OF DEVICE. PRIME PROGRAMMED COMMAND OF DEVICE WILL THEN BE DISABLED FOR TIME EQUAL TO ONE HALF-LIFE OF ISOTOPE CS-137 . . .

There were more details on how the "subject device" was to be disabled—he had forbidden his own computer to ever display or store in memory the word "berserker" in connection with any of his work. But Sabel did not read all the details at once. He was busy looking up the half-life of cesium-137. It turned out to be thirty years! Thirty standard years!

He had beaten it. He had won. Fists clenched, Sabel let out exultation in a great, private, and almost silent shout . . .

This instinctive caution was perhaps well-timed, for at once a chime announced a caller, at the door that led out to the mall. Sabel nervously wiped the displayed words from his computer screen. Might the girl have come back? Not because she had forgotten something—she had brought nothing with her but her clothes.

But instead of the girl's face, his video intercom showed him the deceptively jovial countenance of Chief Deputy Guardian Gunavarman. Had Sabel not become aware of the Potentate's presence on the Fortress, he might have had a bad moment at the sight. As matters stood, he felt prepared; and after a last precautionary glance around the lab, he let the man in confidently.

"Guardian. It is not often that I am honored by a visit from you."

"Doctor Sabel." The black-robed visitor respectfully returned the scientist's bow. "It is always a pleasure, when I can find the time. I wish my own work were always as interesting as yours must be. Well. You know of course that our esteemed Potentate is now in the Fortress . . ."

The discussion, on the necessity of being prepared for a VIP inspection, went just about as Sabel had expected. Gunavarman walked about as he spoke, eyes taking in the lab, their intelligence operating on yet a different level than either Sabel's or Greta Thamar's. The smiling lips asked Sabel just what, exactly, was he currently working on? What could he demonstrate, as dramatically as possible but safely of course, for the distinguished visitor?

Fortunately for Sabel he had been given a little advance time in which to think about these matters. He suggested now one or two things that might provide an impressive demonstration. "When must I have them ready?"

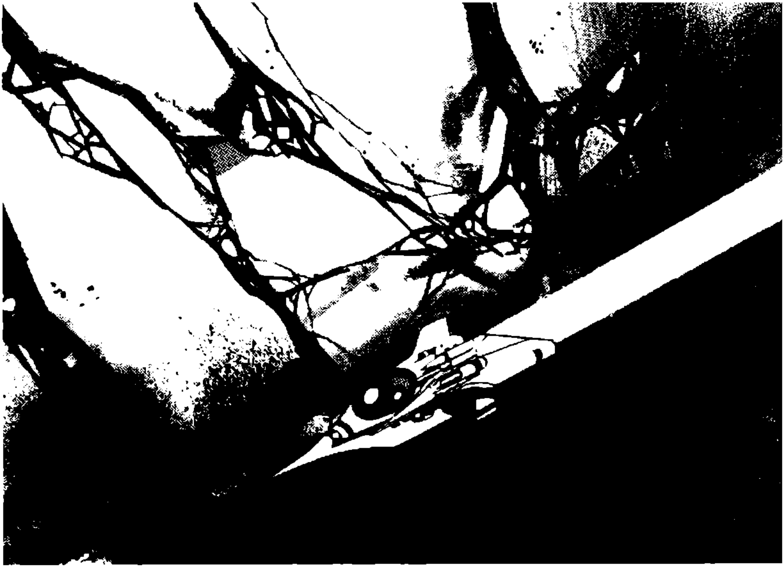
"Probably not sooner than two days from now, or more than five. You will be given advance notice of the exact time." But the Guardian, when Sabel pressed him, refused to commit himself on just how much advance notice would be given.

The real danger of this Potential visit, thought Sabel as he saw his caller out, was that it was going to limit his mobility. A hurried field trip to the outer surface was going to be essential, to get incriminating materials out of his lab. Because he was sure that a security force of Guardians was going to descend on the place just before the Potentate appeared. More or less politely, but thoroughly, they would turn it inside out. There were those on every world of his dominion who for one reason or another wished the Potentate no good.

After a little thought, Sabel went to his computer terminal and punched in an order directed to the metallic fabrication machines in the Fortress's main workshops, an order for the disabling slug as specified by his computer. He knew well how the automated systems worked, and took care to place the order in such a way that no other human being would ever be presented with a record of it. The machines reported at once that delivery should take several hours.

The more he thought about it, the more essential it seemed for him to get the necessary field excursion out of the way as quickly as he could. Therefore while waiting for the slug to be delivered, he loaded up his flyer, with berserker parts hidden among tools in various containers. The vehicle was another thing that had been built to his special order. It was unusually small in all three dimensions, so he could drive it deeply into the caves and passages and cracks of ancient battle-damage that honeycombed the outer stonework of the Fortress.

A packet containing the slug he had ordered came with a clack into his laboratory through the old-fashioned pneumatic system still used for small deliveries, direct from the workshops. Sabel's first look at the cesium alloy startled him. A hard solid at room temperature, the slug was red as blood inside a statglass film evidently meant to



protect it against contamination and act as a radiation shield for human handlers as well. He slid it into a pocket of his light spacesuit, and was ready.

The lab locked up behind him, he sat in his flyer's small open cab and exited the rooftop airlock in a modest puff of fog. The air and moisture were mostly driven back into recycling vents by the steady gravitic pressure of the Radiant above. His flyer's small, silent engine worked against the curve of space that the Radiant imposed, lifting him and carrying him on a hand-controlled flight path that skimmed over glass-roofed plazas and apartment complexes and offices. In its concavity, the inner surface of the Fortress fell more distant from his straight path, then reapproached. Ahead lay the brightly lighted mouth of the traffic shaft that would lead him out to the Fortress's outer layers.

Under Sabel's briskly darting flyer there now passed a garish, glassed-in amusement mall. There entertainment, sex, and various kinds of drugs were all for sale. The *Contrat Rouge* he thought was somewhere in it. He wondered in passing if the girl Greta understood that here her occupation put her very near the bottom of the social scale, a small step above the level of the barely tolerable prostitutes? Perhaps she knew. Or when she found out, she would not greatly care. She would probably be moving on, before very long, to some world with more conventional mores.

Sabel had only vague ideas of how folk in the field of popular entertainment lived. He wondered if he might go sometime to watch her perform publicly. It was doubtful that he would. To be seen much in the *Contrat Rouge* could do harm to one in his position.

The wide mouth of the shaft engulfed his flyer. A few other craft, electronically guided, moved on ahead of his or flickered past. Strings of lights stretched vertiginously down and ahead. The shaft was straight; the Fortress had no appreciable rotation, and there was no need to take coriolis forces into account in traveling through it rapidly. With an expertise born of his many repetitions of this flight, Sabel waited for the precisely proper moment to take back full manual control. The gravitic pressure of the Radiant, behind him and above, accelerated his passage steadily. He fell straight through the two kilometers' thickness of stone and reinforcing beams that composed most of the Fortress's bulk. The sides of the vast shaft, now moving faster and faster past him, were ribbed by the zig-zag joints of titanic interlocking blocks.

This is still Dardania, here, he thought to himself, as usual at this point. The Earth-descended Dardanians, who had built the Fortress and flourished in it even before berserkers came to the human portion of the Galaxy, had wrought with awesome energy, and a purpose not wholly clear to modern eyes. The Fortress, after all, defended not much of anything except the Radiant itself, which hardly needed protection from humanity. Their engineers must have tugged all the stone to build the Fort through interstellar distances, at God alone knew what expense of energy and time. Maybe Queen Helen had let them know she would be pleased by it, and that had been enough.

The Fortress contained about six hundred cubic kilometers of stone and steel and enclosed space, even without including the vast, clear central cavity. Counting visitors and transients, there were now at any moment approximately a hundred thousand human beings in residence. Their stores and parks and dwellings and laboratories and shops occupied, for the most part, only small portions of the inner surface, where gravity was normal and the light from the Radiant was bright. From the outer surface, nearby space was keenly watched by the sensors of the largely automated defense system; there was a patchy film of human activity there. The remainder of the six hundred cubic kilometers were largely desert now, honeycombed with cracks and designed passages, spotted with still-undiscovered troves of Dardanian tombs and artifacts, for decades almost unexplored, virtually abandoned except by the few who, like Sabel, researched the past.

Now he saw a routine warning begin to blink on the small control panel of his flyer. Close ahead the outer end of the transport shaft was yawning, and through it he could see the stars. A continuation of his present course would soon bring him into the area surveyed by the defense system.

As his flyer emerged from the shaft, Sabel had the stars beneath his feet, the bulk of the Fortress seemingly balanced overhead. With practiced skill he turned now at right angles to the Radiant's force. His flyer entered the marked notch of another traffic lane, this one grooved into the Fortress's outer armored surface. The bulk of it remained over his head and now seemed to rotate with his motion. Below him passed stars, while on the dark rims of the traffic lane to either side he caught glimpses of the antiquated but still operational defensive works. Blunt snouts of missile-launchers, skeletal fingers of mass-drivers and beam-projectors, the lenses and screens and domes of sensors and field generators. All the hardware was still periodically tested, but in all his journeyings this way Sabel had never seen any of it looking anything but inactive. War had long ago gone elsewhere.

Other traffic, scanty all during his flight, had now vanished altogether. The lane he was following branched, and Sabel turned left, adhering to his usual route. If anyone should be watching him today, no deviation from his usual procedure would be observed. Not yet, anyway. Later . . . later he would make very sure that nobody was watching.

Here came a landmark on his right. Through another shaft piercing the Fortress a wand of the Radiant's light fell straight to the outer surface, where part of it was caught by the ruined

framework of an auxiliary spaceport, long since closed. In that permanent radiance the old beams glowed like twisted night-flowers, catching at the light before it fell away to vanish invisibly and forever among the stars.

Just before he reached this unintended beacon, Sabel turned sharply again, switching on his bright running lights as he did so. Now he had entered a vast battle-crack in the stone and metal of the Fortress's surface, a dark uncharted wound that in Dardanian times had been partially repaired by a frail-looking spiderwork of metal beams. Familiar with the way, Sabel steered busily, choosing the proper passage amid obstacles. Now the stars were dropping out of view behind him. His route led him up again, into the lightless ruined passages where nothing seemed to have changed since Helen died.

Another minute of flight through twisting ways, some of them designed and others accidental.

Then, obeying a sudden impulse, Sabel braked his flyer to a hovering halt. In the remote past this passage had been air-filled, the monumental length and breadth of it well suited for mass ceremony. Dardanian pictures and glyphs filled great portions of its long walls. Sabel had looked at them a hundred times before, but now he swung his suited figure out of the flyer's airless cab and walked close to the wall, moving buoyantly in the light gravity, as if to inspect them once again. This was an ideal spot to see if anyone was really following him. Not that he had any logical reason to think that someone was. But the feeling was strong that he could not afford to take a chance.

As often before, another feeling grew when he stood here in the silence and darkness that were broken only by his own presence and that of his machines. Helen herself was near. In Sabel's earlier years there had been something religious in this experience. Now . . . but it was still somehow comforting.

He waited, listening, thinking. Helen's was not the only presence near, of course. On three or four occasions at least during the past ten years (there might have been more that Sabel had never heard about) explorers had discovered substantial concentrations of berserker wreckage out in these almost abandoned regions. Each time Sabel had heard of such a find being reported to the Guardians, he had promptly petitioned them to be allowed to examine the materials, or at least to be shown a summary of whatever information the Guardians might manage to extract. His pleas had vanished into the bureaucratic maw. Gradually he had come to understand that they would never tell him anything about berserkers. The Guardians were jealous of his relative success and fame. Besides, their supposed job of protecting humanity on the Fortress now actually gave them almost nothing to do. A few newly-discovered berserker parts could be parlayed into endless hours of technical and administrative work. Just keeping secrets could be made into a job, and they were not about to share any secrets with outsiders.

But, once Sabel had become interested in berserkers as a possible source of data on the Radiant, he found ways to begin a study of them. His study was at first bookish and indirect, but it advanced; there was always more information available on a given subject than a censor realized, and a true scholar knew how to find it out.

And Sabel came also to distrust the Guardians' competence in the scholarly aspects of their own field. Even if they had finally agreed to share their findings with him, he thought their pick-axe methods unlikely to extract from a berserker's memory anything of value. They had refused of course to tell him what their methods were, but he could not imagine them doing anything imaginatively.

Secure in his own space helmet, he whispered now to himself: "If I want useful data from my own computer, I don't tear it apart. I communicate with it instead."

Cold silence and darkness around him, and nothing more. He remounted his flyer and drove on. Shortly he came to where the great corridor was broken by a battle-damage crevice, barely wide enough for his small vehicle, and he turned slowly, maneuvering his way in. Now he must go slowly, despite the number of times that he had traveled this route before. After several hundred meters of jockeying his way along, his headlights picked up his semi-permanent base camp structure in a widening of the passageway ahead. It looked half bubble, half spiderweb, a tentlike thing whose walls hung slackly now but were inflatable with atmosphere. Next to it he had dug out of the stone wall a niche just big enough to park his flyer in. The walls of the niche were lightly marked now from his previous parkings. He eased in now, set down gently, and cut power.

On this trip he was not going to bother to inflate his shelter; he was not going to be out here long enough to occupy it. Instead he began at once to unload from the flyer what he needed, securing things to his backpack as he took them down. The idea that he was being followed now seemed so improbable that he gave it no more thought. As soon as he had all he wanted on his back, he set off on foot down one of the branching crevices that radiated from the nexus where he had placed his camp.

He paused once, after several meters, listening intently. Not now for non-existent spies who might after all be following. For something active ahead. Suppose it had, somehow, after all, got itself free . . but there was no possibility. He was carrying most of its brain with him right now. Around him, only the silence of ages, and the utter cold. The cold could not pierce his suit. The silence, though . . .

The berserker was exactly as he had left it, days ago. It was partially entombed, caught like some giant mechanical insect in opaque amber. Elephant-sized metal shoulders and a ruined head

protruded from a bank of centuries-old slag. Fierce weaponry must have melted the rock, doubtless at the time of the Templars' reconquest of the Fortress, more than a hundred years ago.

Sabel when he came upon it for the first time understood at once that the berserker's brain might well still be functional. He knew too that there might be destructor devices still working, built into the berserker to prevent just such an analysis of captured units as he was suddenly determined to attempt. Yet he had nerved himself to go to work on the partially shattered braincase that protruded from the passage wall almost like a mounted trophy head. Looking back now, Sabel was somewhat aghast at the risks he had taken. But he had gone ahead. If there were any destructors, they had not fired. And it appeared to him now that he had won.

He took the cesium slug out of his pocket and put it into a tool that stripped it of statglass film and held it ready for the correct moment in the reconstruction process. And the reconstruction went smoothly and quickly, the whole process taking no more than minutes. Aside from the insertion of the slug it was mainly a matter of reconnecting subsystems and of attaching a portable power supply that Sabel now unhooked from his belt; it would give the berserker no more power than might be needed for memory and communication.

Yet, as soon as power was supplied, one of the thin limb stumps that protruded from the rock surface began to vibrate, with a syncopated buzzing. It must be trying to move.

Sabel had involuntarily backed up a step; yet reason told him that his enemy was effectively powerless to harm him. He approached again, and plugged a communications cord into a jack he had installed. When he spoke to it, it was in continuation of the dialogue in the laboratory.

"Now you *are* constrained, as you put it, to answer whatever questions I may ask." Whether it was going to answer truthfully or not was something he could not yet tell.

It now answered him in its own voice, cracked, queer, inhuman. "Now I am constrained."

Relief and triumph compounded were so strong that Sabel had to chuckle. The thing sounded so immutably certain of what it said, even as it had sounded certain saying the exact opposite back in the lab.

Balancing buoyantly on his toes in the light gravity, he asked it: "How long ago were you damaged, and stuck here in the rock?"

"My timers have been out of operation."

That sounded reasonable. "At some time before you were damaged, though, some visual observations of the Radiant probably became stored somehow in your memory banks. You know what I am talking about from our conversation in the laboratory. Remember that I will be able to extract useful information from even the most casual, incidental video records, provided they were made in Radiant light when you were active."

"I remember." And as the berserker spoke there came faintly to Sabel's ears a grinding, straining sound, conducted through his boots from somewhere under the chaotic surface of once-molten rock.

"What are you doing?" he demanded sharply. God knew what weapons it had been equipped with, what potential powers it still had.

Blandly the berserker answered: "Trying to reestablish function in my internal power supply."

"You will cease that effort at once! The supply I have connected is sufficient."

"Order acknowledged." And at once the grinding stopped.

Sabel fumbled around, having a hard time trying to make a simple connection with another small device that he removed from his suit's belt. If only he did not tend to sweat so much. "Now. I have here a recorder. You will play into it all the video records you have that might be useful to me in my research on the Radiant's spectrum. Do not erase any records from your own banks. I may want to get at them again later."

"Order acknowledged." In exactly the same cracked tones as before.

Sabel got the connection made at last. Then he crouched there, waiting for what seemed endless time, until his recorder signalled that the data flow had ceased.

And back in his lab, hours later, Sabel sat glaring destruction at the inoffensive stonework of the wall. His gaze was angled downward, in the direction of his unseen opponent, as if his anger could pierce and blast through the kilometers of rock.

The recorder had been filled with garbage. With nonsense. Virtually no better than noise. His own computer was still trying to unscramble the hopeless mess, but it seemed the enemy had succeeded in . . . still, perhaps it had not been a ploy of the berserkers at all. Only, perhaps, some kind of trouble with the coupling of the recorder input to . . .

He had, he remembered distinctly, told the berserker what the input requirements of the recorder were. But he had not explicitly ordered it to meet them. And he could not remember that it had ever said it would.

Bad, Sabel. A bad mistake to make in dealing with any kind of a machine. With a berserker . . .

A communicator made a melodious sound. A moment later, its screen brought Guardian Gunavarman's face and voice into the lab.

"Dr. Sabel, will your laboratory be in shape for a personal inspection by the Potentate three hours from now?"

"I—I—yes, it will. In fact, I will be most honored," he remembered to add, in afterthought.

"Good. Excellent. You may expect the security party a few minutes before that time."

As soon as the connection had been broken, Sabel looked around. He was in fact almost ready to be inspected. Some innocuous experiments were in place to be looked at and discussed. Almost everything that might possibly be incriminating had been got out of the way. Everything, in fact, except . . . he pulled the small recorder cartridge from his computer and juggled it briefly in his hand. The chance was doubtless small that any of his impending visitors would examine or play the cartridge, and smaller still that they might recognize the source of information on it if they did. Yet in Sabel's heart of hearts he was not so sure that the Guardians could be depended upon to be incompetent. And there was no reason for him to take even a small chance. There were, there had to be, a thousand public places where one might secrete an object as small as this. Where no one would notice it until it was retrieved . . . there were of course the public storage facilities, on the far side of the Fortress, near the spaceport.

To get to any point in the Fortress served by the public transportation network took only a few minutes. He had to switch from moving slidewalk to high-speed elevator in a plaza that fronted on the entertainment district, and as he crossed the plaza his eye was caught by a glowing red sign a hundred meters or so down the mall: *Contrat Rouge.*

His phantom followers were at his back again, and to try to make them vanish he passed the elevator entrance as if that had not been his goal at all. He was not wearing his blue habit today, and as he entered the entertainment mall none of the few people who were about seemed to take notice of him.

A notice board outside the *Contrat Rouge* informed Sabel in glowing letters that the next scheduled dance performance was several hours away. It might be expected that he would know that, had he really started out with the goal of seeing her perform. Sabel turned and looked around, trying to decide what to do next. There were not many people in sight. But too many for him to decide if any of them might really have been following him.

Now the doorman was starting to take notice of him. So Sabel approached the man, clearing his throat. "I was looking for Greta Thamar?"

Tall and with a bitter face, the attendant looked as Sabel imagined a policeman ought to look. "Girls aren't in yet."

"She lives somewhere nearby, though?"

"Try public info."

And perhaps the man was somewhat surprised to see that that was what Sabel, going to a nearby booth, actually did next. The automated information service unhesitatingly printed out Greta's address listing for him, and Sabel was momentarily surprised: he had pictured her as beseiged by men who saw her on stage, having to struggle for even a minimum of privacy. But then he saw a stage name printed out in parentheses beside her own; those inquiring for her under the stage name would doubtless be given no information except perhaps the time of the next performance. And the doorman? He doubtless gave the same two answers to the same two questions a dozen times a day, and make no effort to keep track of names.

As Sabel had surmised, the apartment was not far away. It looked quite modest from the outside. A girl's voice, not Greta's, answered when he spoke into the intercom at the door. He felt irritated that they were probably not going to be able to be alone.

A moment later the door opened. Improbable blond hair framed a face of lovely ebony above a dancer's body. "I'm Greta's new roommate. She ought to be back in a few minutes." The girl gave Sabel an almost-amused appraisal. "I was just going out myself. But you can come in and wait for her if you like."

"I . . . yes, thank you." Whatever happened, he wouldn't be able to stay long. He had to leave himself plenty of time to get rid of the recorder cartridge somewhere and get back to the lab. But certainly there were at least a few minutes to spare.

He watched the blond dancer out of sight. Sometime, perhaps . . . Then, left alone, he turned to a half-shaded window through which he could see a large part of the nearby plaza. Still there was no one in sight who looked to Sabel as if they might be following him. He moved from the window to stand in front of a cheap table. If he left before seeing Greta, should he leave her a note? And what ought he to say?

His personal communicator beeped at his belt. When he raised it to his face he found Chief Deputy Gunavarman looking out at him from the tiny screen.

"Doctor Sabel, I had expected you would be in your laboratory now. Please get back to it as soon as possible; the Potentate's visit has been moved up by about two hours. Where are you now?"

"I . . . ah . . ." *What might be visible in Gunavarman's screen?* "The entertainment district."

The chronic appearance of good humor in the Guardian's face underwent a subtle shift; perhaps now there was something of genuine amusement in it. "It shouldn't take you long to get back, then. Please hurry. Shall I send an escort?"

"No. Not necessary. Yes. At once." Then they were waiting for him at the lab. It was even possible that they could meet him right outside this apartment's door. As Sabel reholstered his communicator, he looked around him with quick calculation. There. Low down on one wall was a small ventilation grill of plastic, not much broader than his open hand. It was a type in common use within the Fortress. Sabel crouched down. The plastic bent springily in his strong fingers, easing out of its socket. He slid the recorder into the dark space behind, remembering to wipe it free of fingerprints first.

The Potentate's visit to the lab went well. It took longer than Sabel had expected, and he was complimented on his work, at least some of which the great leader seemed to understand. It wasn't until next morning, when Sabel was wondering how soon he ought to call on Greta again, that he heard during a chance encounter with a colleague that some unnamed young woman in the entertainment district had been arrested.

Possession of a restricted device, that was the charge. The first such arrest in years, and though no official announcement had yet been made, the Fortress was buzzing with the event, probably in several versions. The wording of the charge meant that the accused was at least suspected of actual contact with a berserker; it was the same one, technically, that would have been placed against Sabel if his secret activities had been discovered. And it was the more serious form of goodlife activity, the less serious consisting in forming clubs or cells of conspiracy, of sympathy to the enemy, perhaps having no real contact with berserkers.

Always in the past when he had heard of the recovery of any sort of berserker hardware, Sabel had called Gunavarman, to ask to be allowed to take part in the investigation. He dared not make an exception this time.

"Yes, Doctor," said the Guardian's voice from a small screen. "A restricted device is in our hands today. Why do you ask?"

"I think I have explained my interest often enough in the past. If there is any chance that this—device—contains information pertinent to my studies, I should like to apply through whatever channels may be necessary—"

"Perhaps I can save you the trouble. This time the device is merely the storage cartridge of a video recorder of a common type. It was recovered last night during a routine search of some newcomers' quarters in the entertainment district. The information on the recorder is intricately coded and we haven't solved it yet. But I doubt it has any connection with cosmophysics. This is just for your private information of course."

"Of course. But—excuse me—if you haven't broken the code why do you think this device falls into the restricted category?"

"There is a certain signature, shall we say, in the coding process. Our experts have determined that the information was stored at some stage in a berserker's memory banks. One of the two young women who lived in the apartment committed suicide before she could be questioned—a typical goodlife easy-out, it appears. The other suspect so far denies everything. We're in the process of obtaining a court order for some M-E, and that'll take care of that."

"Memory extraction. I didn't know that you could still—?"

"Oh, yes. Though nowadays there's a formal legal procedure. The questioning must be done in the presence of official witnesses. And if innocence of the specific charge is established, questioning must be halted. But in this case I think we'll have no trouble."

Sabel privately ordered a printout of all court documents handled during the previous twenty-four hours. There it was: Greta Thamar, order for memory-extraction granted. At least she was not dead.

To try to do anything for her would of course have been completely pointless. If the memory-extraction worked to show her guilt, it should show also that he, Sabel, was only an innocent chance acquaintance. But in fact it must work to show her innocence, and then she would be released. She would regain her full mental faculties in time—enough of them, anyway, to be a dancer.

Why, though, had her roommate killed herself? Entertainers. Unstable people . . .

Even if the authorities should someday learn that he had known Greta Thamar, there was no reason for him to come forward today and say so. No; he wasn't supposed to know as yet that she was the one arrested. Gunavarman had mentioned no names to him.

No indeed, the best he could hope for by getting involved would be entanglement in a tedious, time-wasting investigation. Actually of course he would be risking much worse than that.

Actually it was his work, the extraction of scientific truth, that really mattered, not he. And, certainly, not one little dancer more or less. But if he went, his work went too. Who else was going to extract from the Templar Radiant the truths that would open shining new vistas of cosmophysics? Only seven other Radiants were known to exist in the entire Galaxy. None of the others were as accessible to study as this one was, and no one knew this one nearly as well as Georgicus Sabel knew it.

Yes, it would be pointless indeed for him to try to do anything for the poor girl. But he was surprised to find himself going through moments in which he felt that he was going to have to try.

Meanwhile, if there were even the faintest suspicion of him, if the Guardians were watching his movements, then an abrupt cessation of his field trips would be more likely to cause trouble than their continuation. And, once out in the lonely reaches of Dardania, he felt confident of being able to tell whether the Guardians were following him or not.

This time he took with him a small hologram-stage, so he could look at the video records before he brought them back.

"This time," he said to the armored braincase projecting from the slag-bank, "you are ordered to give me the information in intelligible form."

Something in its tremendous shoulders buzzed, a syncopated vibration. "Order acknowledged."

And what he had been asking for was shown to him at last. Scene after scene, made in natural Radiant-light. Somewhere on the inner surface of the Fortress, surrounded by smashed Dardanian glass roofs, a row of berserkers stood as if for inspection by some commanding machine. Yes, he should definitely be able to get something out of that. And out of this one, a quite similar scene. And out of—

"Wait. Just a moment. Go back, let me see that one again. What was that?"

He was once more looking at the Fortress's inner surface, bathed by the Radiant's light. But this time no berserkers were visible. The scene was centered on a young woman, who wore space garb of a design unfamiliar to Sabel. It was a light-looking garment that did not much restrict her movements, and the two-second segment of recording showed her in the act of performing some gesture. She raised her arms to the light above as if in the midst of some rite or dance centered on the Radiant itself. Her dark hair, short and curly, bore a jeweled diadem. Her longlashed eyes were closed, in a face of surpassing loveliness.

He watched it three more times. "Now wait again. Hold the rest of the records. Who was that?"

To a machine, a berserker, all human questions and answers were perhaps of equal unimportance. Its voice gave the same tones to them all. It said to Sabel: "The life-unit Helen Dardan."

"But—" Sabel had a feeling of unreality. "Show it once more, and stop the motion right in the middle—yes, that's it. Now, how old is this record?"

"It is of the epoch of the 451st century, in your time-coordinate system."

"Before berserkers came to the fortress? And why do you tell me it is she?"

"It is a record of Helen Dardan. No other existed. I was given it to use as a means of identification. I am a specialized assassin-machine and was sent on my last mission to destroy her."

"You—you claim to be the machine that actually—actually killed Helen Dardan?"

"No."

"Then explain."

"With other machines, I was programmed to kill her. But I was damaged and trapped here before the mission could be completed."

Sabel signed disagreement. By now he felt quite sure that the thing could see him somehow. "You were trapped during the Templars' reconquest. That's when this molten rock must have been formed. Well after the time when Helen lived."

"That is when I was trapped. But only within an hour of the Templars' attack did we learn where the life-unit Helen Dardan had been hidden, in suspended animation."

"The Dardanians hid her from you somehow, and you couldn't find her until then?"

"The Dardanians hid her. I do not know whether she was ever found or not."

Sabel tried to digest this. "You're saying that for all you know, she might be still entombed somewhere, in suspended animation—and still alive."

"Confirm."

He looked at his video recorder. For a moment he could not recall why he had brought it here. "Just where was this hiding place of hers supposed to be?"

As it turned out, after Sabel had struggled through a translation of the berserkers' co-ordinate system into his own, the supposed hiding place was not far away at all. Once he had the location pinpointed it took him only minutes to get to the described intersection of Dardanian passageways. There, according to his informant, Helen's life-support coffin had been mortared up behind a certain obscure marking on a wall.

This region was free of the small blaze-marks that Sabel himself habitually put on the walls to remind himself of what ground he had already covered in his systematic program of exploration. And it was a region of some danger, perhaps, for here in relatively recent times there had been an extensive crumbling of stonework. What had been an intersection of passages had become a rough cave, piled high with pieces great and small of what had been wall and floor and overhead. The fragments were broken and rounded to some extent, sharp corners knocked away. Probably at intervals they did a stately mill-dance in the low gravity, under some perturbation of the Fortress's stately secular movement round the Radiant in space. Eventually the fallen fragments would probably grind themselves into gravel, and slide away to accumulate in low spots in the nearby passages.

But today they still formed a rough, high mound. Sabel with his suit lights could discern a dull egg-shape nine-tenths buried in this mound. It was rounder and smoother than the broken masonry, and the size of a piano or a little larger.

He clambered toward it, and without much trouble succeeded in getting it almost clear of rock. It was made of some tough, artificial substance; and in imagination he could fit into it any of the several types of suspended-animation equipment that he had seen.

What now? Suppose, just suppose, that any real chance existed . . . he dared not try to open up the thing here in the airless cold. Nor had he any tools with him at the moment that would let him try to probe the inside gently. He had to go back to base camp and get the flyer here somehow.

Maneuvering his vehicle to his find proved easier than he had feared. He found a roundabout way to reach the place, and in less than an hour had the ovoid secured to his flyer with adhesive straps. Hauling it slowly back to base camp, he reflected that whatever was inside was going to have to remain secret, for a while at least. The announcment of any important find would bring investigators swarming out here. And that Sabel could not afford, until every trace of the berserker's existence had been erased.

Some expansion of the tent's fabric was necessary before he could get the ovoid in, and leave himself with space to work. Once he had it in a securely air-filled space, he put a gentle heater to work on its outer surface, to make it easier to handle. Then he went to work with an audio pick-up to see what he could learn of the interior.

There was activity of some kind inside, that much was obvious at once. The sounds of gentle machinery, which he supposed might have been started by his disturbance of the thing, or by the presence of warm air around it now.

Subtle machinery at work. And then another sound, quite regular. It took Sabel's memory a little time to match it with the cadence of a living heart.

He had forgotten about time, but in fact not much time had passed before he considered that he was ready for the next step. The outer casing opened for him easily. Inside, he confronted great complexity; yes, obviously sophisticated life-support. And within that an interior shell, eyed with glass windows, Sabel shone in a light.

As usual in suspended-animation treatment, the occupant's skin had been covered with a webbed film of half-living stuff to help in preservation. But the film had torn away now from around the face.

And the surpassing beauty of that face left Sabel no room for doubt. Helen Dardan was breathing, and alive.

Might not all, all, be forgiven one who brought the Queen of Love herself to life? All, even goodlife work, the possession of restricted devices?

There was also to be considered, though, the case of a man who at a berserker's direction unearthed the Queen and thereby brought about her final death.

Of course an indecisive man, one afraid to take risks, would not be out here now faced with his problem. Sabel had already unslung his emergency medirobot, a thing the size of a suitcase, from its usual perch at the back of the flyer, and had it waiting inside the tent. Now, like a man plunging into deep, cold water, he fumbled open the fasteners of the interior shell, threw back its top, and quickly stretched probes from the medirobot to Helen's head and chest and wrist. He tore away handfuls of the half-living foam.

Even before he had the third probe connected, her dark eyes had opened and were looking at him. He thought he could see awareness and understanding in them. Her last hopes on being put to sleep must have been for an awakening no worse than this, at hands that might be strange but were not metal.

"Helen." Sabel could not help but feel that he was pretending, acting, when he spoke the name. "Can you hear me? Understand?" He spoke in Standard; the meagre store of Dardanian that he had acquired from ancient recordings having completely deserted him for the moment. But he thought a Dardanian aristocrat should know enough Standard to grasp his meaning, and the language had not changed enormously in the centuries since her entombment.

"You're safe now," he assured her, on his spacesuited knees beside her bed. When a flicker in her eyes seemed to indicate relief, he went on: "The berserkers have been driven away."

Her lips parted slightly. They were full and perfect. But she did not speak. She raised herself a little, and moved to bare a shoulder and an arm from clinging foam.

Nervously Sabel turned to the robot. If he was interpreting its indicators correctly, the patient was basically in quite good condition. To his not-really-expert eye the machine signalled that there were high drug levels in her bloodstream; high, but falling. Hardly surprising, in one just being roused from suspended animation.

"There's nothing to fear, Helen. Do you hear me? The berserkers have been beaten." He didn't want to tell her, not right away at least, that glorious

Dardania was no more.

She had attained almost a sitting position by now, leaning on the rich cushions of her couch. There was some relief in her eyes, yes, but uneasiness as well. And still she had not uttered a word.

As Sabel understood it, people awakened from SA ought to have some light nourishment at once. He hastened to offer food and water both. Helen sampled what he gave her, first hesitantly, then with evident enjoyment.

"Never mind, you don't have to speak to me right away. The-war-is-over." This last was in his best Dardanian, a few words of which were now belatedly willing to be recalled.

"You-are-Helen." At this he thought he saw agreement in her heavenly face. Back to Standard now. "I am Georgicus Sabel. Doctor of cosmophysics, Master of . . . but what does all that matter to me, now? I have saved you. And that is all that counts."

She was smiling at him. And maybe after all this was a dream, no more . . .

More foam was peeling, clotted, from her skin. Good God, what was she going to wear? He bumbled around, came up with a spare coverall. Behind his turned back he heard her climbing from the cushioned container, putting the garment on.

What was this, clipped to his belt? The newly-charged video recorder, yes. It took him a little while to remember what he was doing with it. He must take it back to the lab, and make sure that the information on it was readable this time. After that, the berserker could be destroyed.

He already had with him in camp tools that could break up metal, chemicals to dissolve it. But

the berserker's armor would be resistant, to put it mildly. And it must be very thoroughly destroyed, along with the rock that held it, so that no one should ever guess it had existed. It would take time to do that. And special equipment and supplies, which Sabel would have to return to the city to obtain.

Three hours after she had wakened, Helen, dressed in a loose coverall, was sitting on cushions that Sabel had taken from her former couch and arranged on rock. She seemed content to simply sit and wait, watching her rescuer with flattering eyes, demanding nothing from him—except, as it soon turned out, his presence.

Painstakingly he kept trying to explain to her that he had important things to do, that he was going to have to go out, leave her here by herself for a time.

"I-must-go. I will come back. Soon." There was no question of taking her along, no matter what. At the moment there was only one space suit.

But, for whatever reason, she wouldn't let him go. With obvious alarm, and pleading gestures, she put herself in front of the airlock to bar his way.

"Helen. I really must. I—"

She signed disagreement, violently.

"But there is one berserker left, you see. We cannot be safe until it is—until—"

Helen was smiling at him, a smile of more than gratitude. And now Sabel could no longer persuade himself that this was not a dream. With a sinuous movement of unmistakable invitation, the Queen of Love was holding out her arms . . .

When he was thinking clearly and coolly once again, Sabel began again with patient explanations. "Helen. My darling. You see, I *must* go. To the city. To get some—"

A great light of understanding, acquiesence, dawned in her lovely face.

"There are some things I need, vitally. Then I swear I'll come right back. Right straight back here. You want me to bring someone with me, is that it? I—"

He was about to explain that he couldn't do that just yet, but her renewed alarm indicated that that was the last thing she would ask.

"All right, then. Fine. No one. I will bring a spare space suit . . . but that you are here will be my secret, our secret, for a while. Does that please you? Ah, my Queen!"

At the joy he saw in Helen's face, Sabel threw himself down to kiss her foot. "Mine alone!"

He was putting on his helmet now. "I will return in less than a day. If possible. The chronometer is over here, you see? But if I should be longer than a day, don't worry. There's everything you'll need, here in the shelter. I'll do my best to hurry."

Her eyes blessed him.

He had to turn back from the middle of the airlock, to pick up his video recording, almost forgotten.

How, when it came time at last to take the Queen into the city, was he going to explain his long concealment of her? She was bound to tell others how many days she had been in that far tent. Somehow there had to be a way around that problem. At the moment, though, he did not want to think about it. The Queen was his alone, and no one . . . but first, before anything else, the berserker had to be got rid of. No, before that even, he must see if its video data was good this time.

Maybe Helen knew, Helen could tell him, where cached Dardanian treasure was waiting to be found . . .

And she had taken him as lover, as casual bedpartner rather. Was that the truth of the private life and character of the great Queen, the symbol of chastity and honor and dedication to her people? Then no one, in the long run, would thank him for bringing her back to them.

Trying to think ahead, Sabel could feel his life knotting into a singularity at no great distance in the future. Impossible to try to predict what lay beyond. It was worse than uncertain; it was opaque.

This time his laboratory computer made no fuss about accepting the video records. It began to process them at once.

At his private information station Sabel called for a printout of any official news announcements made by the Guardians or the city fathers during the time he had been gone. He learned that the entertainer Greta Thamar had been released under the guardianship of her court-appointed lawyer, after memory extraction. She was now in satisfactory condition in the civilian wing of the hospital.

There was nothing else in the news about goodlife, or berserkers. And there had been no black-robed Guardians at Sabel's door when he came in.

DATING ANOMALLY PRESENT was on the screen of Sabel's laboratory computer the next time he looked at it.

"Give details," he commanded.

RECORD GIVEN AS EPOCH 451st CENTURY IDENTIFIES WITH SPECTRUM OF RADIANT EPOCH 456th CENTURY, YEAR 23, DAY 152.

"Let me see."

It was, as some part of Sabel's mind already seemed to know, the segment that showed Helen on the inner surface of the Fortress, raising her arms ecstatically as in some strange rite. Or dance.

The singularity in his future was hurtling toward him quickly now. "You say—you say that the spectrum in this record is identical with the one we recorded—what did you say? How long ago?"

38 DAYS 11 HOURS, APPROXIMATELY 44 MINUTES.

As soon as he had the destructive materials he needed loaded aboard the flyer, he headed at top speed back to base camp. He did not wait to obtain a spare space suit.

Inside the tent, things were disarranged, as if Helen perhaps had been searching restlessly for something. Under the loose coverall her breast rose and fell rapidly, as if she had recently been working hard, or were in the grip of some intense emotion.

She held out her arms to him, and put on a glittering smile.

Sabel stopped just inside the airlock. He pulled his helmet off and faced her grimly. "Who are you?" he demanded.

She winced, and tilted her head, but would not speak. She still held out her arms, and the glassy smile was still in place.

"Who are you, I said? That hologram was made just thirty-eight days ago."

Helen's face altered. The practiced expression was still fixed on it, but now a different light played on her features. The light came from outside the shelter, and it was moving toward them.

There were four people out there, some with hand weapons leveled in Sabel's direction. Through the plastic he could not tell at once if their suited figures were those of men or women. Two of them immediately came in through the airlock, while the other two remained outside, looking at the cargo Sabel had brought out on the flyer.

"God damn, it took you long enough." Helen's lovely lips had formed some words at last.

The man who entered first, gun drawn, ignored Sabel for the moment and inspected her with a sour grin. "I see you came through five days in the cooler in good shape."

"Easier than one day here with him—God damn." Helen's smile at Sabel had turned into an equally practiced snarl.

The second man to enter the shelter stopped just inside the airlock. He stood there with a hand on the gun holstered at his belt, watching Sabel alertly.

The first man now confidently holstered his weapon too, and concentrated his attention on Sabel. He was tall and bitter-faced, but he was no policeman. "I'm going to want to take a look inside your lab, and maybe get some things out. So hand over the key, or tell me the combination."

Sabel moistened his lips. "Who are you?" The words were not frightened, they were imperious with rage. *"And who is this woman here?"*

"I advise you to control yourself. She's been entertaining you, keeping you out of our way while we got a little surprise ready for the city. We each of us serve the Master in our own way . . . even you have already served. You provided the Master with enough power to call on us for help, some days ago . . . yes, what?" Inside this helmet he turned his head to look outside the shelter. "Out completely? Under its own power now? Excellent!"

He faced back toward Sabel. "And who am I? Someone who will get the key to your laboratory from you, one way or another, you may be sure. We've been working on you a long time already, many days. We saw to it that poor Greta got a new roommate, as soon as you took up with her. Poor Greta never knew . . . you see, we thought we might need your flyer and this final cargo of tools and chemicals to get the Master out. As it turned out, we didn't."

Helen, the woman Sabel had known as Helen, walked into his field of vision, turned her face to him as if to deliver a final taunt.

What it might have been, he never knew. Her dark eyes widened, in a parody of fainting fright. In the next moment she was slumping to the ground.

Sabel had a glimpse of the other, suited figures tumbling. Then a great soundless, invisible, cushioned club smote at his whole body. The impact had no direction, but there was no way to stand against it. His muscles quit on him, his nerves dissolved. The rocky ground beneath the shelter came up to catch his awkward fall with bruising force.

Once down, it was impossible to move a hand or foot. He had to concentrate on simply trying to breathe.

Presently he heard the airlock's cycling sigh. To lift his head and look was more than he could do; in his field of vision there were only suited bodies, and the ground.

Black boots, Guardian boots, trod to a halt close before his eyes. A hand gripped Sabel's shoulder and turned him part way up. Gunavarman's jovial eyes looked down at him for a triumphal moment before the Chief Deputy moved on.

Other black boots shuffled about. "Yes, this one's Helen Nadrad, all right—that's the name she used whoring at the Parisian Alley, anyway. I expect we can come up with another name or two for her if we look offworld. Ready to talk to us, Helen? Not yet? You'll be all right. Stunner wears off in an hour or so."

"Chief, I wonder what they expected to do with suspended animation gear? Well, we'll find out."

Gunavarman now began a radio conference with some distant personage. Sabel, in his agony of trying to breathe, to move, to speak, could hear only snatches of the talk:

"Holding meetings out here for some time, evidently . . . mining for berserker parts, probably . . . equipment . . . yes, Sire, the berserker recording was found in his laboratory this time . . . a publicity hologram of Helen Nadrad included in it, for some reason . . . yes, very shocking. But no doubt . . . we followed him out here just now. Joro, that's the goodlife organizer we've been watching, is here . . . yes, Sire. Thank you very much. I will pass on your remarks to my people here."

In a moment more the radio conversation had been concluded. Gunavarmen, in glowing triumph, was bending over Sabel once again. "Prize catch," the Guardian murmured. "Something you'd like to say to me?"

Sabel was staring at the collapsed figure of Joro. Inside an imperfectly closed pocket of the man's spacesuit he could see a small, blood-red cylinder, a stub of cut wire protruding from one end.

"Anything important, Doctor?"

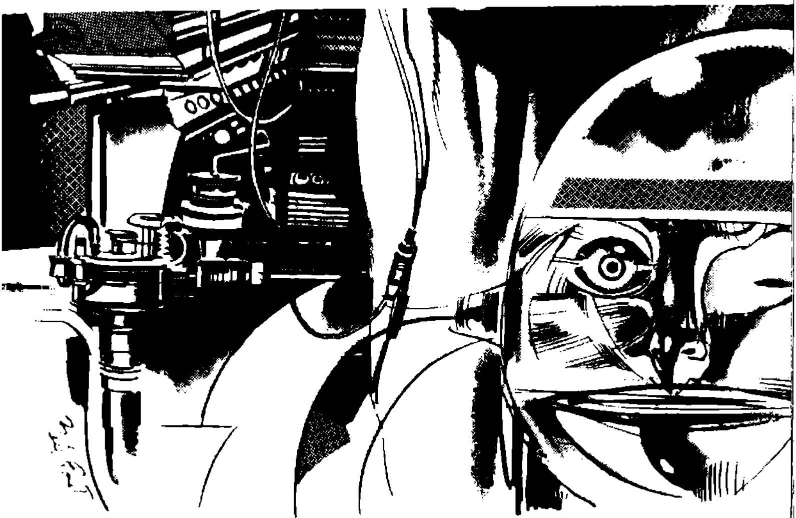
He tried, as never before. Only a few words. "Dr-aw . . . your . . . wea-pons . . ."

Gunavarman glanced round at his people swarming outside the tent. He looked confidently amused. "Why?"

Now through the rock beneath the groundsheet of his shelter Sabel could hear a subtly syncopated, buzzing vibration, drawing near.

"Draw . . . your . . ."

Not that he really thought the little handguns were likely to do them any good. ●



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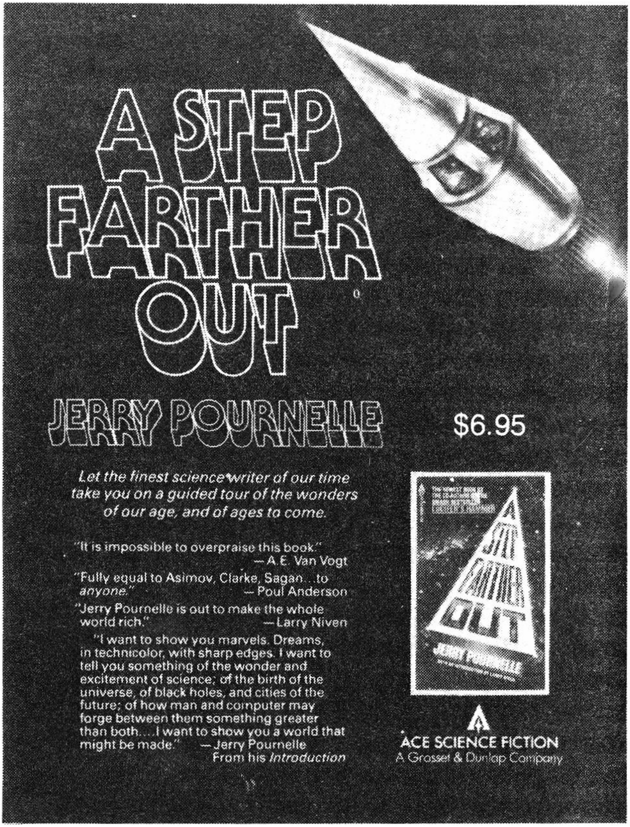
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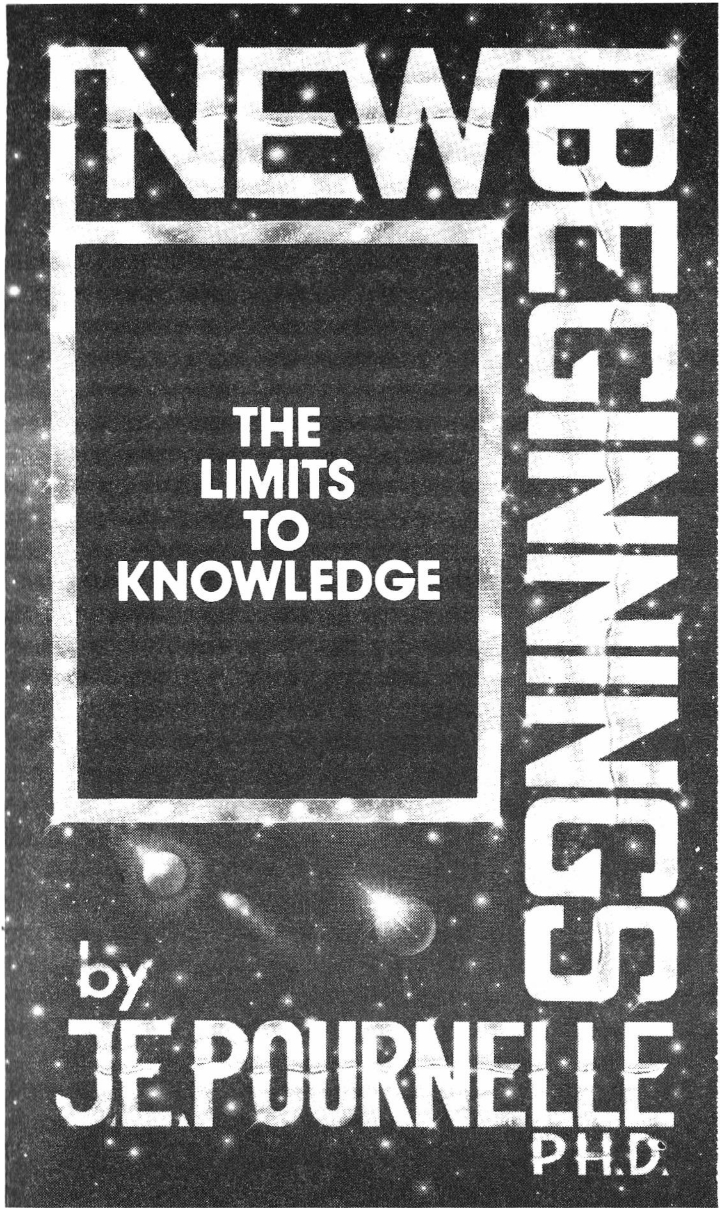

NEW BEGINNINGS
THE LIMITS TO KNOWLEDGE
by
J.E. POURNELLE
PH.D.

"WE CAN, IN A WORD, HAVE SOME CONTROL OVER OUR DESTINIES, RATHER THAN SIMPLY TAKING WHAT NATURE DISHES OUT TO US."

*

This will be my fifth annual report on the state of the sciences. For the benefit of those who've just started reading my columns, I'd better explain that when Jim Baen and I were at another magazine I developed the habit of reporting the annual meetings of the American Association for the Advancement of Science in the column following the meeting. This proved to be popular with readers, so I'll continue it here.

This year's meeting was not well attended. For one thing, after several years of holding AAAS meetings in late February, the Council decided to go to the first week of January; we got aboard the airplane still wearing funny hats from the New Year's Eve party. Secondly, the meeting had originally been planned for Chicago, but last year Dr. Margaret Mead realized that Illinois has not ratified the Equal Rights Amendment and used her not inconsiderable influence to cause the Council to move the meeting to Houston. Whatever effect that had on the ERA, it was a near disaster for the AAAS, which darned near went bankrupt.

Alas, this was the year the AAAS invited me to speak. My session was reasonably well attended, but had nothing like the audience a similar panel had in Washington in 1978. Sigh. And Larry Niven and I were the only science fiction writers at the meeting this year; last year there was a veritable horde, as I expect there will be next year, but I doubt I'll be invited to speak then. I suppose there's justice though: because of the sparse attendence at Houston, Larry and I had several of the world's brightest people all to ourselves without interruption for *hours;* and I guess given my druthers I prefer that to having a larger audience.

Every year they have a theme title for the AAAS meeting and this year's was "Science and Technology: Resources for Our Future". A hopeful title, but the mood of the meeting wasn't hopeful at all. Last year's meeting had gloom enough, but this year's was worse, and it wasn't the awful weather that was responsible.

A lot of scientists are convinced that the public has lost faith in science and technology.

Remember when the TV commercials used actors dressed in white coats and pacing in front of blackboards, or in laboratories, to sell any conceivable product? When "scientist" was a magic word and assured approval? When scientists were looked up to and respected as the saviours of the world? Well, them days is gone; or at least the scientists think they have. There was more *apologia* than planning in this year's meeting.

The point is illustrated by the panel that best fit this year's theme: the panel on Macro-engineering. It was entitled "How Big and Still Beautiful?"

One of the speakers was a lady psychiatrist whose point was that we must have the courage to say "no"; courage enough not to undertake vast projects. As if we need that advice! As if in this era of Proxmired projects, with a Vice President who tried annually to abolish NASA while in the Senate, and a President who declares war on the energy crisis but mentions research not at all in the speech; in this era when the Congress itself asks the NASA director and the President's Science Advisor where is the imagination, where are the new dreams—in this era of limits, the American Association for the Advancement of Science feels it necessary to include its enemies on its own platform.

But isn't that "fair"? "Balanced"? Perhaps. But you may be certain that the opposition doesn't include science advocates in *their* programs. And where do we rally our own troops? Boost our sagging morale? If the American Association for the Advancement of Science can't be partisan in the cause of advancing science, just who can be?

Then came the macro-engineering "cases in point"; but unfortunately, most lacked vision or imagination. There wasn't anything about really large projects, such as the Soviet hydrology plan for refilling the Caspian Sea, or the proposed (and alas perhaps moribund) joint US-Canada-Mexico water project for routing Arctic rivers southward to provide both water and electric power. There was a good paper on the future of the large rigid airship (it could easily have a bright future), and a disappointing paper from Peter Vajk whose excellent new book *Doomsday Has Been Cancelled* would have made a better topic than his brief on hypersonic flight. There was nothing about Ocean Thermal power systems, or Solar Power Satellites. In fact, while there was a lot of talk about defining macro-engineering, there just wasn't much *macro-engineering*.

With a notable exception. Dr. Kenneth Billman of the NASA-Ames Research Center wasn't originally scheduled, but he and Stuart Bowen (Beam Engineering, Sunnyvale) presented SOLARES—and that qualifies as a macro-engineering project under anybody's definition.

The better-known Solar Power Satellite concept would use large satellites to gather sunlight and covert it into useful energy, then beam that down to Earth either as laser beams or microwaves. SOLARES offers an alternative: orbit large mirrors, and beam down sunlight. The energy conversion would be done on Earth. One major problem with Earth-based solar receptors is that the sun doesn't shine 24 hours a day; with SOLARES it effectively would.

And by large mirrors, Dr. Billman means *large* — something on the order of two kilometers in radius. The mirrors look like bicycle wheels: thin films of reflective material, with masts at the center, and spokes from the masts to the rim. A series of flywheels and energy-storage systems aboard the mirror allow it to be "aimed" at the appropriate places on Earth.

Unlike SPS, which uses geo-synchronous (GEO) orbits, SOLARES is considerably lower—largely because the spot size (the size of the beam that hits the ground) from a mirror in GEO would be as big as the State of Maine, and that's a bit much. Also unlike SPS, SOLARES has some subsidiary uses. For example: while we were in Houston the local TV was full of weather news. The winter was bitter cold, and much of the citrus crop was lost. SOLARES could have prevented that: the mirrors could be used to direct sunlight onto the crop fields by day and by night. (It's unlikely that the SOLARES mirrors themselves would be used for that; instead, mirrors designed for optimum use in aiding agriculture would be deployed. The concept is called SOLETTA, and has been studied at NASA-Ames. But if we deploy SOLARES, we can build SOLETTA quite cheaply.)

The other advantage of SOLARES over SPS is that the space component is a much smaller part of the cost. It's much harder to estimate the cost of space-deployed hardware than it is to get reliable figures on ground installations, so the SOLARES cost estimates are probably a little firmer than those of SPS.

You can see obvious problems. For one thing, where would you put the receiving stations? Are there communities that want to be perpetual lands of the midnight sun? Perhaps not, but the ground installations could be on islands, possibly at equatorial sites. The SOLARES solar energy would be used to power chemical reactors making methanol or ammonia (or even hydrogen, although due to transportation problems there's a lot less enthusiasm for the "hydrogen economy" now than in the past). The resulting stored energy could then be supertanked to points of use.

I'm not myself convinced; I still think SPS is a better way to go; but certainly SOLARES deserves a careful look. The interesting part is that the first stage of development is the same for both SPS and SOLARES: building a fully recoverable large lift vehicle, a sort of super-shuttle which can bring the cost to orbit down to about $15/pound (constant 1978 dollars). With that vehicle we could build both SOLARES and SPS, start moon mines, begin real space industries, and put into orbit a telescope that would let us look at the *cloud structure* on planets orbiting Alpha Centauri. We get the science and space industries almost free—you can use the Heavy Lift Vehicle on weekends.

We also get lunar mines: if you're undertaking large construction projects in space, there comes a point when it's cheaper to build a Moon base and use lunar resources than to send up construction materials from Earth. For SPS that turns out to be between 7 and 20 10-gigaWatt (10 billion kiloWatt) satellites. I haven't seen a similar analysis for SOLARES, but I'd guess that before you've put up 100 mirrors you've probably passed the breakeven point for opening lunar mines.

Billman proposes that we pay for SOLARES by a tax on energy: the concept is similar to the way we paid for the Interstate Highway System with taxes on automobiles, their accessories, and their fuels. After all—we MUST replace the US energy establishment, and doing that will cost well over a trillion dollars ($1000 billion). Even with zero-growth our present power plants will not be eternal; a one to three percent tax on energy use, with the money going into a trust fund to be used to finance a new energy system, makes a lot of sense—because, you see, once we put up either SPS or SOLARES, energy can be supplied just about free, in the same sense that the highways are "free." The problem with space energy systems is the enormous front-end cost. But it isn't all *that* big; we're talking about $100 billion, less than the cost of a war, less than the capital needed to develop the Mexican oil fields. After that investment the cost per kiloWatt generated by space systems is more than competitive with present methods—and unlike oil or coal or nuclear fission it is eternal.

* * *

Many of the most exciting events in a AAAS meeting are impossible to summarize; I can only mention them in passing, and I apologize for teasing you; I wish I had space to cover them adequately.

For example: Roger Penrose has a new theory of the universe, making use of a concept called "twistors." Twistors are a mathematical concept, something between a tensor and a quark. If Penrose is right, he'll have a set of primitives from which he can derive normal space-time. To explain more than that would take a whole column—which you'll get one of these days. Penrose is undoubtedly the world's foremost geometer, and it's hard to say whether he or Stephen Hawking (they have been associates at Oxford) will be first with a new physics that adequately explains the wealth of experimental data coming from the high-energy accelerators and the radio astronomers. Perhaps neither, of course; but I wouldn't bet a lot against them.

The climate study people were out in force, with, alas, few reasons for joy. As I stated last year, Earth has enjoyed several hundred years of nearly optimum weather/climate. Now the picnic is over and we're going back to normal—which means shorter growing seasons, much more variable weather with many "unseasonably cold" winters, and in general a lot less pleasant conditions.

Also, if we don't stop pumping carbon-dioxide into the atmosphere we may be due for another horror: a large part of the Antarctic icecap may slide off into the sea. The resulting rise in ocean will drown many coastal cities and plains, and vastly reduce the arable land.

However, if we *do* stop pumping in the carbon dioxide, we may be due for a new Ice Age. There's considerable evidence that one is coming.

That's the bad news. The only cheerful point is that if we're due for a new Ice Age, as many suspect we are, it's unlikely to happen in our lifetime; and studies of Antarctica are giving scientists a handle on warning signs, so that we will probably be able to predict the coming of the ice in time to do something about it.

Which brings me to another commercial. Despite silly theories to the contrary, "natural" conditions are not necessarily favorable for *us*. Neither nature nor Earth are all that benign. We've been fairly lucky so far, but there's no reason to believe that if we just sit back and wait, nature will treat us as if she especially cares for us. We do, however, have the capability to change things to suit us. SOLARES and SPS and in general a massive space capability would let us fine-tune the Earth's heat balance. With those we can add heat where needed to stop the ice, or intercept sunlight that would have reached the Earth anyway and use that for our energy sources if we don't want to add heat. We can also use carbon dioxide as a starting material for some of the energy-conversions (such as making methanol by direct conversion of sunlight) and thus adjust the atmospheric makeup. We can, in a word, have some control over our destiny, rather than simply taking what nature dishes up for us.

There was a lot more on climate, but not much definitive; however, stand by. The climate people are moving toward a real understanding of the weather machine, and I look for exciting developments in the next few years.

Another exciting session was "Chemistry in Space", which sounds like a space industrialization topic, but wasn't: it seems that nature keeps large-scale chemical reactors going out there, and there's a wealth of chemistry happening, including formation of primitive organics. There's even a small but finite chance that some kind of large sentient cloud (shades of Fred Hoyle!) could develop in space; the chemistry out there is complex enough. This is another of those topics that deserve a whole column, and will probably get one some day.

Some sessions were pure fun. A good example was Yale Professor W. R. Bennett's paper on "Simulation of Literature." Bennet first traced the origin of Eddington's statement that "if an army of monkeys were strumming on typewriters, they might write all the books in the British Museum," a theme employed by a lot of science fiction writers. The concept seems first to have been employed by Archbishop of Canterbury Tillotson in a book published posthumously in 1719, who wanted to show how improbable the world is, and thus demonstrate the existence of God.

Bennett used a computer to simulate monkeys, and not surprisingly found that the random output is incomprehensible; you'd have to wait a long time for anything intelligible to emerge. Suppose, however, that we fiddle with the probabilities: instead of treating each letter, and the space between letters, as equally probable, we use the "etaoin shrdlu" formula. The result is gibberish, but here and there a word appears.

The next step is to feed in the correlations. That is, q is always followed by u; t is often followed by h; and so forth. Feed those into the computer and the result looks even more like English—and we needn't stop with first-order correlations. Why not second, third, even fourth? And while we're at it, why just straight English? Let's make up a matrix of probabilities as used by, say, Shakespeare, and Hemingway, and Poe.

By now the output is still gibberish, but it almost makes sense—and also sounds like the authors! Shakespearian example: "A GO THIS BABE AND JUDGMENT OF TIMEDIOUS RETCH AND NOT LORD WHAL IF THE EASELVES AND DO AND MAKE AND BASE GATHEM I AY BEATELLOUS WE PLAY MEANS HOLY FOOL MOUR WORK FROM INMOST BED . . ."

Hemingway: "Mount me Sam we snot leaketifuldn't migh toon't mit darsomade Sam say grid the ally firly whe so rusloo . . ."

The implication is clear. I'm going to have my computer find my 10th-order probability matrix, and then set it to writing these columns. (I promise to throw away unanswered any letter implying I already do that . . .).

* * *

There were also the inevitable panels on the planets; they're fascinating, but gave us nothing that regular readers of my columns don't know already. We found no life on Mars, and—surprisingly—not even organics; no one is sure why. We still don't know what formed the large channels, particularly those which seem to run a number of small channels together to build one large one. It looks like water erosion, but where's the water? On the other hand, there's a very good chance that a lot of Mars is permafrost, thus saving my story *Birth of Fire* for a few more years.

The only conclusion was that there isn't one: certainly the old model of an original thick atmosphere gradually dissipating is wrong, but we have no better.

Then there's Venus: are there plate techtonics there? If not, why not? We need more probes to be certain. If there is active plate techtonic activity, there won't be lots of ancient impact craters.

As I write this we're preparing for the Voyager encounter with Jupiter. About half of the stars of the sf profession will be out for it: JPL has asked me to help arrange their visit, and my compliments to their public relations people for thinking of us. By the time you read this we'll have truly wonderful pictures of Jupiter and his moons; I've already seen one photo showing details, *structure,* in the Red Spot, and the probe is still millions of miles out.

All of which is of more than trivial interest. Next time someone asks you why we should spend money on probes to the planets, point out that until we understand the history of the Solar System we won't understand the geology of Earth. As a purely practical matter: are Ice Ages triggered by external events (such as variations in the Sun and thus the illumination received here)? Or are they local phenomena? For that matter we know the Sun is a mildly variable star; how variable? It could affect our energy-systems designs.

Also, since it's rather hard to do laboratory experiments with the weather, we'd better look at other places and get other examples; Mars happens to have a very simple weather system (compared to ours) and thus lets meteorologists test simplified theories. Even the dullest must see that understanding the weather has practical dollars-and-cents value. (It's also *fun,* but we don't have to let the outsiders in on that secret.)

* * *

AAAS meetings are an exercise in frustration: there's just so much to cover. Which should I do: go to a press conference with the climate specialists; listen to Peter Bergmann on general relativity; go to a session on bio-feedback; have cocktails with three astrophysists including one fairly certain to win a Nobel Prize one day; go to a session on artificial intelligence; or go to a panel on nuclear waste disposal? Impossible decision, no? Even with help. Mrs. Pournelle covers education and brain physiology for me, and some of the social science stuff, but subtracting out her areas of interest still leaves more than any human can get to.

When there are a lot of us—us meaning science fiction types with some understanding of the hard sciences—we can trade off among ourselves, and talk about what we heard in the evening; but this year there weren't a lot of us. There were only Larry and myself and our ladies. Thus I fear I missed a lot of excellent papers, and a couple of times I got suckered into going off to sessions that turned out to be worthless, such as the one on personal computers in which a full professor of computer science demonstrated that he knows less about public use of computers than I do (and has zero imagination in the bargain).

So, since I can't get to all the sessions, and I can't possibly summarize all those I do get to, I try each year to capture the feel of the meeting; and to generalize that into a report on the sciences.

This year that seems exceedingly hard to do, and I'm not sure I understand why. Partly, I suppose, it has to do with the papers: there was a lot of solid data, fascinating stuff, but not many of the landmark sessions that often set the tone of the whole meeting. (Yang on unified field theory two years ago; Sagan, Drake, Murray, and Ruffini on space science five years ago when the spacecraft were first reaching other planets; the Skylab crew just returned to Earth; that sort of thing.) But that's not the whole explanation. I think the problem was the mood I mentioned in my introduction.

Science is losing confidence.

This was brought home to me when, after the AAAS meeting, I visited the Johnson Space Center (JSC) south of Houston. You go down there and you see amazing capabilities. They literally know how to save the world. For less national effort than we spent on the Panama Canal, and for far fewer lives (the Canal cost upwards of 25,000!) we could build enough non-polluting energy sources to put an energy floor under the world: to guarantee that everyone would have a basic energy minimum. This isn't a theoretical capability. It's quite real.

And we aren't doing it.

Well, all right. Maybe space power systems are not the way to go. There may be better ways (and if you consider *only* the energy aspects, there probably are; one big payoff of space energy systems is space itself; the science we could do on weekends, the potential for adjusting climate, the additional knowledge about Earth, etc., etc.). But granted there may be better ways, we aren't doing them either. As I pointed out two columns ago, major breakthroughs in fusion don't change the national timetable, because we don't have a national timetable.

Science moves along, quietly developing fantastic capabilities—and the President doesn't even know about them. Instead he gives an afternoon to Amory Lovins, who wants "soft energies." At the AAAS meeting a White House spokesman, lawyer member of the Council on Environmental Quality and a top advisor to Carter, speaking in a panel on nuclear waste disposal displayed such a shocking lack of knowledge of the elementary physics of nuclear wastes as to render any advice he might give virtually worthless; but his opinion counts for a lot more than any scientist's.

Proxmire has cut the $1.6 million request for a million-channel radio astronomy receiver right out of the budget, and awarded the request a "Golden Fleece" because one use for the receiver would have been in the Search for Extraterrestrial Intelligence (SETI).

Despite their breakthroughs, the fusion research labs aren't being properly funded.

Wherever we look we see science cut back.

Meanwhile, on campuses across the nation, *The Limits To Growth* remains the most influential book in academe. DOOM is in the air. The intellectual community grooves on it.

Now on most college campuses, the science and engineering departments are lightyears away from the liberal arts, belles lettres, and social "sciences" departments. The sciences and the liberal arts might as well be on different planets for all the communication between them; but there is a slow osmotic leak of attitude and mood from liberal arts to science (although not much in the other direction)—and I think the message finally got to the scientists.

We're doomed.

Of course we aren't, and most scientists know it. That's what makes it so frustrating. But somehow the message doesn't get across. Worse, the scientific community generally takes its view of the outside world from the intellectuals; if the social "scientists" say that the public has lost faith in science, then it must be true—and God knows the low budgets and slashed projects are objective evidence of this lost faith.

Thus the discouragement. If we can save the world, and know we can, but hear only that the world is doomed, then what's the point? And I fear there was a lot of that attitude at both the AAAS meeting and at JSC.

But now for the good news.

Fellows, it ain't so. The public has not lost faith in science, and certainly hasn't lost interest. Want evidence? You're holding it. *Destinies* was an instant success.

But that's science *fiction.* We know about the long lines for *Star Wars,* and the big bucks science fiction writers are (at long last and *Deo gratia*) getting, but what about science itself?

Once again look at what you're holding. Baen has been deliberately putting more and more non-fiction into *Destinies,* and the sales keep going up. (In fact, he's letting me reveal a trade secret: people say they buy the magazines for the fiction, but they read the non-fiction first—it's almost as if they want the fiction as an excuse.) Look at *OMNI,* another instant success, and just crammed with non-fiction. Walk down a major street in New York

City and see how many stores use valuable window space to display complex electronic calculators for sale to the general public. Look at how many Radio Shack TRS-80 computers have been sold. And so forth. I could go on for the rest of the column. The American public hasn't lost either interest or confidence in science.

Take a poll. Ask your friends which they trust: lawyers or scientists? Politicians or engineers? (I'm tempted to say "lawyers, politicians, child molesters, mass murderers, or bank robbers", but I won't.) Ye gods, the public isn't composed of fools. NASA should be preening, not apologizing: name another government agency that routinely brings in major projects costing tens of billions on time and within budget!

One of these days the politicians are going to discover a secret: there are votes out there for those who give Americans worthwhile goals, and who haven't lost confidence in American know-how. Example: in 1961 President Kennedy had just experienced the worst military-political disaster since the Braddoc expedition. He neither properly supported nor called off that Bay of Pigs invasion. So what did he do? He announced that we'd put a man on the moon by 1970, and his popularity soared.

Another case in point: during the Watergate scandal Nixon went on national TV to announce Project Independence: with American technology we could and should make ourselves energy independent before 1985. Here was a goal worth tightening our belts for, and once again the people responded. Now true: Nixon didn't mean it, and that became fairly obvious quite soon; but imagine this scenario: Nixon announces Project Independence, doubles the NASA budget, quadruples the fusion research budget, funds a variety of other projects on the theory that if you're paying $50 billion a year overseas you can afford nearly anything; and publicly burns the still-unheard tapes. Would he not have finished his term of office? And quite possibly have selected his successor, too.

Surely there is a national figure who can appreciate the American need for big and worthwhile goals, and who wants a place in the history books. President Carter could still do it. If not Carter, there are other political figures who are very responsive to the mood of the people. Governor Brown, are you listening? Somewhere there must be one who understands: to rally the American people to work toward something both difficult and magnificent requires only the courage to sound the trumpet.

Which brings me at last to my own paper presented at the AAAS meeting. (You just knew I'd get there, didn't you?)

The session was titled "Science in Society: The Limits to Usable Knowledge." It was organized by Dr. William Gale of Bell Laboratories and Dr. Greg Edwards of the National Science Foundation. Those who read my column last year will recall that Drs. Gale and Bell organized the most interesting session of the 1978 annual meeting, the one in which Freeman Dyson spoke of practical immortality and the life of the universe. (Incidentally, in last year's report I credited Bill Gale with a number of ideas that actually originated with Greg Edwards. My apologies.)

Probably the best of the papers in the "Limits to

Knowledge" session was Bill Gale's exploration of "Fundamental Limits to Knowledge": just how far, and how small, can we explore? We'd just heard Dr. James Gunn (Caltech astronomer, not related to the SF writer) conclude that the universe is open: we do not live inside a black hole in someone else's universe, and ours will continue to expand forever. Given that, we can see that as the universe expands, it gets colder; but as it gets colder, it becomes easier for machines to "think" and takes less energy to operate them.

Grant that, and the limits to knowledge are a long way off indeed.

For instance: let's make some reasonable assumptions about the universe. Observation shows that the farther away an object is, the faster it is moving away from us. (Actually, the dimmer the object the more red-shifted its light appears; we assume that the observed red shift is due to the farthest galaxies moving away from us; and thus we also assume that the more red-shifted an object, the farther away. It's not quite as circular as that, but nearly so.) We give the ratio of Change-in-range/Range (how fast it's moving away divided by how far away) the name Hubble Constant in honor of the astronomer who first noticed that the galaxies are red-shifted. Estimates by reliable people give the Hubble Constant as anywhere from 40 to 110 so you can see that the size and expansion rate of the universe remains in some doubt; but it's reasonable to suppose we'll never see past the edge of the universe: Gale's paper puts that at no more than 2×10^{10} light years or 2×10^{26} meters; a long way indeed, and a limit we can probably live with. Incidentally, a telescope about 150 meters in radius will look out that far and see 39th Magnitude objects.

Next, how small an object can we see? Well, that depends on what we're looking at it with: to be exact, by the energy per particle in an accelerator. In the 1980's we expect to get 2 trillion electron volts—which is about 3 ergs! (An erg is an incredibly tiny amount of energy, about what a mosquito uses in jumping off your nose—but all of it in one particle is a LOT.) With 2×10^{12} eV we should be able to look at particles of about size 10^{-19} meters.

So we build bigger accelerators. Eventually we'll run up against a fundamental limit again, the point at which quantum mechanical fluctuations are thought to destroy the concepts of geometry and make "length" meaningless. That's at 1.6×10^{-35} meters, another limit we'll have to live with.

Before we get there, though, we've some building to do. Dr. Gale has thoughtfully made up Figure One which shows the sizes of accelerators and their power requirements in order to look at very small structure.

Gale concludes that if the goal of science is a complete understanding of the universe, then we're a long way from the limits. We've only examined a very small corner of a very small galaxy. To look further we'll need a lot more equipment (some of it rather large: big orbiting telescopes, of course, but also linear accelerators large compared to the solar system!); meaning we'll need a lot more wealth; meaning that to fulfill the goals of science will require enormous growth of society.

There was considerably more. Karl Pribram of Stanford talked not so much about limits as frontiers: there's more and more evidence that the

FIGURE ONE: LINEAR ACCELERATORS TO STUDY *SMALL* OBJECTS
(Courtesy Dr. William Gale, Bell Laboratories)

Length		energy/ particle	total energy	size probed
Planetary	10^2 Km	1.6 erg	2 US electrical*	10^{-19} Meters
Solar system	10^6 Km	10^4 erg	6 kg fused Hydrogen	10^{-23} Meters
Intergalactic	1 LY	10^{11} erg	10^{-3} Sols**	10^{-30} Meters
Galactic***	10 LY	10^{16} erg	100 Sols	10^{-35} Meters

*Twice the present installed US generating capability. We may not do this for a while.
**One Sol = the present output of our Sun; no small amount.
***I confess I don't immediately see how we would build these latter two. Perhaps Macrostructures, Inc. (L. Niven, President) would undertake them. *JEP*

holographic model of the brain is useful and quite possibly correct. We may not be so very far from the direct man/computer interface and communications that I've used in my stories; it seems that the way the brain stores and processes information can probably be described with equations that engineers have been working with for years. (For more on this subject, see my previous columns, or my soon to be published *A Step Farther Out.*)

My own contribution to the panel on "The Limits to Knowledge" came last. I won't summarize it for you, because in a sense it was no more than a summary of what I've been saying in these columns for years.

The title was "The Only Limit is Nerve".

I believe that. ●

FROGS AND SCIENTISTS

Being the First
in a Series
of Exceedingly Short
FABLES AND FAIRYTALES
OF THE FUTURE,

by
FRANK HERBERT

Two frogs were counting the minnows in a hydroponics trough one morning when a young maiden came down to the water to bathe. "What's that?" one frog (who was called Lavu) asked the other. "That's a human female," said Lapat, for that was the other frog's name.

"What is she doing?" Lavu asked.

"She is taking off her garments," Lapat said.

"What are garments?" Lavu asked.

"An extra skin humans wear to conceal themselves from the gaze of strangers," said Lapat.

"Then why is she taking off her extra skin?" Lavu asked.

"She wants to bathe her primary skin," Lapat said. "See how she piles her garments beside the trough and steps daintily into the water?"

"She is oddly shaped," Lavu said.

"Not for a human female," Lapat said. "All of them are shaped that way."

"What are those two bumps on her front?" Lavu asked.

"I have often pondered that question," Lapat said. "As we both know, function follows form and vice versa. I have seen human males clasp their females in a crushing embrace. It is my observation that the two bumps are a protective cushion."

"Have you noticed," Lavu asked, "that there is a young male human watching her from the concealment of the control station?"

"That is a common occurrence," Lapat said. "I have seen it many times."

"But can you explain it?" Lavu asked.

"Oh, yes. The maiden seeks a mate; that is the real reason she comes here to display her primary skin. The male is a possible mate, but he watches

from concealment because if he were to show himself, she would have to scream, and that would prevent the mating."

"How is it you know so many things about humans?" Lavu asked.

"Because I pattern my life after the most admirable of all humans, the scientist."

"What's a scientist?" Lavu asked.

"A scientist is one who observes without interfering. By observation alone all things are made clear to the scientist. Come, let us continue counting the minnows." ●

Illustrated by Alicia Austin

An Open Letter from Robert A. Heinlein

Send your membership dues to the L-5 Society, 1620 N. Park Ave., Tucson, AZ 85719 602/622-6351

Dear Friend:

If SF is simply fun and/or money to you, skip this. But if you believe as I do that our race can and will and _must_ spread out into space, stick around.

L-5 Society's sole purpose is to place a colony at Lagrange Point #5, the one trailing the Moon at 60°.

Sounds silly? It does to us, too, on gloomy days. We are about as far along as Willy Ley and Von Braun and Goddard were in the '30s . . . but one generation later Neil Armstrong stepped down on Luna.

And things move faster today. Technology doubles every seven years. We could build that city in space today ... but we'll be able to build it faster, easier, more economically in the '90s. Or (I'm an optimist!) in the '80s. I have already lived from horse & buggy to space shuttle; I cannot believe that human progress will come to a sudden stop. Space will be colonized.

Space _will_ be colonized . . . although possibly not by us. If we lost our nerve, there are plenty of other people on this planet. The construction crews may speak Chinese or Russian -- Swahili or Portuguese. It does not take "good old American know-how" to build a city in space. The laws of physics work just as well for others as they do for us.

I don't think we've lost our nerve. We can put a construction crew of our own up there . . . and space is big enough for everyone -- all races, all languages. We need never be crowded again.

Dues are $20/year ($15 for students) and include the monthly magazine _L-5 News_ with all the latest space news, data not in newspapers and must be dug out from technical journals and specialized sources -- our editors do it for you. The Society supplies other services, too, but I'm not going to list them, as the L-5 Society was not organized to serve or amuse its members.

ITS SOLE PURPOSE IS TO FOUND THE FIRST COLONY IN SPACE!

How's your nerve? Are your eyes on the stars? Send in your dues and join us.

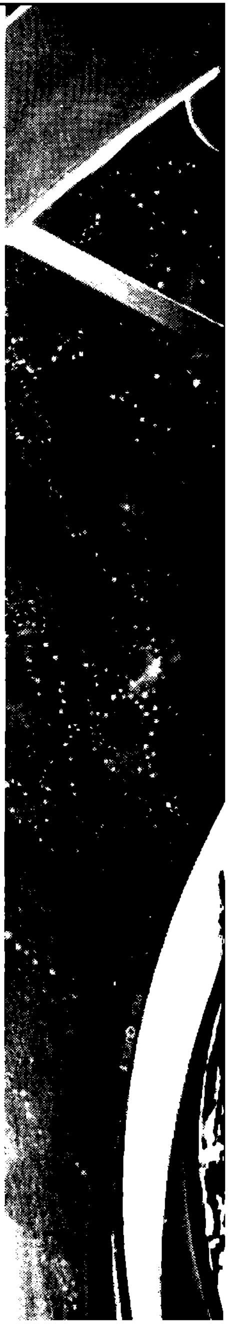
Welcome aboard!

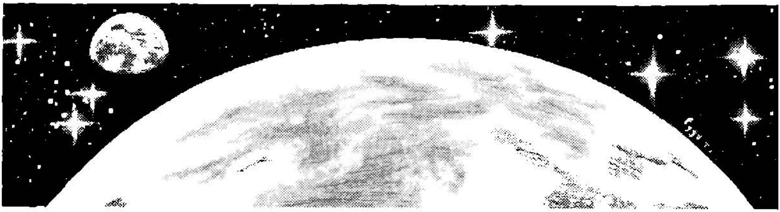
Robert A. Heinlein
for the
Membership Committee

THE L-5 REVIEW #1

Edited by Alcestis R. Oberg

"IF YOU ARE EXCITED BY THE FUTURE AND BY THE IDEA OF SPACE COLONIZATION, GET A SUBSCRIPTION TO THE L-5 NEWS OR BECOME AN L-5 SOCIETY MEMBER."





"L-5" or "Lagrange point 5" is a point in space equidistant from the Earth and the Moon. Because the astrodynamics of the Earth-Moon system creates gravitational equilibrium here, it was believed to be a good location for a large space colony. Although recent studies suggest that other orbits may be more feasible than L-5, the name "L-5" is still meaningful: it's the point in space around which the dream of space colonization took shape and became more solid.

The "L-5 Society" is a group of people committed to the idea of using outer space for human habitation and industry. There are many local chapters of the L-5 Society across the country (and some overseas too!); these chapters organize and sponsor activities, exhibits, lectures and movies to keep themselves and the general public informed on space activities and opportunities.

The *L-5 News* is the monthly magazine of the L-5 Society. It covers a wide range of issues: advances in space technology and engineering both here and abroad, current U.S. space policies and legislation, progress in space medicine, biology and life-support systems, international law governing outer-space transactions, economics involved in the development of space, and much more. It carries the most up-to-date information on both the theoretical and practical level of the effort to conquer the "high frontier," and on the people who are committed to humanity's presence in outer space in the future.

This column, "The L-5 Review," will consist of excerpts, abstracts and digests of the best material of current issues of the *L-5 News*, as selected by its editor, Alcestis Oberg. In those cases where material is taken from by-lined articles, the authors' names will be given at the beginning of the item.

If you are excited by the future and by the idea of space colonization, get a subscription to the *L-5 News* or become an L-5 Society member. Write for information to:

The L-5 Society
1620 N. Park
Tucson, AZ 85719

HUMANS IN SPACE

Planning Begins for New Astronaut Selection

A new call for astronauts may be issued by NASA later this year. According to George Abbey, Director of Flight Operations at NASA's Lyndon B. Johnson Space Center in Houston, a new class will probably be selected before the current class graduates in July 1980. The new group would be smaller than the present one and could be the first of a routine annual astronaut selection process.

Five to ten individuals—pilots, mission specialists or scientists from a particular discipline, or some combination—would be picked on an "as needed" basis. Announcements would routinely be made early in a given year with a closing date of June 30, followed by a six month selection process. Those chosen as astronaut-candidates would then report for duty on or about the following July 1.

Exact selection criteria and schedules depend upon Space Shuttle progress and upon attrition and retirement from the current astronaut corps. Although no formal selection process is under way, the address for inquiries is still in effect: Code AHX, NASA Lyndon B. Johnson Space Center, Houston, Texas 77058.

Who Will Go?

"We don't want risk-takers who see danger as a kind of cleansing by fire!" exclaimed Dr. Kirmach Natani of the Department of Psychiatry of the University of Oklahoma Health Science Center. In a talk given at the AAAS Convention in Houston in January on assessing candidates for jobs in space, he said he hoped this type of individual might be screened out in a selection procedure that would combine psychological and neurological information. "What we need is survivability, social adaptability, high performance in stressed circumstances, and innate cautiousness."

Psychological evaluation is often done now by means of psychometric measurements which involve interviewing a candidate and asking this person how he or she feels about various things. Also, socio-cultural background, intelligence and physical well-being are taken into consideration. "But the weakness with this kind of evaluation is that it assumes the individual knows how he feels and is honest about his feelings." A neurometric assessment, on the other hand, would test the nervous system of the candidate and would provide a different kind of data. The equipment required for this is a desk microprocessor, flow charts of procedures for testing tasks and responses, and a strange-looking testing apparatus in which the candidate sits in a deliberately uncomfortable hunched position as his or her physiological responses are tested. As the candidate's responses to novel situations and tasks are tested, the physiological data is fed to the computer, which compiles and analyzes this information on a specific response-by-response basis. Since the test situations arise suddenly, the candidate does not have time to deliberate but must respond quickly. In this way, the individual's unconscious, nonverbal, innate responses to novel situations can be assessed.

The weakness of this method is that it favors individuals who do well at visual tasks and perform well in a hunched position. "This could be overcome by giving a battery of tasks in a variety of positions," Natani said.

A neurometric assessment provides much valuable information about the nervous system of an individual. Such as assessment may help future personnel administrators weed out those who are accident prone and those who become negligent and careless when bored. Also a candidate may be counseled in areas of weakness and can be given specific reasons for non-selection. When psychometric and neurometric assessments are combined, a fairly competent and precise evaluation of a candidate can be made. This will aid those who must select and reject candidates for jobs in space.

Natani said that because a space habitat is a hazardous environment, thoughtless and reckless behavior on the part of one person may endanger the whole habitat. "It doesn't hurt to choose someone who is somewhat paranoid, that is to say, one who continually takes into account the potential hazards of one's environment." And since novel situations are bound to arise in space habitats, it is important to assess and to predict a candidate's behavior ahead of time.

"In the past, astronauts came from 'stressed backgrounds'; they were used to stress and novelty. But now people applying for jobs in space come from unstressed backgrounds; they are not test pilots. Neurometric assessments of these people can play an important role in the screening procedure," Natani claimed.

The clumsy of the world need not despair, though; once the hazards of space life are reduced, they too could be chosen as space colonists, Natani assured the audience.

Unexpected Psychological Benefit on Salyut 6

The cosmonauts aboard Salyut 6, isolated from normal life on Earth and surrounded by lifeless space, manifested a particular attachment to any organisms that grew aboard the station. This was confirmed by cosmonauts from previous missions, who lovingly tended onion stems and fish in the aquarium, claiming that biological experiments were a pleasure rather than a work assignment. In fact it offered them a kind of emotional relaxation, and they were always ready to return to the care of their nurslings even during their "free time."

New Data on the Long-Term Effects of Zero Gravity

Soviet Academician Oleg Gazenko reported that Cosmonauts Kovalenok and Ivanchenkov withstood their record-breaking 140-day flight on Salyut-6 remarkably well. Gazenko said that the preliminary findings showed remarkably good results in the areas of greatest concern: how weightlessness affects the heart, the coordination, the metabolism and the state of the blood.

Electrocardiograph research, conducted in detail during the flight, did not show any deviations from the norm throughout the flight. Functional tests at dosed physical stresses and also with the application of negative pressure to the lower part of the body also showed that these reactions were adequate and, most important, showed that no negative dynamic was noted. With the passage of time, the responses to these tests did not worsen. Ultrasonic electrocardiographs did not reveal any pathological changes in the condition of the heart, even though the quantity of blood which the heart pumps out with every beat had indeed diminished, though to a lower degree than had been previously recorded.

Also as the cosmonauts became accustomed to weightlessness, they became more coordinated.

The condition of the cosmonauts' blood was particularly intriguing. The control samples of blood which the cosmonauts took by themselves during the flight showed only a moderate reduction in the number of erythrocytes and hemoglobin—considerably less than the values which were obtained from earlier flights of shorter duration. The specialists who analyzed the data believed the cosmonauts did lose less of their circulatory blood than those who had flown earlier. This was at least partially due to their having drunk more water and exercised more than the crews of previous missions.

As for readaptation to Earth's gravity, the "severe period" only lasted about three or four days. The cosmonauts did not need any medicines and they gained back the few pounds they had lost within twelve days.

From the medical point of view, Gazenko summed up the principle results of the flight by saying that the cosmonauts underwent it well, maintained a good working capacity, successfully fulfilled their whole program, and underwent their return to Earth conditions very well.

USING THE RESOURCES OF SPACE

Ra-Shalom, by John Phillips

A team of scientists led by Dr. Eleanor Helin at the California Institute of Technology recently reported the discovery of a large, Apollo class asteroid which may be of the "carbonaceous chondritic" type. If so, the find may prove to be highly significant for any possible future program of space industrialization.

Asteroids represent an alternative to lunar resources as a supply of raw materials for space manufacturing enterprises. The carbonaceous chondritic type are of special interest due to the presence of significant quantities of nitrogen, hydrogen, and carbon, elements required to establish life support systems for space settlements. If these elements can be obtained from extraterrestrial resources, lift-costs to bring them from Earth can be avoided, which would enhance the economics of space industrialization considerably. Furthermore, the use of extraterrestrial sources of life support system elements removes major constraints in the design of such systems.

Assuming that an abundance of nitrogen, hydrogen and carbon will be available from processing carbonaceous chondritic asteroids, life-support systems can now be designed around extended food chains. Abundant supplies of foods derived from traditional agricultural and livestock species can be anticipated, while system stability and reliability can be assured by designing redundancy into the space farm. Surplus production can be stored, and some might even be shipped to outposts too small or temporary to justify having their own agricultural systems. Most important, life support systems need be only partially closed with respect to recycling of materials. Toxic heavy metals, for example, can be concentrated by water hyacinth plants in an aquatic wastewater recycling system. The dried plants can then be processed through an incinerator—and ash containing the heavy metals can be jettisoned or sent to the space manufacturing facility as raw material.

Eleanor Helin has given the newly found asteroid the name "Ra-Shalom" in honor of the Camp David Peace Conference. "Ra" is the name of the Eyptian Sun-god, symbol of enlightenment; "Shalom" is the traditional Hebrew greeting meaning "peace."

Moon Mining, by William N. Agosto

Most of the studies on processing lunar materials for industrial use focus on smelting metal out of oxides and silicates in the lunar soil. But there is a much more accessible metal resource on the Moon. It is metallic nickel-iron powder which makes up about a half of a percent by weight of the finely divided lunar soil. About ten percent of Moon soil metal is in the form of free standing metal particles without silicate or other non-metallic attachments. That means that approximately 2 billion metric tons of pure nickel-iron powder are available in the top 10cm of soil over the entire lunar surface. And there's more below. The idea that high-energy chemical engineering has to be used to obtain structural metal from the Moon is probably metallurgical Earth-chauvinism; there is, after all, no free iron to speak of in the Earth's crust. On the Moon, you can scoop it up with a magnet.

Nickel-iron is the most magnetic fraction of lunar soil. Several magnetic passes at the proper field strength may extract soil metal to 98% purity. And there are electrostatic techniques for separating soil metal as well. One method called tribo-electrification was reported by Ian Inculet of the University of Western Ontario at the Lunar Planetary Conference in Houston last year. Tribo-electrification separates particles according to size, dielectric constant and conductivity. It has been used to separate hematite iron ore from slag and carbon from fly ash in industrial exhausts. It can be automated, uses little power, and works best at low humidity. In the lunar environment it could be a very effective soil separating process indeed—not just for iron, but for other particulate minerals as well.

The metal powder thus obtained can be fabricated into machine parts and tools by powder metallurgical techniques which mold the finished product directly without machining, and in the dry lunar environment it might be possible to substantially reduce the powder sintering temperatures and pressures (about 800° C and 10,000 psi) used on Earth. Alternatively, the metal powder could be melted in solar furnaces, residual slag skimmed or vaporized, and the metal evaporated directly onto core molds.

The high nickel content of the powder alloy (about 10%) will toughen the finished product and probably more than compensate for the residual non-metallic inclusions. There is very little chromium (less than 0.1%) and correspondingly more phosphorus (about 5%) in lunar metal. But anticorrosive components like the chromium in Earth stainless steel may not be necessary under the low oxidizing conditions of most space applications.

Extremes of processing temperature can be readily maintained on the Moon. For example, molten metal could be poured directly into underground cryogenic (super cold) chambers to achieve the precipitous cooling rates necessary to make metallic glass, a substance which has many desirable properties: it is far more corrosion resistant than standard crystalline metal of the same formulation, has three times the tensile strength of steel, and withstands 50% more shear stress. It also has very versatile electromagnetic properties that make it suitable for magnetic memory and superconduction applications. Metallic glass could be made on the Moon and might become the ideal source of superconducting magnets for mass-driver operations in space.

The more you look at the Moon, the better it looks from the industrial point of view. There are abundant stores of aluminum and titanium ores in an already finely subdivided state. There are implanted volatiles and carbon from the solar wind in the soil, and a host of glass making components. But Moon metal is probably the most accessible space structural resource of them all.

ENERGY FROM SPACE

Solar Power Satellites, by Carolyn Henson

Solar power satellites may someday catch the Sun's energy and beam it to Earth. They could collect energy by using silicon, gallium arsenide or "sandwich" solar cells to convert sunlight directly to electricity. Or they might convert sunlight to heat, which can power thermionic converters or turbogenerators.

How will they get the energy back to Earth? One way is with microwave beams, another is by infrared laser. Both can pass through clouds, although a rain storm can block the infrared light. Once the energy reaches Earth it must be converted to electricity. Microwaves are converted by rectifying antennas. An infrared beam might be fed into a "reverse laser" or specially tailored solar cells which would convert coherent light into electricity.

How large will solar power satellites be? The most popular design at present would be almost 100 square kilometers—about the size of Manhattan Island. A satellite that size would provide ten gigawatts (10 billion watts) of electricity, enough to power the entire city of New York with plenty to spare. To be economical, a microwave-style power satellite could be no smaller than 25 square kilometers in area, transmitting 2.5 gigawatts (because of inherent optical limitations). Power satellites using laser transmission could be much smaller.

How will power satellites be built? They might be prefabricated and shipped into orbit, where space workers would build them. Another possibility is that ores from the Moon or from asteroids could be processed into raw materials in lunar or space factories. Power satellites, space craft, space habitats and more could be built in these factories. However power satellites are built, they can be a major stepping stone toward opening up the solar system for human habitation.

Why do many researchers believe solar power satellites could be the key to cheap and plentiful power? First, sunlight in space is abundant—six to ten times as much per area as we receive on Earth. And it is not interrupted by long winter nights and rainy weather. Secondly, space solar collectors can be made out of exceedingly light materials. In free fall they need only resist tidal forces, orbital perturbations, micrometeorites, solar wind and light pressure.

Space solar power satellites are also very controversial.

Controversy over Space Power Satellites

There are many arguments for and against the construction of solar power satellites in space. The key issues are those of the cost of such a system, its reliability and its environmental impact.

The most controversial of these is the question of cost. Although cost estimates can never be more than approximations, there are many methods used to predict costs of long-term projects like the space solar power satellite (SPS). Garry DeLoss, a professional lobbyist with the Environmental Policy Center, is an outspoken critic of current costing methods. He said: "The supposedly objective cost estimates for the SPS are being made by the corporations, NASA space flight centers, consulting firms, and academicians who have a vested interest in encouraging a massive government commitment to SPS. This leads to cost estimates that are mere self-fulfilling prophesies, or what one critic calls 'legislating all the answers.' Richard Caputo, who directed a two-year Jet Propulsion Laboratory (JPL) study of the SPS recognized the same pattern of behavior, and characterizes the cost estimates he examined as based on 'assumptions of success' rather than a real data base. The SPS proponents appear to begin by calculating the cost goal which the total SPS system must meet to compete with other energy sources, and then allocate that cost goal among the various subsystems of the SPS. Hence, they tend to reach similar conclusions about the total cost of the SPS based on widely varying estimates about the costs of the subsystems."

But Gordon Woodcock, SPS study manager for Boeing, claimed that a Design-to-Cost analysis was used. This "defines, on an overall economic basis, a set of cost targets for a system or a project. These targets are then allocated against elements of the system, and the design activity attempts to meet, or beat, the allocated targets. SPS cost figures published in 1976-78 are cost estimates and not target figures." Researchers believe the capital cost, including the ground receiving stations would range between $1000 to $2000 per kilowatt installed capacity. What about cost overruns?

"Cost overruns," says Mr. Woodcock, "do not arise from inability to estimate cost, but rather from a tendency of procurement agencies to change their minds about what they really want, from competitive bidding to beat the competition, and from poor management."

What about reliability? Mark Gibson, who did a study of the SPS at the University of Maryland, said: "Defects are inevitable considering the size and high power level of the satellites. Repairs will be expensive if not impossible. Environmental degradation in space will cause some power loss due to micrometeorites and proton radiation. Solar storms may cause severe damage to the cells." And Garry DeLoss claimed: "Saboteurs could attack the receiving antennae, which would have almost indefensible perimeters of many miles, or the high voltage transmission lines."

Carolyn Henson, President of the L-5 Society, however, quickly responded by saying that: "U.S. and Soviet astronauts have performed successful repairs on an Apollo command module, Skylab and Salyut. Because SPS consists of many identical units in parallel, it will usually be possible to continue operation while technicians repair and maintain the satellite." Gordon Woodcock responded on the question of sabotage by saying: "As for vulnerability, *all* energy systems are vulnerable, especially foreign supplies. Almost any system ex-

cept SPS is vulnerable to terrorist action. The idea that a terrorist could do much damage to an SPS receiving site recognizes neither the size nor the redundancy of the receiving system."

Of course, everybody is concerned about environmental impact. Mark Gibson claimed that: "The largest potential environmental problems are related to the number of space flights necessary to deploy an SPS. The pollutants and exhaust from the rockets will create water vapor in the ionisphere, heating the upper atmosphere." But Gordon Woodcock stated that: "The total quantities of fuel required to place an SPS in geosynchronous orbit are roughly 850,000 tons of methane and 150,000 tons of hydrogen (plus about 3 million tons of oxygen). At an SPS construction rate as high as 2 to 4 per year, the fuels consumed by the SPS launch fleet would be roughly equal to the fuels consumed by cars and trucks in Florida. The real issue has to do with where the pollution goes—the rocket vehicles will deposit some of it in the upper atmosphere. Studies are presently being conducted by the U.S. Department of Energy to determine the effects of SPS launch operations on the upper atmosphere."

Will there be a health hazard from the microwaves used to beam energy from the SPS to Earth? Mark Gibson said: "Microwaves have been shown to cause central nervous system disorders, cataracts, genetic changes and have been identified as possible factors of cancer development and Sudden Infant Death." Gordon Woodcock responded that: "The microwave power beam system currently proposed for SPS utilizes energy intensities too low to be of immediate physical danger.

Further, the more intense region of the beam would be absorbed by a receiving antenna. The principal concern is related to long-term effects of the small amounts of beam energy that spill over outside the receiving area. The spillover levels are within the range of experience of significant numbers of people exposed to the same kind of radiation from radio transmitters, microwave ovens, and other similar sources; nonetheless, before embarking on a large-scale program to transmit power from space by this means, one would wish to be considerably more sure than we are today that there really are no long-term, low-level, harmful effects. Thus, the research programs presently proposed for solar power from space give major emphasis to environmental effects assessments as well as technology research."

The complete text of the debate over the SPS is to be found in the November issue of the *L-5 News*. The controversy over this and many other options continues to rage. But the opportunity to use a source of energy that will never be diminished, never be depleted—the Sun—is at hand; SPS could be built not 50 years from now, or 20 years from now, but tomorrow. It is one more option Americans should consider as the resources of the Earth are becoming diminished and as the world faces an energy-poor future.

OVERSEAS ACTIVITIES AND PLANS FOR SPACE

European Moon Probe Discussed

The European Space Agency (ESA) has encouraged discussion of an all-European Moon probe to be launched early in the 1980s. Called POLO, for Polar Orbiting Lunar Observatory, the spacecraft would be launched by the ESA 'Ariane' booster and would orbit the Moon from pole to pole at an altitude of 100 kilometers. From this vantage point, the POLO satellite would map lunar magnetic and gravity fields in regions not investigated by American probes in the Lunar Orbiter and Apollo programs. In addition, gamma and x-ray detectors would scan the surface chemistry and geology.

NASA plans for an American 'Lunar Polar Orbiter' (LPO) have been axed for budgetary reasons. A fallback effort to fly American instruments on a projected Soviet lunar orbiter in 1980–82 is in limbo, victim of chilled Washington-Moscow diplomacy.

Besides expanding scientific knowledge of regions of the Moon not explored by Apollo, a lunar polar orbit satellite could search for one of the most valuable lunar resources of all: ice. Its existence in eternally-dark polar craters is predicted by theory, yet no trace of such icecaps has been found in Apollo research. Scientists had hoped to find evidence for lunar polar icecaps (which would probably be buried under several meters of lunar soil, but which could amount to the volume of water in Lake Erie) either from hydrated lunar grains thrown off the polar regions by meteor impacts, or from bursts of water vapor 'smelled' by instruments left behind at the Apollo landing sites. Neither approach has produced unambiguous evidence of the existence of such polar caps.

European interest in the lunar mission is symptomatic of a new confidence among ESA officials, who are searching for new directions open to

European space research. One enthusiastic proposal even called for the launch of a European Moon shot in mid-1980 on the fourth test flight of the Atlas-Centaur-sized Franco-German 'Ariane' booster; the payload, which would not be the proposed POLO itself, would have been assembled from backup GEOS-3 satellite parts. But that plan has been rejected, and a more ambitious program of lunar and planetary probes for the mid-1980's is now being prepared for budgetary consideration early next year.

Soviets Planning for a Future in Space

Konstantin Feoktistov, cosmonaut and top space engineer, was asked in a TASS interview what he thought people might be doing in the future in space. He responded: "We are preparing a kind of reserve for the future in our space program. Let me take two concrete examples: the creation of economically rational orbital production and the preparation for the gradual habitation of outer space.

"What do we need orbiting plants for? Modern pharmaceutical and metallurgical industries need superpure compounds, metals, crystals, vaccines, and the like. Here on Earth the production of some of these substances is technologically unfeasible because of the Earth's gravity; in outer space the conditions for it are ideal. For instance, it is possible to purify medical preparations with the most insignificant electrostatic forces. I think that by the mid-eighties we'll be able to provide profitable and regular production facilities in Earth orbit.

"As far as cosmic settlements are concerned, I think these will probably be built in the future, but I do not regard outer space as an escape from the problems that humanity has not yet solved. I believe these must be solved here on Earth, although I do not rule out the possibility that in time the cosmos may become the second home of human beings. Professor Gerard O'Neill of Princeton University has ideas that are both serious and imaginative about the creation of space settlements. Another interesting proposal is that of Academician Nikolai Semenov who proposes to saturate the Martian atmosphere with sufficient oxygen so that people can freely settle on this planet. Of course, this project sounds fantastic now, but only a while ago the thought of a person walking in space seemed just as absurd."

When asked what he thought a 21st century spaceship might look like Feoktistov said: "I think it will be an electrical jet craft with a powerful nuclear plant that will contain a reactor and converters of heat into electrical energy—turbine generators or thermal converters. The electrical jet engines will be of either the ion or plasma type, in which a stream of electrically charged particles accelerated in the propelling device provides the necessary thrust. To keep the capacity of the on-board power unit within the limits of our technological possibilities, the engine thrust must be very small, with the result that the spaceship will accelerate very slowly, taking several months to get away from the Earth and the same time to decelerate near the planet it is headed for.

"Another distinguishing feature of this spaceship will be gigantic surfaces for dissipation of the excessive heat developed by the nuclear unit. Hence, the ship will look like a sharp-pointed triangle. At its apex will be the reactor, the radiator will be the wedge, and a considerable distance away will be the living quarters housing the instruments, control panels and crew cabins. In front of the radiator will be a shield to guard against radiation. And, finally, somewhere nearby will be a descent module for landing on the planet of destination, since the craft I am talking about will serve only for transport between planets."

Nuclear Power For Soviet Spaceships

Professor O.M. Belotserkovski, director of the Moscow Physical and Technical Institute, foresees the use of nuclear energy in Soviet spacecraft of the future. In an interview last fall, he was quoted as saying: "The future of space flights depends also on the creation of new rocket engines utilizing nuclear energy. The search for still other sources of energy is in progress. It is known, for example, that energy gradients on the order of several thousand volts exist in the Earth's magnetosphere. The 'solar wind' contains still greater reserves of energy. Its power could impart a speed to a spacecraft on the same order as the speed of the 'solar wind' itself. Then the problem of the duration of a flight also would become considerably less acute than it is at present."

U.S. SPACE POLICY

Carter Sets Space Policy, by Leonard David

The Carter policy centers on three principles, with prime interest given to a space program which "will reflect a balanced strategy of applications, science and technology development," according to a White House press statement. The key elements of this program emphasize Earth applications, such as climate, weather, pollution, and resource monitoring satellites and a space science and exploration program that is vigorous, yet provide for a "short term flexibility to impose fiscal constraints when conditions warrant." Also outlined are supportive statements of space cooperation with other nations, as well as the need to take advantage of the Space Shuttle's flexibility to reduce the cost of operating in space.

A second specific aspect of the policy notes that "more and more, space is becoming a place to work—an extension of our environment. In the future, activities will be pursued in space when it appears that national objectives can most efficiently be met through space activities." The policy's third theme is bound to put a damper on those ready to dip into zero-gravity swimming inside a space colony anytime soon. The policy states: "It is neither feasible nor necessary at this time to commit the U.S. to a high-challenge space engineering initiative comparable to Apollo. As the resources and manpower requirements for Shuttle development phase down, we will have the flexibility to give greater attention to new space applications and exploration, continue programs at present levels or contract them. To meet the objectives specified above, an adequate Federal budget commitment will be made."

As for power-generating satellites, the Carter policy is equally direct. "It is too early to make a commitment to the development of a satellite solar power station or space manufacturing facility, due to the uncertainty of the technology and economic cost-benefits and environmental concerns." But, as if to give space colonizers something to hang their helmets on, the policy continues to suggest that "there are, however, very useful intermediate steps that will allow the development and testing of key technologies and experience in space industrial operations to be gained. The U.S. will pursue an evolutionary program that is directed toward assessing new options which will be reviewed periodically by the Policy Review Committee. The evolutionary program will stress science and basic technology and will continue to evaluate the relative costs and benefits of proposed activities."

Other topics covered in recent issues of the *L-5 News* include an analysis of Russia's guest cosmonaut program ("political exploitation of space events", complained author Jim Oberg in the November issue), an in-depth, first-person account of the October 1978 International Astronautical Federation conference in Dubrovnik, Yugoslavia, a look at how "Congress Views Space" and what space enthusiasts can do to improve the view, the latest developments in the liability claims on the Cosmos-954 crash in Canada last year with all the implications for the impending Skylab crash, reports of plans for a Chinese mini space station and a French space shuttle, a protrait of the new "Institute for the Social Science Study of Space", and additional items on space activities around the world. ●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SPIDER VS. THE HAX OF SOL III

BY SPIDER ROBINSON

Visions And Venturers, Theodore Sturgeon, Dell, 300 pp., $1.75
Tales From Gavagan's Bar, L. Sprague DeCamp & Fletcher Pratt, Owlswick Press, 310 pp., $13
The Schimmelhorn File, Reginald Bretnor, Ace, 288 pp., $1.95
Spacial Delivery, Gordon Dickson, Ace, 176 pp., $1.75
Murder & Magic, Randall Garrett, Ace, 266 pp., $1.95
The Best Of Analog, ed. Ben Bova, Ace, 418 pp., $2.25
Convergent Series, Larry Niven, Del Rey, 240 pp., $1.95
Other Times, Other Worlds, John D. MacDonald, Fawcett, 287 pp., $1.95
The Best Of All Possible Worlds, ed. Spider Robinson, Ace, 000 pp., $0.00 (To come)
Retief's War, Keith Laumer, Pocket, 172 pp., $1.75
Yargo, Jacqueline Susann, Bantam, pages and price unknown.
Tomorrow And Beyond, ed. Ian Summers, Workman, 158 pp., $9.95
The Third Book Of Virgil Finlay, ed. Gerry De La Ree, 128 pp., $15.50
Beauty And The Beasts: The Art of Hannes Bok, ditto
The Art of The Fantastic, ditto
Space Art, ed. Ron Miller, Starlog, 192 pp., $7.95
The Magic Goes Away, Larry Niven & Esteban Maroto, Ace, 219 pp., $4.95
Dreamsnake, Vonda N. McIntyre, Dell, 313 pp., $1.95
The Door Into Fire, Diane Duane, Dell, 304 pp., $1.95
And Having Writ . . ., Donald R. Bensen, Ace, 256 pp., $1.95
Capitol, Orson Scott Card, Ace, 278 pp., $1.95
Hourglass Productions: SF Interviews, one hour each, $4.98

• • •

IN THE BEGINNING, THERE WAS THE MONOBLOC.

And the monobloc looked upon itself and said, "Gaaah. Ninety percent of me is shit."

And exploded with violence unimaginable, a single stupendous detonation that sprayed immense gobbets of shit in all directions. In a twinkling known space was filled with assorted matter, expanding relentlessly outward.

This, at least, is my theory, the only theory I can devise that explains the condition of this office of mine. My memory repeatedly tries to convince me that I *carried* all these books in here from the mailbox downstairs, but that is plainly ridiculous: if I had the strength and initiative required, I would unquestionably have carried most of these down to the trash bin by now. What I mean, most of these books have good *reason* to all be crawling away from each other.

It was easier when I lived in the woods, by the Bay of Fundy. The only heat source of any consequence was a big old Ashley Automatic pot in the living room, and it would accept up to thirty-two hardcovers or ninety paperbacks at a time. The glue with which they bind 'em these days (even most of the "hardcovers," I'm bitter to say) makes books excellent firestarter on a cold morning. As far as I know, I am the only person in science fiction ever to have held regular Theme Bonfires, a tradition I will take over the Georgette Heyer Memorial Tea any day. Whole nights devoted to sword and sorcery, to disaster novels, a bimonthly Roger Elwood Night . . . those were the days, I tell you.

But now I live in Halifax with hot water heat, not an incinerator in sight, and people, take it from me, science fiction is *booming*. I have to use everything I learned from a childhood (inexplicably) spent on

New York subways in the rush hour to force my way into this office, so that I can sit here and try to make sense of it. I'm getting twice as many review books now as I was two years ago, and it's to the point where it's more than I can do to keep them *stacked,* let alone keep track of them.

However, to continue laboring my original metaphor, there is *some* order to the mess. In my capacity as Deity to this particular Universe, I have sought to *impose* order on things—arbitrarily and inconsistently, as deities are wont to do. Those particles which I perceive as being of insignificant mass I allow to expand outward unimpeded and unheeded. But those which seem like they might have something *to* them are gravitically attracted together into a large cardboard box labeled "READ THESE." I sample, at my leisure, such as I have time and will for, and in short order one of two things occurs: either I get ten pages in and kick it across the room into the general heap, where there is wailing and gnashing of pages; or I finish it and wedge it into another box labeled "THESE READ." Every three months I look at that cluster and tell you, in these pages, what it looks like.

I *never* have enough pages.

Usually it works out like so: I have about twenty books read that I want to talk about. By the time I'm finished talking about ten or so, I count pages and discover that I'm nearly out of space. So I cobble together a few hasty minireviews, and mentally compose letters of apology to the authors of the half-dozen or more discussion-worthy books I have not even mentioned.

Lately, however, the influx has doubled, and I've cut back from twelve columns a year to eight. There are *fifty* books and other items spilling out of the THESE READ box.

You see, there's a catch to this business of 90% of everything being shit—at least when you're speaking of sf. Ninety percent of the sf being written, sketched, painted or otherwise uttered *at any given time* is indeed excremental. But the good stuff *keeps coming back*. Editors remember; and when they get boom-time budgets they go back over forty years of dynamite unrecognized sf and recognize it all to hell. Half of the titles published this year will be reprints; better than half of the books in the THESE READ box are reprints or rediscoveries of some kind. Hence Robinson's Amendation To Sturgeon's Law: at the present time, only about 70% of sf is shit.

Which is why we are discussing more titles than usual this month. None of the books I'm about to talk about deserves the brief, telegraphed appraisal it's going to get—but neither will the ones I simply can't fit at all deserve oblivion.

As the Firesign Theatre once said, therefore, "Forward—into the past!" Into the heart of the Great Cream Nebula.

To me, one of the most astonishing and frustrating things about sf in the last 20 years has been the staggering number of uncollected, unanthologized Theodore Sturgeon stories.

I don't mean early, experimental efforts of a man learning his craft: a startling number of them *have* appeared in Sturgeon collections already. I mean mature works of a known genius, which appeared in now-defunct magazines, were reprinted perhaps in one or two now-defunct anthos, and are today remembered and read only by fanatic collectors and patrons of excellent libraries. Well, this situation is being rectified: Dell Books has purchased three books of uncollected Sturgeon, and the first of these to appear, *Visions And Venturers,* is a delight.

Oddly, one of the eight stories, "The Touch Of Your Hand," *does* appear in an in-print Sturgeon collection, *A Touch Of Strange.* But of the rest, none has been anthologized in from eleven to twenty years. Three of those stories ("The Nail And The Oracle," "The Traveling Crag" and "Won't You Walk—") are absolutely superb; two are merely excellent ("Talent," and "One Foot And The Grave"); and two—curiously the first two in the book—rate only very good, which is the lowest rating that can be applied to a Sturgeon story ("The Martian And The Moron" and one I'm not certain how to name: it's given variously as "The Hag Seleen," ". . . Séleen" and ". . . Sèleen").* Regardless, when you run the book through the Spidermeter (stories enjoyed/total stories X 100), it keeps coming out 105%. Anything over 70%, in these troubled times, is a recommendation to buy, and anything over 100% is a recommendation to buy two copies. I don't think I've enjoyed a story as much as "Won't You Walk—" in years: it's about a man who tried to steal a car, which steals him instead.

Oh, and the Jim Odbert b&w interior illos range from okay to excellent, with only one ("A Touch Of Your Hand") plain awful.

And these days $1.75 for 300 pages of *anybody* is a bargain. For Sturgeon it's a steal.

*would *accent grave* be a bilingual pun here? If so it's acute one.

I have been dying to read *Tales From Gavagan's Bar* for years now. My very first professional sale was a bar story, about a bar where they let you smash your glass in the fireplace. [Since then I have sold over a dozen more stories set in Callahan's Place; they are collected in *Callahan's Crosstime Saloon* (Ace) and the forthcoming *Time Travelers Strictly Cash* (also Ace).] Ever since then I have been hearing my bar stories compared (sometimes even favorably) to two other famous sf bar-story cycles: Arthur Clarke's *Tales From The White Hart,* with which I was familiar, and Fletcher Pratt & L. Sprague De Camp's Gavagan's Bar series, with which I was not. So I fell with small cries of delight on Owlswick Press's reprint of the 25-year-old *Tales From Gavagan's Bar.*

And stopped reading halfway through.

Now, don't get me wrong: I will certainly finish the book eventually, and what I did read I enjoyed. The stories are witty, inventive, hilarious in places. What they're *not,* exactly, is stories. "Sketches," I think, comes closer.

I don't mean length, although the longest of them is 14 pages; Fredric Brown wrote stories shorter than that. What I mean is that each of the Gavagan's Bar pieces is a (witty, clever) sketch for a story that never got written. There are no resolutions, no character growth, no development of any kind. Each is essentially an anecdote, and none of the ones I've read so far *go* anywhere.

Example: the first story in the book, "Elephantas Frumenti." A delightful idea: Mr. Witherwax uses the "square-cube law" to prove that the "wasps the size of dogs" described in Wells' *Food Of The Gods* could not have existed, or flown if they did. Then it occurs to him that the corollary is quite true: a house-fly-sized elephant could easily fly. Such a beast would need a high-energy diet, might burn alcohol, might therefore nest in the rafters of bars. At that point, Witherwax notices that his neglected glass is empty, and that from it to the table-edge are a line of little damp footprints, "circular, each about the size of a dime, with a small scalloped front edge, as if made by . . ."

Lovely notion for a story. That's where this one *ends*, 6 pages after it begins. Clarke's White Hart boys would have tried to catch one of the little tuskers; Larry Niven's Draco Tavern proprietor would have tried to merchandise them; and my own Callahan's Place regulars would have tried to get to know them, find out what *they* saw when they got drunk (Caucasians?). The Gavagan's gang simply learn of their existence, then drop the matter forever. Each of the tales I read went the same way: a funny situation is sketched, and then left standing there. Like Inga Pratt (Fletcher's widow)'s interior illos, they are *good* sketches, witty sketches, tasteful sketches—but they are also *sketchy* sketches. Halfway through, the only character I knew at all well was Mr. Cohan the bartender. And so, although I am very glad to own a copy and will certainly come back to it over the years—I was able to put it down.

This is clearly a personal fetish. If you have no aversion to a book of 29 verbal sketches and over 50 pen & ink sketches, or if, like me, you don't mind sampling a couple now and then as tasty tidbits, by all means send $13 to Owlswick Press, Box 8243, Philadelphia PA 19101. An extremely well-made hardcover.

Other rediscoveries and reprints worth your time and dimes:

The Schimmelhorn File, by Reginald Bretnor (AKA "Grendel Briarton," creator of Ferdinand Feghoot) is a file for sawing through the bars of stuffy old sanity. The adventures of Papa Schimmelhorn, the moron/genius and dirty old man, were first chronicled in "The Gnurrs Come From The Voodvork Out," which appeared in the Winter/Spring 1950 *Fantasy & Science Fiction* and has been anthologized at least three times that I know of, most recently nine years ago. It was followed by five more Papa Schimmelhorn stories, each more outrageous and hilarious than the last, and this is them. Their collection is long overdue. Don't miss them on any account; wonderfully wacky stuff.

Spacial Delivery by Gordon R. Dickson is part of Gordy's story-cycle involving the Dilbians. These aliens are ten feet tall and bearlike, never under any circumstances give a straight answer to any question, have a sense of humor that humans (whom they call "Shorties") often find unnerving, and just *love* to have fun. They hold Shorties in fond contempt, tempered with honest admiration for the proverbial Shorty "slipperiness," a trait they admire over all others. The stories are all set-pieces: an unsuspecting human is dumped on Dilbia by a distant bureaucratic government, finds himself in some hilariously impossible situation, and at last extricates himself by living up to the "foxy Shorty" reputation. The novel *Spacepaw* is part of the Dilbia cycle, as are a number of shorter stories. *Spacial*

Delivery is one of the best examples you could find. Funny stuff; recommended.

Murder And Magic by Randall Garrett is also part of a saga, in this case the adventures of Lord Darcy and Master Sean. It is a very ambitious, triple-threat saga. It is sf, in that it takes place in a parallel world in which Richard the Lion-Heart did *not* die at the Siege of Chaluz in 1199, his nephew Arthur was not murdered 3 years later by John, and the Plantagenet line descended unbroken to the present day. It is fantasy, in that this parallel world has discovered and codified the laws of magic, rather than those of physics (although Garrett himself disputes the fantasy label: he maintains that magic exists, in this world, waiting to be studied.) And it is mystery, in that what Lord Darcy *does*, with the aid of his forensic sorcerer Sean, is solve murders. *Murder And Magic* is a representative sample, four delightful and quite ingenious puzzle stories, most of which originally appeared in *Analog* magazine. Well worth your attention.

The Best Of Analog, edited by Ben Bova, is almost exactly what it says, lacking only one of my *Analog* stories for complete accuracy. But by the time Ben had gotten *this* far he was over 400 pages, so I forgive him. No, but frivolously, folks, this book contains four Hugo-winners ("Home Is The Hangman," Zelazny; "A Song For Lya," Martin; "The Hole Man," Niven; and "Tricentennial," Haldeman), two Nebula winners ("Hangman" again, and Vonda McIntyre's "Of Mist, Grass And Sand," of which more anon) and a stunning story ("Child Of All Ages") by John W. Campbell Award-winner P. J.

Plauger, who I think is shockingly underpublished these days. The *non*-award-winners range from very good to excellent, with the majority on the high end of the spectrum. All 15 stories appeared during Ben's 5-year, 5-Hugo tenure as editor of *Analog* (he is now fiction editor at *Omni*), and there's not a turkey in the bunch. At 400 pages, it's a bargain—hell, the $6 Baronet trade paperback version is a bargain. Spidermeter: 95%.

Convergent Series by Larry Niven is also recommended, but frankly only half-heartedly. I am a Niven addict and found it the least satisfying Niven collection so far. Del Rey Books is to be commended for having salvaged the only excellent stories from the now-defunct *The Shape Of Space* that have not been elsewhere resurrected, and one of them, "The Deadlier Weapon," (not an sf story) is one of the most memorable short stories I've ever read. And of the other older stories that make up the first part of this collection, nearly all are at least Average Niven—that is to say, above average for 'most anybody else. But only a couple of the *newer* stories, which make up over half the table of contents, are more than just okay. An awful lot of them, and particularly the majority of the Draco Tavern stories, seemed to me perfunctory, throwaways, stories that couldn't have taken more than an hour apiece to write. There's nothing *wrong* with that—after all, they only take a minute or two to read—but eight of them in a row is a great plenty, and one or two just didn't make it. Perhaps if they'd been sprinkled through the book instead of clustered they'd have put me off less. Fortunately the book ends with two very strong stories, "Night On Mispec Moor" and "Wrong Way Street." I know Larry has been busy with an important novel (*Ringworld Engineers* is its working title), and it's hard to say this about a writer I admire so much, but I'd almost rather see no short Niven at all than Niven doing card tricks.

Still, any book with "Deadlier Weapon," "The Meddler," and "The Nonesuch" in it is definitely worth buying. Spidermeter: 75%.

Other Times, Other Worlds, by John D. MacDonald, is a similar case. I am a devoted MacDonald addict: not only do I own all 63 of his published books, I have been known to spend hours hanging around the *Analog* office, digging out and reading the sf stories MacDonald sold to John Campbell during his apprenticeship. *OT,OW* comprises most of them, plus a few that sold to other magazines, from the 40s to the early 50s—and one story, "The Annex," which *Playboy* ran in '68. To his enormous credit, MacDonald went to great lengths, in the midst of his wife Dorothy's hospitalization (happily past at this writing), to ensure that his publishers didn't attempt to fob this off as new stuff—and got his way.

I would have to say that in quality these stories range from mediocre to excellent—and for MacDonald "excellent" is an uncharacteristically low rating. (I can't understand how come "The Hunted" was left out—it's miles better than some of these. Part of the problem is that they're so bloody old—these are among the very first things MacDonald ever wrote, and it took even him a while to learn his trade. Part of the problem is that he never had an overwhelming love for sf or fantasy—once he stopped needing the money he pretty much stopped writing it. Part of the problem is that shorter lengths have never been his strong point (he has written three sf novels; see my last column for details); he's only Playboy class there, he said enviously.

Nonetheless, better than half the stories in *OW, OT* stand up just fine, and the overall rating is 70%. But if you are not a rabid John D. fan, I would suggest you start with a couple of his Travis McGee novels. Then you'll be hooked, and you'll come to *OW, OT* in the natural course of things.

Retief's War, by Keith Laumer: last column I complimented *Retief And The Warloads* by saying that it was almost as good as the other Retief novel, *Retief's War.* This one is every bit as good. Another fine and timely rediscovery, good light entertainment for those idle hours, footwork that makes Astaire look like a Galapagos tortoise, heavy on the satire. See last column for extended remarks on Retief.

The Best Of All Possible Worlds, Vol. I, edited by Spider Robinson, of course deserves the reviewer's second-highest accolade: Just The Way I'd Have Done It Myself. (The highest is the rare "Better Than I Could Have Done It.") It is *not* a collection of Utopia stories. What I did, I picked five of my all-time favorite sf stories that are not widely reprinted and commonly known (Sturgeon's "Need," Niven's "Inconstant Moon," Ing's "Portions Of This Program . .," Heinlein's "The Man Who Traveled In Elephants," and an excerpt from William Goldman's *The Princess Bride.*) Then I asked each of those authors to pick *his* favorite story by someone *else*, and bought those stories too (in order: Carr's "Hop Friend," Oliver LaFarge's "Spud And Cochise," Boucher's "They Bite," Anatole France's "Le Jongleur De Notre Dame," and Sheckley's "10th Victim"). There is much introductory matter by myself and the primary authors involved, and I think the book lives up to the title that Jim Baen gave it: my favorite stories plus my favorite writers' favorite stories equals the BOAPW. Right now I'm compiling Volume Two.

A clear and obvious 100% on the Spidermeter.

Just before I leave the subject of rediscoveries, I would like to take a moment to commit a mortal sin.

I believe in principle that a reviewer ought never to review a book he or she has not read; in fact, with rare exceptions (such as the one earlier in this column) I don't think it proper to review a book I haven't finished. But I just finished the press release they sent me, and frankly, kiddies, Daddy doesn't want to hear any more.

Are you ready? They've discovered a long-forgotten Jacqueline Susann novel. Her very first, completed 23 years ago and never sold. "She had discovered Ray Bradbury and the Hayden Planetarium during this period," recalls her husband, "and the manuscript she showed me was a kind of science fiction love story."

Dig, this was 13 years before she felt ready to tackle *Valley of the Dolls*.

"It thoroughly reflects the romanticism of the young Susann," says Bantam, "and is written in a style inimitably her own . . . by a woman who obviously was many years ahead of her time." (Presumably because she wrote sf before *Star Wars*. Even if she did fail to sell it in the midst of a boom-cycle.)

As it happens, the late Ms. Susann saw fit to title this gem *Yargo*. For my sight-unseen opinion, simply delete the o.* I could be wrong—but I'm positive.

Less than half a column to go and I still have books crawling up my goddam leg (or could there have been impurities in that last rolling paper?.) How about a change of pace? Let's get away from the rediscovery/reprints and check out some sf and fantasy art.

It gets tricky here. The odds are excellent that you don't know the terminology and nomenclature of art criticism. Furthermore, I can assure you that I don't know them. Worst, I'm not at all convinced that the terminology and nomenclature needed to evaluate *science fiction* art *exist* as yet.

But we can fake it together. Hopefully, I need only apprise you of the existence of most of these (since they will not fit in the paperback pockets of your bookstore's sf section where you can find them), whereupon you will seek them out, glance through them, and make your own decision—as, I trust, you always do with art books. (You don't listen to *critics*, do you?)

I can scarcely imagine anyone turning down a chance to purchase *Tomorrow And Beyond*, however. It is a random collection of over 300 full-color

*just as I once reviewed an Elwood antho, *Epoch*, with "delete the -po-."

works of sf and fantasy art (including many book-cover paintings), representing over 65 artists, selected by Ian Summers, former Executive Art Director for Ballantine Books, and arranged loosely in twelve thoughtful categories. The very first thing to say is that the reproduction is *staggeringly* good; I've never seen such exquisite color. The second thing to say is that the selection is informed and diverse; there's something here for everybody. The third thing to say is that the layout is superb, and there has been no attempt to crap up the art with pretentious accompanying text: even the captions have been saved to the end of the book.

I would say that a full 50% of the paintings and photos hit me so hard that no adjective weaker than "stunning" will serve; the rest went from excellent to not-my-cup-of-coffee. Some of the artists were already known to me as excellent (DiFate, Schoenherr, Sweet); unfamiliar or half-familiar names whose work I shall now assiduously seek out include Peter Caras, Carl Lundgren, Michael Whelan, Brad Holland, Ron Miller, photographer Jake Rajs (inexplicably omitted from the list on the back cover), and especially my 3 standout favorites: David Schleinkofer (who got the cover), Larry Kresek (who just painted a brilliant cover for Jeanne's and my new novel, *Stardance,* before which I had never heard of him) and above all Rowena Merrill, a lady who, on the strength of these selections, deserves a book-showcase of her own.

There have been quite a few grab-bag selections of sf and fantasy art these days. This is the one to buy if you're only buying one. I can't think of a better use for ten bucks, and I can think of a *lot* of uses for ten bucks. If you can't find it locally, and are willing to trust me, order from Workman Publishing Co., 1 West 39 St., New York NY 10018.

You would think that by the time Gerry De La Ree got up to *The Third Book of Virgil Finlay,* he would have begun to run out of the very best stuff; you'd expect to find a few near-misses and failed experiments for filler. I did, anyhow, and was pleasantly startled. I like *TTBOVF,* if anything, *better* than I liked the first volume. (I never saw the second: it sold out before Gerry could get me a review copy. The first is likewise out-of-print in hardcover, but an Avon trade paperback edition has gone through 3 printings since 1976 with no end in sight.) Those younger readers who don't know who Finlay was: forget it. It would take 10,000 words to convey a hint of what a genius and a seminal influence he was. We shall not see his like again (although a spiritual descendant, Toronto artist Mac•An•T•Saoir, is showing signs of filling the void. More of him later.) If you are old enough to remember the Finlay magic, send your $15.50 in haste to Gerry De La Ree, 7 Cedarwood Lane, Saddle River NJ 07458. It may well be too late: Gerry's is a strictly limited (1300-copy) edition, and the serious collectors have him pretty well staked out. But it's worth trying; the inevitable trade paperback will take years to stumble into the stores, will probably be on inferior paper, and will certainly not be so finely bound. And with luck you might get on Gerry's mailing list.

A similarly endangered species is Gerry's 1000-copy edition of *Beauty And The Beasts: The Art of Hannes Bok.* And *almost* as highly recommended: I find Bok to be a bit more of an acquired taste than

Finlay. One, I add, which I am in the process of acquiring—with the help of this excellent collection. A mainstay of *Weird Tales*, Bok is customarily ranked with Finlay and Edd Cartier as one of the giants of his day (despite a vastly more limited output); his style is odd, angular, striking and quite unmistakable. He was heavily into the bizarre, the dark and the anguished: seldom is a Bok character seen at peace. His monsters are incredible.

Also from De La Ree, and probably more likely to be available, is *The Art of the Fantastic,* a sampler of b&w fantasy art ranging from the above-mentioned Big Three to contemporary artists like Freas, Fabian and Kirk. Frankly it is more of a collector's item than a reader's item, at least in my estimation—some of the more than 24 artists editor Gerry unearthed struck me as stiffs, and I could have done without the six pages of Conans, each worse than the last. But the good stuff is real good, and the historically interesting stuff is (historically) interesting. Like the above two books, it's high-quality repro on expensive paper, well-bound.

Mac•An•T•Saoir (prounced "Mac an *dur*") was once known by the pseudonym "Ron Macintyre." By any other name he is hot stuff—and almost utterly unknown. I saw my first Mac piece in the biannual catalog/fanzine of Bakka, Toronto's sf store, and on the strength of it went to great trouble to acquire both of Mac's existing folios. He appears at this stage of his career to have mastered nearly every technical skill and gimmick Finlay ever knew, and added to them a sensibility uniquely his own; he misses occasionally but not often. (I think he leans a little heavily on photographs.) On my office wall as I type are 15 pieces of artwork: 2 beloved Jack Gaughans, a DiFate, a Freas, a Feck, and 10 Mac•An•T•Saoirs. His total available output is two folios, each one 20 loose b&w prints in a large manila envelope (he works slow). I don't know if the first one, *Children Of The Night* (1972) is still around; it was a limited edition. You could write to Mac at 310 Queen St. West, Toronto, Ontario M5V 2A1 and ask; I believe the price is up to $5. The second, *Thunder And Roses* (1975), is better than the first, deservedly sells for $10, and can be obtained from either Urisk House, 26 Edmonton Dr., Willowdale, Ontario M2J 3W6 or from Mac•An•T•Saoir himself. Bankers being the joyless souls they are, perhaps checks sent to Mac should be made out to "Robert Macintyre."

If Mac keeps growing at the rate evinced by these two folios (and he seems to be—I hear he's getting into color), we're all going to be hearing more of him by and by.

Nearly as impressive as *Tomorrow And Beyond* is *Space Art,* edited by artist Ron Miller and published by *Starlog* magazine. It is by definition much more restricted in scope than Summers' book: the Starloggers (I picture lumberjacks with pressure helmets) chose to "confine" themselves to nine planets, assorted moons and comets, and one asteroid belt—with small sidetrips into space hardware and the universe at large. The amazing thing is the extent to which the book triumphs over its restricted scope. You would think that when you've seen, for instance, one Saturn you've seen them all. This book contains 22 Saturns, each more beautiful than the last. Among the 77 artists represented (!) are Bonestell (of course), DiFate, Schoenherr, Schomburg, James Wyeth, Whelan, Chris Foss, and—for heaven's sake—author Hal Clement! (I didn't know he could art.) For me the standout discovery was Ludek Pesek, a simply phenomenal talent whose painting of Saturn as seen from within the Ring is alone worth the $7.95 this book will set you back.

Some of the 77 artists, of course, are lightweights or outright duds (outright but in-left, if you follow, and I don't know why you should)—and that minor quibble underlines my only major quibble: it seems to me no book of astronomicals can be taken seriously without at least *one* Rick Sternbach painting—if not half a dozen. I can't properly come down on Miller for that: for all I know he *tried* to get Sternbachs, and failed for any number of honorable reasons. But one Sternbach would have been worth a dozen of some of these other turkeys. (Other minor quibble: nothing by the excellent and reknowned former NASA artist Nicholas J. Sokcevic—a fellow Nova Scotian and refugee from the United Snakes.)

Still, this book is definitely the most pawed item on my coffee table (*Tomorrow And Beyond* only just arrived today), since I got up, I mean, and I recommend it most highly. I'll be browsing through it for story-inspiration for years to come. And $7.95 is dirt cheap for an art book these days. Apply to O'Quinn Studios Inc., 475 Park Ave. South, New York NY 10016.

But I'm *damned* if I can understand why its cover logo loudly mislabels it a "Photo Guidebook."

Oh no. I'm running out of space. And no discussion of contemporary fantasy art would be complete without mentioning *The Magic Goes Away,* a landmark event in that genre, the first time so far that interior illustrations have actually succeeded in vastly enhancing a story (which happened to be terrific in the first place.) Esteban Maroto's drawings are wonderful beyond belief, each and every one (there are *hundreds*), and it is a public sin that Boris Vallejo got top billing over him for supplying one of his visually striking but essentially mindless covers (the scabbard hangs on the same side as the swordarm. Maybe Vallejo thought it was, like, a holster?) Those of you sensible enough to want a copy that will last through repeated readings and porings, Ace will sell you a hardcover, on excellent paper, in a limited 1000-copy edition signed by Larry Niven, for $13.95—which you can see by comparing with De La Ree's prices is a *hell* of a bargain.

Both as art and as story (though I have some minor quibbles with the ending) *The Magic Goes Away* will be remembered in years to come as a genuine milestone, the one that opened the door for some of the best books ever printed.

Oh Christ, here they come with my medication. You see what I mean? I have *ten pages* more left to say. Quickly then, dammit: on no account fail to buy these four books.

Dreamsnake, Vonda N. McIntyre—as Orson Scott Card said in a demonically perceptive review elsewhere, this is the most successful feminist sf novel *precisely* because it ignores feminism, creates a believable world where sex-discrimination and sex-differentiation just don't exist, and tells a damn good story in it. This book, which begins with the Nebula-winning novelette "Of Mist, Grass And Sand," is perhaps the best new novel I've read all year.

The Door Into Fire, Diane Duane, runner-up for that last title—and it's a *first novel!* A first anything for this David Gerrold discovery, who deserves the 1980 John W. Campbell Award For Best New Writer on the strength of it. She too has written a world where gender is not role: her two heroes are lovers, for example (of each other, I mean). This is the most original and creative sword and sorcery novel I have ever seen, slightly flawed and the more lovable for it. Diane's evocative descriptions of the actual mechanics of spell-casting are unique and marvelous, her characterizations excellent, her insights mature and her resolutions trenchant. Oh, and her jokes are funny. I tend to hate s&s on sight (*Magic Goes Away* and *The Princess Bride* are the only two exceptions I can think of) but this was a treat. A sequel is in the works, and eagerly awaited.

And Having Writ . . . , by old-hand editor/author Donald R. Bensen: an alternate universe story in which the Tunguska Crater never happened—they managed to decelerate and land safely! And then tried to tamper further with history . . . Written with enormous inventiveness, historical acumen, deft skill and mordant satiric wit—a clichéd moral, but lots of fun getting there.

Capitol, Orson Scott Card, a first-collection of stories with a common background-world, from the most recent (1978) winner of the Campbell

Award. Stories range from good to very good—no superbs or excellents, but no poors or pigs either. Card shows (to corn a phrase) tremendous potential; I have a suspicion he's a shade too prolific at present.

One last spasm: anyone wishing one-hour cassette interviews, competently produced and professionally packaged, with such sf writers as Leiber, Kurtz, Garrett, Bradley, Benford, Moore and others (I've lost the damn press release in this heap) are advised to send a list of their wishes and $4.98 apiece to Hourglass Productions, 10292 Westminster Ave., Garden Grove CA 92643. Editors Bob and Mary Drayer will be happy to send you a free catalog on request. All the interview*ers* are writers, some well-known, some not so well known. Sound quality is as good as you can expect from field recording not done on a Nagra, and the authors are informative and entertaining (I have heard the first four above-mentioned).

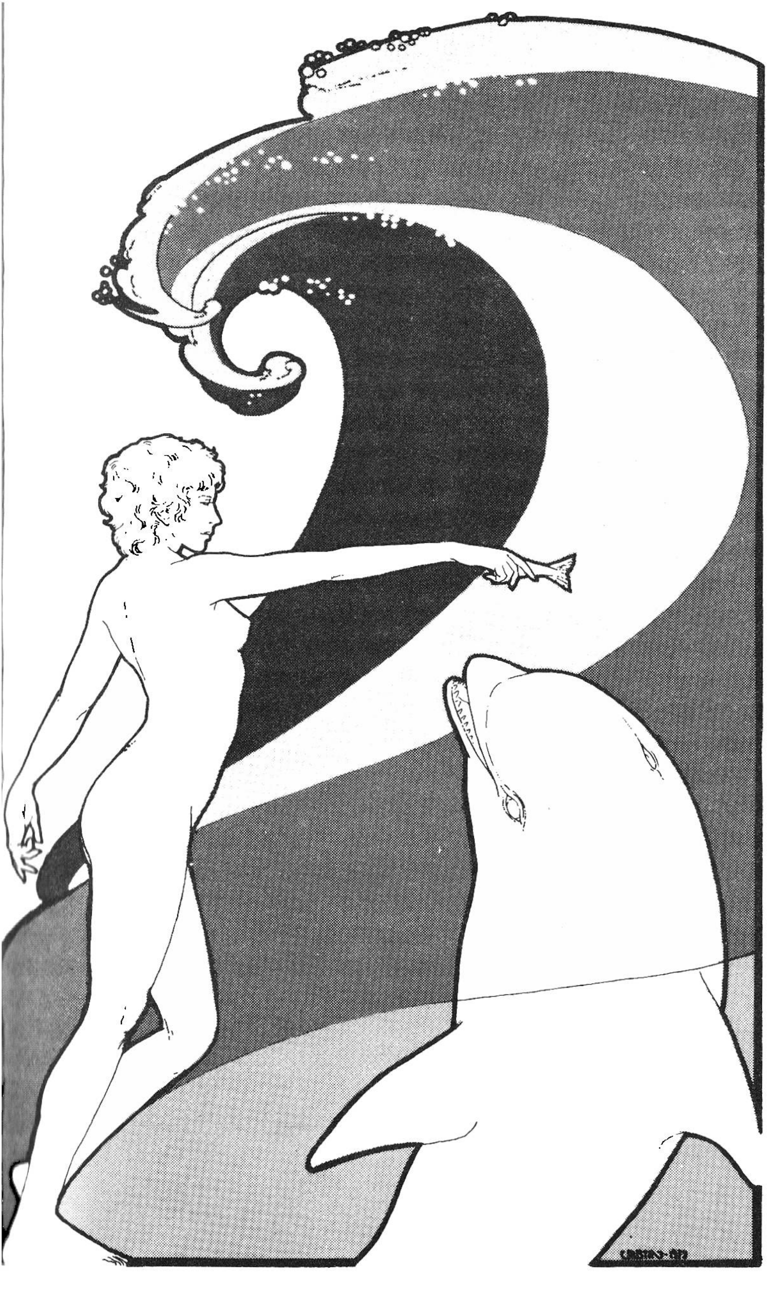
Gosh. Only left out two dozen good books. Better than I expected.

At this point in the vast time-warp between my writing and your reading, mail response is just beginning to trickle in to my first *Destinies* column. (To save even further message-lag, write to me directly at 1061 Wellington St. #6, Halifax, Nova Scotia B3H 3A1.) It's gratifying, but I predict it won't be a flood of enthusiastic response until the *second* column sees print.

After all, it took Samson two columns to bring down the house. ●

LIQUID ASSETS

BY DEAN ING



Illustrated by Alicia Austin

The ocean has never been a forgiving environment...

Because she'd had an exhausting week training a young bottlenose, Vicki Lorenz dallied in her bungalow over the standard Queensland breakfast of steak and eggs. And because it was Saturday, the Aussie marine biologists had trooped off to Cooktown, leaving Cape Melville Station to her for the weekend. Or maybe they just wanted to avoid her fellow Americans scheduled to fly in; she couldn't blame them for that. She did not know or care why a research site near the nor-east tip of Australia had attracted visiting honchos.

Though it was midmorning in September, the sun had not yet forced its way through the pile of cumulus that loomed eastward over the Barrier Reef like the portent of a wet summer. She chose her best short-sleeved yellow blouse as concession to her visitors, and faded denim shorts as refusal to concede too much. She flinched when the sun searchlighted through her bedroom window to splash her reflection in the full-length mirror. Short curls, intimidated toward platinum by tropical summers, complemented the blouse, bright against her burnt-bronze skin. In two years, she thought, she'd be as old as Jack Benny, and her deceptive youthful epidermis would begin its slow sea change into something like shark leather. She tucked the blouse in, assessing the compact torso and long thighs that gave her a passable, if angular, figure with less than average height. It would do, she thought. If Korff had liked it so much, it had to be in good taste.

Against her will, her eyes searched out the curling poster she had tacked against the bedroom wall two years ago, after Korff's boat had been found. Sunlight glinted off the slick paper so that she saw only part of the vast greenish tube of a surfer's dreamwave which some photographer had imprisoned on film. At the lower left was a reprinted fragment from Alec Korff's *'Mariner Adrift'*:

> *The wave is measured cadence*
> *In the ocean's ancient songs*
> *Of pélagic indifference*
> *To mankind's rights and wrongs . . .*

And knowing that indifference as well as anyone, he'd made some trifling mistake along the treacherous reef, and it had cost him. Correction: it had cost *her*. Well, no doubt it benefited the reef prowlers. Korff would have been pleased, she thought, to know that his slender body had finally become an offering to the flashing polychrome life among the coral. She turned then, self-conscious in the sliver of light, and made a mocking bow toward the sun. Scuffing into sandals, she padded out to her verandah. It was then that she saw Pope Pius waiting before the sea gate far below, a three-meter torpedo in grey flesh.

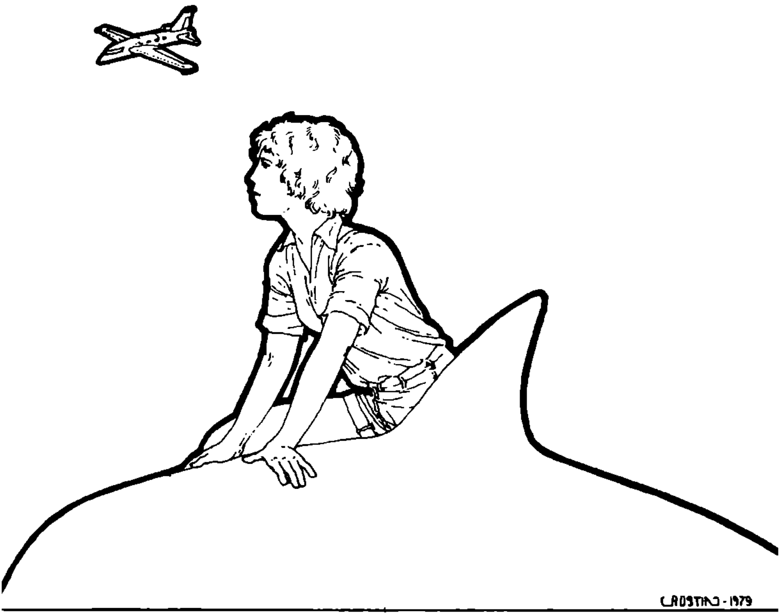
She called his name twice, trotting down the path. She knew it was her old friend Pius even though his identifying scars were below the water's surface. The slender mass of the microcorder, on its harness just ahead of the high dorsal fin, was unmistakable. He heard and greeted her, rearing vertically, the sleek hairless body wavering as tail flukes throbbed below. He was an adult *griseus*, a Risso's dolphin, with exquisite scimitar flippers and a beakless prominent nose that made the name *Pius* inevitable. Inevitable, that is, if you had Korff's sense of the absurd.

Soon she had activated the pneumatics, the stainless grate sliding up to permit free passage from Princess Charlotte Bay into the concrete-rimmed lagoon. She whistled Pius in, whistled again. Then she clicked her tongue and spanked the water to urge him forward. The cetacean merely sidled near the planking outside the sea gate, rolled to view her with one patient eye, and waited.

Vicki sighed and fetched the lightly pickled squid, tossed one of the flaccid morsels just inside the gate. No response—perhaps the slightest show of impatience or wariness as if to say, *I'm jack of it, mate; it's dicey in there.* Except that Pius was cosmopolitan, no more Aussie than he was Japanese or Indonesian. As usual, she tended to append false values to the people of the sea, and then to chide herself for it.

Eventually Vicki went outside the sea gate and knelt on the wood. Pius rolled to assist her, breathing softly to avoid blowhole spray that could soak her with its faint alien rankness. She fed him one small squid, earning a rapid burst of friendly Delphinese complaint at her stinginess, and she knew he would wait for her to return.

The videotape was fully spent. The batteries should be good for another cartridge but Vicki took fresh nicad cells from the lab with a new blank tape cartridge just to be on the safe side. She was hurrying back to Pius when she saw the aircraft dip near. Sure enough, it was one of the Helio Couriers which, everybody knew, meant that the passengers had clout with American cloak-and-dagger people. On the other hand, there'd been a lot of that kind of air traffic in the area for the past fortnight. She was increasingly glad that McEachern and Digby



had gone to Cooktown to get shickered. *Plastered,* she told herself; *must revert to American slang for the day.*

Something seemed to be bothering the big *griseus,* she thought, fumbling to replace the equipment on Pius's backpack. He had never refused to enter the sea gate before. *Don't get shirty,* she thought; *if I'm late it's my bum, not yours.* And because of Pius, she was clearly going to be late. The fact of his early return made the tape important, though. The microcorder operated only when triggered by calls made by Pius himself, and it pinged to remind him of squid when the cartridge was expended. That meant he might return once a month—though he was very early this time. Two years ago it had been once a week, and no one was sure why Pius communicated with his fellows less as time passed. Perhaps he was growing laconic with age, she thought, giving him a pat before she upended the squid bucket.

Pius whirled and took a mouthful of delicacies in one ravening swoop, paused an instant to study Vicki, then seemed to evaporate into the bay, leaving only a roil of salt water in his wake. Water and uneaten squid. *Boy, you must have a heavy date,* she mused. It did not occur to Vicki Lorenz that the big cetacean might be hurrying, not toward, but away from something.

* * *

She wheeled the decrepit Holden sedan onto the taxi strip, chagrined to see that the pilot had already set his chocks and tiedowns. The portly fellow standing with the attache case would be Harriman Rooker, from the cut of his dark suit and the creases in his trousers which might have been aligned by laser. The little weatherbeaten man sitting on the B-four bag, then, had to be Jochen Shuler.

Vicki made breathless apologies. "I had a visitor who wouldn't wait," she smiled. "Dolphins can be a surly lot."

So could State Department men. "At least you make no secret about your priorities, Dr. Lorenz," Rooker said. "It *is* Dr. Victoire Lorenz?" The hand was impeccably manicured, its grip cool and brief, the smile a micron thick.

"I truly am sorry," she said, fighting irritation, and turned toward the smaller man. Shuler wore rumpled khakis and no tie, his voice a calm basso rasp leavened with humor. "Forget it," he said, with a shoulder pat that was somehow not patronizing. "It's not as if we were perishable."

The imp of extravagance made her say it: "Everybody's perishable in tropical salt. You come here all bright and shiny, but you leave all sheit and briny." Shuler's control was excellent; his wiry frame shook silently but he only put his head down and grinned. Rooker was plainly not amused. Well, at least she could relate to one of them.

The pilot, Rooker explained, was prepared to stay and take care of the Courier. He looked as though he could do it, all right. The bulge in his jacket was no cigarette case. Rooker selected three of his four pieces of luggage for the Holden's boot (*trunk, dammit; trunk,* Vicki scolded herself). One, a locked leather and canvas mail sack, required both men to lift. Shuler lugged his one huge bag into the rear seat. The bag clinked. Perrier water? Booze?

Vicki appointed herself tour guide without thinking and drove along access roads until she was pointing out the salt water pens where young dolphins and other cetaceans were monitored. "We know Delphinese has dialectal differences, just as people and honeybees have local variants of language. We're using recorders to identify various subspecies by sonic signatures. I've made friends with a big Risso's dolphin that roams around loose with a video recorder, sort of a linguistic shill. Maybe we can get some idea whether a *grampus orca,* a killer whale, sweet-talks a little *tursiops* before he swallows it. Generally, larger species communicate in lower frequencies—." She broke off, glancing at Harriman Rooker who sat erect beside her, his right arm lying precisely along the windowframe. *Straightens pictures,* she guessed. His left hand was in his lap and—inexcusable for a trained observer—Vicki realized only then that a wrist manacle bound the man to his equipment. She pulled to a stop, killed the engine. "You didn't come here for a tour," she accused. With sudden intuition, she did not want to know why they had come.

Rooker's pale eyes swept her face, hawk-bright, unblinking. "No," he agreed. "We are here for an exchange of information—and other valuables. A matter of the most extreme urgency, Dr. Lorenz."

"Vicki, please," she urged with her most engaging smile.

"If I must. I suggest that *you* tell *us* what our next move should be."

She searched the implacable features, puzzled, then faintly irked. She felt as if she had been thrust into the middle of a conversation she hadn't been listening to. "Well, you could try telling me what information you need, and why the urgency."

He stared until she grew positively uneasy. And that made her, unaccountably, angry. Then, "Tell us about Agung Bondjol," he said. Softly, but cold, cold.

"Uh. A kid from Djakarta, wasn't he? Right; he was with that Wisconsin senator on the *R. L. Carson* when she sank a few hundred miles south of here last month. One of the four people lost."

From the back seat: "Some kid."

"Thank you, Jo," Rooker said quickly, in that'll-be-enough tones. "Nothing more, Dr.—Vicki?"

"If there was, I didn't read it. I don't pay much attention to the news on any medium, you know."

"Apparently. Now tell us about Alec Korff." The transition was verbally smooth, but for Vicki it was viciously abrupt.

She took a deep breath. "Poet first, I suppose; that's how he liked it. And because he could be acclaimed at that and starve at the same time, he made his living as a tooling engineer.

"Korff got interested in interspecies communication between cetaceans and humans; his mystic side, I guess. He didn't give two whoops about explicit messages. Just the emotional parts."

Low, but sharp: "You're sure of that?"

Long pause, as Vicki studied the sea for solace. Then she said, "Certain as one person can be of another. He once said that the truth is built from gestures, but words are the lumber of lies. He hated phonies and loved cetaceans.

"You know, of course, that I lived with Korff. Met him while I was getting my doctorate at Woods Hole and he was designing equipment for whales and dolphins. Prosthetic hands they could work with flipper phalanges, underwater vocoders, that sort of thing. When I landed the job here, he came with me."

She waited for Rooker to respond. When he did not, she sighed, "Korff was happy here. I knew when he was really contented because he'd compose doggerel on serious topics and laugh his arse off about it. Hiding his pearls like a swine, he said. Everybody's heard *"Mariner Adrift"*, but did you ever hear *"Fourteen Thousand Pounds Of God"?* Pompous *and* self-deprecating, and hides a great truth right out in the open.

'The orca's fangéd dignity
Fills me with humility.
One is wise to genuflect
To seven tons of self-respect.'

The killer whale doesn't really have fangs, of course. Just teeth a tyrannosaur would envy. Korff knew that. He knew a hell of a lot about cetaceans."

Still no response. Rooker was not going to let her off the hook. "And two years come November," she recited quickly, fingernails biting her palms, "Korff took his goddam sloop along the goddam Barrier Reef and caught a goddam tradewind squall or something and goddammit, *drowned!* Is that what you wanted to hear?"

"Quite the contrary," Rooker said, still watching her.

Instantly she was out of the car. "I don't know why I let the consulate talk me into this pig-in-a-poke hostess job on my own time, and now it's become cat-and-mouse insinuation, and I won't have it! If you know anything, you know how I felt about Korff and—and you can go piss up a rope, mate," she stormed. She slammed the door so hard the Holden groaned on its shocks.

Halfway to her bungalow afoot, she looked back to see Shuler patiently following. He had a bottle in each hand, so she waited. It seemed a good idea at the time.

Given that they knew her fondness for mezcal, how did they know she couldn't get it locally? Vicki considered many such nuances in the next hour, sitting cross-legged with Jo Shuler while they plastered themselves into a thin film on her verandah. At first he answered nearly as many questions as he asked. She learned that he was detached from the U.S. Mine Defense Labs in Panama City, Florida; an expert in experimental sonar video and no ignoramus on dolphin research either. He had read her papers on cetacean language, but his own papers were classified. He did not elaborate.

Shuler even managed to explain his companion's cryptic manner, after a fashion. It wasn't nice, Vicki decided, but it made sense. "Okay," she said, stifling a belch, "so some nit at Rand Corporation figured Korff was alive and that I knew it. I'm sure he isn't, and if he is, I don't." She shrugged: "You know what I mean. So much for heavy thinkers at Rand."

Shuler regarded her gravely, listing to port a bit. "Why are you so sure?"

"You want it straight?" Why was she so willing to bare these intimacies? Something beyond her normal candor was squeezing her brains. "Okay: Alec Korff had a few leftover sex hangups, and very tough standards, but he was highly sexed. Me, too. My mother hated him for his honesty about it. She was a tiny little thing, always trying to prove something by vamping him. Then one day she phoned—I was on the extension and I don't think either of them knew it. She implied she might fly up to see him alone. Korff suggested she could ride a whiskbroom and save the price of a ticket." She spread her hands wide. "How could I not love a man like that? Anyway, the point is that we clicked. It was like finding the other half of yourself. He played poet for me and I played floozy for him." With a sly grin: "It'd take him years to develop a replacement, I think. Oh yes, he'd have got in touch with me, all righty." She took a mighty swig, remembering. "You can go back to the car and tell Mr. stiff-corset Rooker all about it."

"I bet he's blushing about the corset," Shuler laughed, then looked abashed.

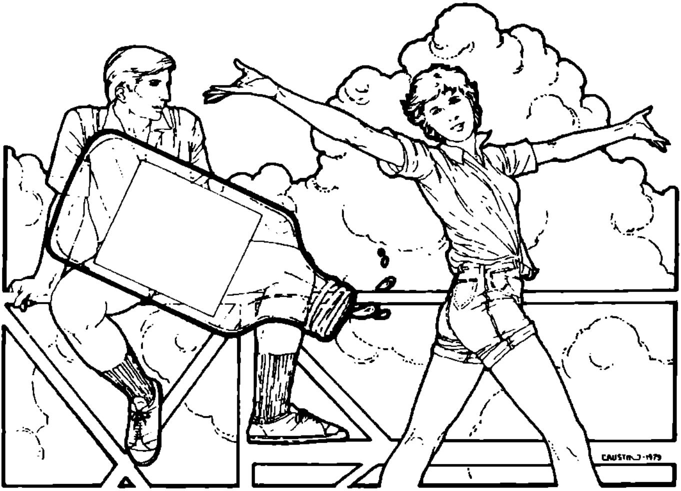
Vicki squinted hard. "You're bugged, aren't you? He's been listening!" She saw guilt, and a touch of truculence, and went on. "You two have been rough-smoothing me, haven't you? He's really the rough and you're really the smooth. How many of my old friends did you bastards interview before I fitted into your computers?" She stared grimly at her bottle; she had consumed over a pint of the stuff and now she had a good idea why Shuler was drinking from another bottle.

"I dunno about that, Vicki, I was briefed just like Rooker was. He's used to representing the government, negotiating with some pretty weird groups. I'm just a technician like you. Lissen, lady, we're hip-deep in hockey—all of us."

She flung the bottle far out over the turf, watched it bounce. "Not me, I feel bonzer."

"You're just high."

"High? I could hunt kookaburra with a croquet



mallet," she boasted, then went down on hands and knees near the immobile Shuler, shouting, "That's a bird, Rooker, you twit!" Then she saw past Shuler's foolish grin, realized that he carried a shoulder holster too, and sat back. "You people scare me. Go away."

"We're scared too," he said, no longer playing the drunk. As though Rooker were standing before them he went on, "She's about to pass out on us, Harriman. Why can't we drop this interrogation farce and accept her at face value? Or d'you have any nasty little questions to add to mine before the drug wears off?"

Australian slang is compost-rich with unspeakable utterance. Vicki Lorenz had heard most of it, and found it useful now. She had not exhausted her repertoire when she began to snore.

Jo Shuler waited for a moment, moved near enough to tap his forefinger against her knee. Snores. "Drive that heap on over here," he said to his signet ring. "She's out. We can put a call through while she sleeps it off. For the record, I say we take a chance on her." Then he managed to carry Vicki inside to the couch, and waited for Harriman Rooker.

* * *

Late afternoon shadows dappled the verandah before Vicki had swept the cobwebs from her mind. To Rooker's apology she replied, "Maybe I could accept those vague insinuations if I knew what's behind them. What's so earth-shaking about that kid, Bondjol?"

"He's small loss in himself," Rooker agreed. "He's a renegade Sufi Moslem—pantheist, denied the concept of evil, embraced drugs to find religious ecstasy, learned he could purchase other ecstasy from the proceeds of his drug-running—tricks that'd get him arrested in Djakarta if he weren't the pampered son of an Indonesian deputy premier."

"I take it a deputy premier's a real honcho."

"Oh, yes; roughly equal to half a vice president for openers. But the elder Bondjol is quite the pivotal figure. He's made it very clear: if the United States wants to keep some leased bases, Bondjol gets his son back."

Vicki considered this. "If you think I can round up a million dolphins and send them out to find the body—forget it. I'm not sure I could even get such complicated messages across in Delphinese—"

"Somebody sure as hell can," Jo Shuler put in.

Rooker: "You still don't understand. Western media haven't broken the story yet, but it's all over Indonesia: Agung Bondjol is alive, sending notes on driftwood—or was, ten days ago. I think you'd better view this tape," he added, patting the attache case.

It took an interminable twenty minutes to locate a compatible playback machine in the lab. The men stood behind Vicki as she sat through the experience. The *R. L. Carson* had been a four-hundred tonner, a small coastal survey vessel inside the great Barrier Reef with Australian permission, under contract to the United States Navy. The vessel carried unusual passengers: the swarthy young Bondjol with two camp followers and Bondjol's host, Wisconsin Senator Distel Mayer. This part of the tape, chuckled Jo Shuler, had been surreptitious film footage saved by a crew member. The good senator had paid more attention to one of Bondjol's young ladies than he had to the wonders of the reef. Thus far it was an old story, a junketeering politician with a foreign guest on a U.S. vessel far from home.

Shuler cut through Vicki's cynical thoughts: "Now you know why Mayer's so helpful in persuading our media to hold the story. The next stuff, I put together at M.D.L. from the ship's recordings. It's computer-enhanced video from experimental sonar equipment."

The scene was panoramic now, a vertical view of sandy bottom and projecting coral heads with preternatural color separation. Visually it seemed as if animation had been projected over a live scene. It was a hell of a research tool, she thought longingly. The audio was a series of clicks and coos, with a descending twitter. Vicki punched the tape to 'hold' and glanced toward the Navy civilian. "Don't ask," Shuler said quickly. "I promise you'll be the first nonmilitary group to get this enhancement rig. It may take a year or two, we're working on better . . ."

"That's not it," she said. "The audio, though: isn't it ours?" She re-ran the last few seconds as Rooker shrugged his ignorance.

"The Great White Father signal," Shuler nodded. "Sure. It's becoming standard procedure for the Navy in such treacherous channels, when they don't mind making the noise. But it won't be any more," he added darkly.

Cape Melville Station had developed two messages in Delphinese that, in themselves, justified every penny spent on research. The first message was a call for help, repeatedly sent by a battery-powered tape loop whenever a modern life jacket was immersed in salt water. During the past year, over a hundred lives had been saved when cetaceans—chiefly the smaller dolphins but in one documented case, a lesser rorqual whale—towed shipwrecked humans to safety. The device had come too late for Korff, though.

The Great White Father signal had a very different effect. It seemed to make nearby cetaceans happy, to provoke playful broachings and aerobatics as though performing for a visiting dignitary. "I hope you don't let whalers get a copy of this," Vicki said ominously. "It was intended as a friendly greeting. The people of the sea are too trusting for their own good."

"Is that a fact," murmured Harriman Rooker, his eyebrows arched. "Roll the tape."

The tape repeated its record, then proceeded as the *Carson* swept over sandy shallows, reef fish darting into coral masses that projected nearly to the hull. Then Vicki saw a thin undulating line of bright brown cross the video screen, rising slightly as the ship approached. Something darted away at the edge of the screen; something else—two somethings, then others, regular brown cylindrical shapes—swerved into view, attached to the brown line like sodden floats on a hawser. One of the cylinders disappeared, suddenly filled the screen, moved away again. Then the varicolored display turned brilliant yellow for an instant.

"Concussion wave," Shuler explained.

Nearby coral masses seemed to roll as the picture returned, hunks of the stuff crumbling away with reef flora and fauna.

Vicki stopped the tape again. "Did the boilers explode?"

"The *Carson* was diesel," said Shuler. "It took us hours to identify those drums and the cable, but there's not much doubt it was some of our old munitions. A mine cable barrier, the kind we used in the Philippines forty years ago. Five hundred pound TNT charges intended against assault boats. We're not sure exactly how it got to Australia, but we're not ruling out your cetaceans, Vicki."

A silent *ahh,* then quick re-runs of the underwater explosion. Vicki's fingers trembled as she flicked the tape to 'hold' again. "Much as I hate to say it," she poked a finger against an ovoid gray blur on the screen, "that could be a cetacean. Big one, maybe a *pseudorca* —false killer whale."

"The sonar says it was live flesh," Shuler responded, "possibly big enough to haul a cable barrier into position."

Vicki drummed her fingers against the screen, then flicked off the display. "Could this be the work of terrorists?"

"I was picked because of modest experience in that arena," Rooker said. "Yes, it obviously *is*. But up 'til now we've counted on human leadership."

"Didn't someone take Bondjol away? You said he was alive."

"We thought you might have some ideas," Rooker said apologetically. "There are thousands of islands to check, and not enough aircraft. We've tried. The witnesses—all citizens of the United States except for Bondjol and his two child concubines—agree on some uncanny points the Indonesians don't know. One: there was a second blast while they were filling the inflatable lifeboats. Perhaps the *Carson* wasn't sinking fast enough?

"In any case, two: almost the moment she went down, every one of the lifeboats was capsized. Not by sharks, in spite of what some of the crew claimed. No one drowned or sustained a shark attack. Two nonswimmers have toothmarks proving they were carried *back* to the lifeboats by dolphins. Distel Mayer himself says he was buffeted, ah, rudely, by something godawfully big and warm. He shipped a bit of water while it was happening, I'm happy to say."

"Same thing happened to most of the crew," Shuler added.

Vicki, to the stoic Shuler: "You think they were being visually identified?"

Rooker: "Don't *you?*"

"Maybe." Vicki stared blindly at the video screen, testing hypotheses, thinking ahead. "But this presupposes that a big group of cetaceans knew exactly whom they were after, and culled him out of a mob. That's—it's not very credible," she said politely.

"We are faced by incredible facts," Rooker agreed. "Of course Bondjol's junket on the *Carson* was previously announced on Radio Indonesia. And in the non-Moslem press, his picture is better known than his father would like."

Vicki was tempted to offer acid comment on pelagic mammals with radios and bifocals, then recalled that Pius had a video recorder of the latest kind. She tried another last-ditch devil's advocacy: "What proof do you have that Bondjol didn't drown?"

Jo Shuler moved to retrieve the classified tape from her. "Show her the glossies, Harriman." Then, as Rooker exchanged items in his tricky attache case, Shuler went on, "Out of fifty-six people, four were missing when they got to the mangroves near shore. Three were crewmen. They were found in the *Carson* when drivers retrieved the ship recordings. Bondjol wasn't found. Nobody saw him go under, or knows how he was taken away. But if you can believe our Indonesian friends, here's what was tossed from the sea into a little patrol boat off Surabaya a week later when everybody figured young Bondjol was only a bad memory." He flicked a thumb toward the photographs that Rooker held.

The first three photographs showed a scrap of metal, roughly torn from a larger sheet. It looked as though it had been subjected to salt corrosion, then roughly scrubbed, before someone covered it with cryptic marks. Vicki took a guess: "Malayan?"

"Bahasa, the official Indonesian language," said Rooker. "Roughly translated, 'Saved from American plot by whales. I am on island in sight of land, but sharks cruise shoreline. Living on coconut milk and fish that come ashore, I am, et cetera, Agung Bondjol, son of et cetera, et cetera.' I hardly need add that there was no American plot that we know of."

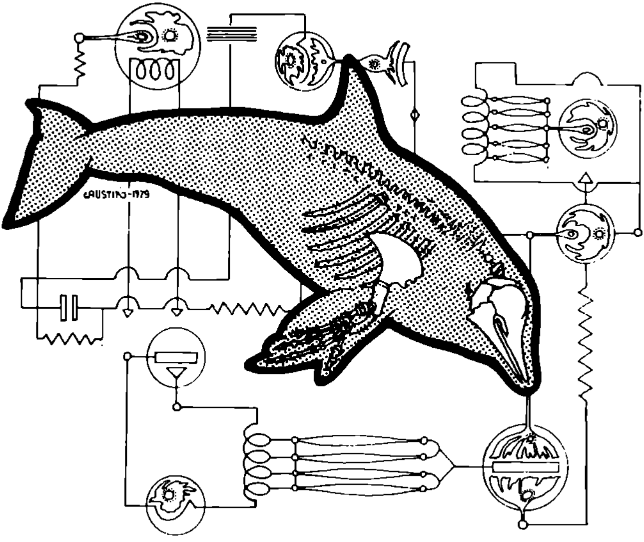
She ignored his faint stress on his last four words. "I'll bet there aren't any sharks around, either. Some dolphin dorsal fins look awfully suspicious to most people." In spite of herself, she was beginning to accept this awesome scenario. "Dolphins often scare whole schools of fish ashore, right here in Queensland. The aboriginals divide the catch with them, believe it or not."

Silent nods. She turned her attention to the other glossies, fore and obverse views of a second metal fragment. It looked much like the first one, except for a pattern of dots and lines incised on the obverse side, and Vicki admitted as much.

"The jagged edges appear to fit together," Rooker said, using a finger to trace torn and evidently matching sides of the metal sheets. "This piece showed up a week ago. Poor little rich boy: 'Third day, sick of fish and coconuts; small whales will not let me swim. Death to evil Senator Mayer and American imperialists responsible. Finder please remit to Deputy Premier Bondjol, et cetera, signed Agung Bondjol, ad nausaeum.' At least he seems to be rethinking his ideas about evil," Rooker finished. His eyes held something that could have been cold amusement.

Vicki tapped the last photograph. "How was this one delivered?"

"Thought you'd never ask," Shuler said. "It was literally placed in the hands of a research assistant



near the study pens at Coconut Island, last Saturday. By a bottlenose dolphin."

Vicki could not avoid her yelp. "Oahu? The marine labs?"

"You got it. Halfway across the Pacific at flank speed—maybe just to prove they could do it. The pattern on the back is the simplest code you could imagine: one for 'a', two for 'b', but in binary. Easier to peck it out that way. It reads in clear American English."

As gooseflesh climbed her spine: "Bondjol didn't encode it?"

"No-o *way!* Analysis shows Bondjol scratched his message with sharp coral fragments, but our metal sheet was torn and the obverse incised with some tool. The tool was an alloy of iron, lots of chromium, some manganese, a little selenium—in other words, austenitic stainless steel."

"Now," Rooker put in, "do you see why we wonder about Korff?"

She nodded, letting her cold chills chase one another. More than once, cetaceans wearing Korff's experimental manipulators had escaped the pens —a fact she had mentioned in scholarly papers. "But you're implying a lot of—of subtlety. For one thing, that they've somehow learned much more about human languages than we have about theirs."

"Unless Alec Korff, or someone like him, is behind it," Rooker insisted softly. "He could have two motives: money; politics."

Vicki moved away to the lab's crockery tea service because it gave her hands something to do while she considered these bizarre ideas. The men accepted the strong brew and waited until she met Rooker's gaze. With fresh assurance: "Not big money, because he ran from it. Believe me, I know," she smiled ruefully. "Politics? He didn't want anyone governing anyone, which is why he used to say ours was the least of a hundred evils. No," she said with conviction, "I wish—God, you don't know how I wish—I could believe you. But Korff is—dead. I know it here," she added, placing a small fist near the hard knot just under her heart.

A searching look passed between the men. "She's probably right, you know," Shuler muttered at last.

"So much the worse," said the diplomat. "We are forced to concede the possibility that cetaceans must be classed as hostile, tool-using entities who can interdict us across three-quarters of the globe."

"Oh, surely not hostile," Vicki began, then paused. "All the same, if I were whaling I might seriously consider some less risky line of work.

Starting today. Oh: what was the binary message?"

Rooker's mirth was faint, but it came through. "Assurance that young Bondjol was safe, and a demand for ransom in exchange for his whereabouts."

"What do they demand, a ton of pickled squid?" Vicki was smiling back until she thought of the gradual attenuation of data on the Pius tapes. If cetaceans were getting subtler, they would reveal only what they wanted to reveal. And Pius had behaved strangely—. She strode to the forgotten tape she had taken from Pius that morning, but paused in disbelief as Rooker answered her question.

"They demand ten million Swiss francs, in hundreds. They promised to contact us again, and gave Melville Station's co-ordinates."

In a near-whisper, Vicki Lorenz held up the Pius cartridge between thumb and forefinger. "I have a terrible suspicion," she said, and threaded the tape for playback.

She was right, as she had known she would be. Not only did they see an unshaven Bondjol from the viewpoint of Pius just offshore; they could hear the man's excited cries as he struggled with his dinner. The rest was sunlight filtered through deep water, eerie counterpoint to a long series of flat tones and clicks. Vicki shared unspoken surmise with Shuler as they listened: binary code.

Vicki and Jo Shuler easily programed the lab computer to print out the simple message as Harriman Rooker stood by. There were a few mistakes in syntax, but none in tactics. They would find a red-flagged float, attach the ransom to it, and tow the float into the bay. They would find Bondjol's co-ordinates on the same float, after the ransom was examined.

"I've been going on the assumption that it's counterfeit," Shuler grinned to his companion.

"Unacceptable risk," Harriman Rooker said blandly. "We don't know how much they know. It's marked, all right—but it's real." Shuler's headshake was quietly negative, but Vicki saw something affirmative cross his face.

It was not yet dark. Vicki hurried from the lab and was not surprised to spy a small channel marker buoy bobbing just outside the sea gate, a crimson cloth hanging from its mast.

Vicki drove the Holden to the sea gate with Harriman Rooker while Shuler, in a dinghy, retrieved the buoy. Rooker unlocked the mail bag, shucked it down from the sealed polycarbonate canister, and smiled as Vicki glimpsed the contents. Vicki mentally estimated its weight at a hundred kilos, obviously crammed with more liquid assets than she had ever seen. The clear plastic, evidently, was to show honest intentions. She turned as Jo Shuler, breathing hard from his exertions, approached them from behind. Something in her frozen attitude made Harriman Rooker turn before, silently, they faced the little man holding the big automatic pistol.

Shuler was not pointing it at anyone in particular. A sardonic smile tugged at his mouth as Jo Shuler, staring at the equivalent of nine million dollars in cash, took one long shaky breath. Then he flung the weapon into the dusk, toward the tall grass, as hard as he could. "Let's get this crap onto the buoy," he grunted as the others began to breathe again.

They towed the world's most expensive channel maker into the bay, hurrying back without conversation, half expecting some dark leviathan to swallow them before they reached shore. They had all seen the buoy plunge beneath the surface like a tiny cork float above a muskellunge.

The trio stood very close on the wharf, sharing a sense of common humanity and, a little, of deliverance as they peered across the darkling water. "Don't worry," Vicki said finally. "They'll keep their end of the bargain."

"That's what I was thinking," Jo Shuler replied, "back at the car. I couldn't very well do less."

As though to himself, Rooker murmured, "The most adept seafarers on the globe, and they could have been such an asset. I don't share your optimism, Vicki. Isn't it time you finally gave up on them?"

"I'm more worried about how they intend to use *their* assets," Vicki said softly. "And how they'll raise more money when they want it. Anyway," she said, turning back toward the Holden, "you ask the wrong question. The real question is, have *they* finally given up on *us?*" She wondered now if Korff had outlived his usefulness to the sea people. One thing sure: his surviving work included more than poetry.

Given language, she had said, cetaceans would develop other tools. But given other tools, Korff had argued, they'd develop further linguistically. Since she and Korff had worked to develop cetacean assets at both ends, she knew the argument would never be resolved. But which species would be caught in the middle?

She could almost hear the laughter of Alec Korff.

VEHICLES FOR FUTURE WARS

BY DEAN ING

HIGHER PERFORMANCE...
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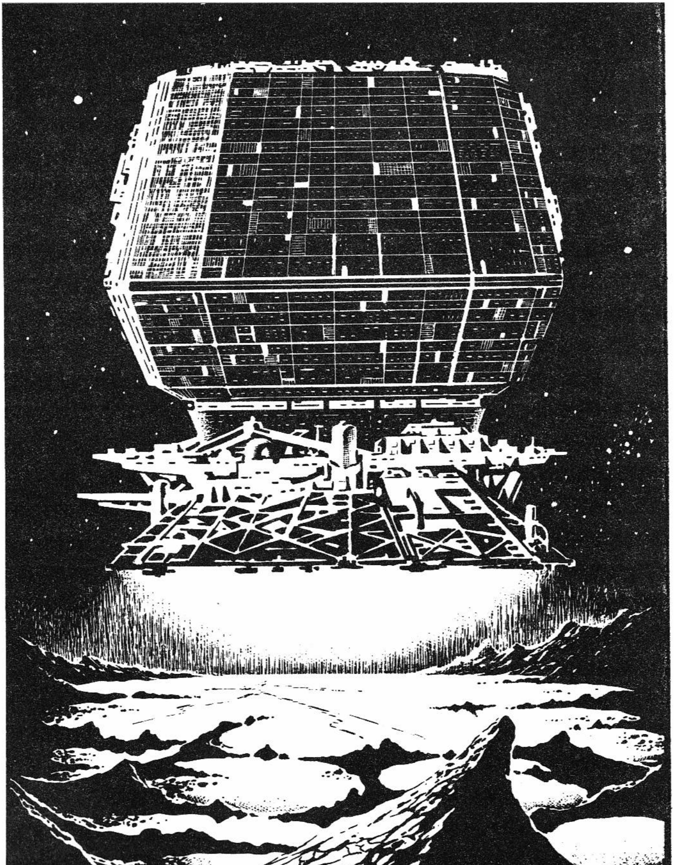


Illustrated by Steve Fabian

Long before the first ram-tipped bireme scuttled across the Aegean, special military vehicles were deciding the outcomes of warfare. If we can judge from the mosaics at Ur, the Mesopotamians drove four-horsepower chariots thundering into battle in 2500 B.C.; and bas-reliefs tell us that some Assyrian genius later refined the design so his rigs could be quickly disassembled for river crossings. In more recent times, some passing strange vehicles have been pressed into military service—Hannibal's alp-roving elephants and six hundred troop-toting Paris taxicabs being two prime examples. Still, people had seen elephants and taxis before; application, not design, was the surprise element. Today, military vehicle design itself is undergoing rapid change in almost all venues: land, sea, air, space. Tomorrow's war chariots are going to be mind-bogglers!

Well, how will military vehicles of the next century differ from today's? Many of the details are imponderable at the moment, but we can make some generalizations that should hold true for the future. And we can hazard specific guesses at the rest.

It's possible to list a few primary considerations for the design of a military vehicle without naming its specific functions. It should have higher performance than previous vehicles; it should be more dependable; and it should be more cost-effective. Those three criteria cover a hundred others including vulnerability, speed, firepower, maintenance, manufacturing, and even the use of critical materials. Any new design that doesn't trade off one of those criteria to meet others is likely to be very, very popular.

It may be fortunate irony for peace lovers that the most militarily advanced countries are those with the biggest problems in cost-effectiveness. Any nation that pours billions into a fleet of undersea missile ships must think twice before junking the whole system—tenders, training programs and all—for something radically different. That's one reason why the U.S. Navy, for example, hasn't already stuffed its latter-generation POLARIS missles (after POSEIDON and TRIDENT, what's next?) into the smaller, faster, more widely dispersed craft. A certain continuity is essential as these costly systems evolve; otherwise, costs escalate like mad.

Still, new systems do get developed, starting from tiny study contracts through feasibility demonstrations to parallel development programs. There is probably a hundred-knot Navy ACV (Air Cushion Vehicle) skating around somewhere with an old POLARIS hidden in her guts, working out the details of a post-TRIDENT weapon delivery system. Even if *we* don't already have one, chances are the Soviets do—and if we can prove that, we'll have one, all righty.

The mere concept of POLARIS-packing ACV's says little about the system design, though. We can do better but, before taking rough cuts at specific new designs, it might be better to look at the power plants and materials that should be popular in the near future.

POWER PLANTS

Internal combustion engines may be with us for another generation, thanks to compact designs and new fuel mixtures. Still, the only reason why absurdly powerful Indianapolis cars don't use turbines now is that the turbine is outlawed by Indy officials: too good, too quiet, too dependable. In other words, the turbine doesn't promise as much drama, sound and fury—perfect reasons for a military vehicle designer to choose the turbine, since he doesn't want drama; he wants a clean mission.

Turbines can be smaller for a given output if they can operate at higher temperatures and higher RPM. Superalloy turbine buckets may be replaced by hyperalloys or cermets. Oiled bearings may be replaced by magnetic types. Automated manufacturing could bring the cost of a turbine power unit down so low that the unit could be replaced at every refueling. In short, it should be possible to design the power plant and fuel tanks as a unit to be mated to the vehicle in moments.

The weapons designer won't be slow to see that high-temperature turbines can lend themselves to MHD (magnetohydrodynamics) application. If a weapon laser needs vast quantities of electrical energy, and if that energy can be taken from a hot stream of ionized gas, then the turbine may become the power source for both the vehicle and its electrical weapons. Early MHD power plants were outrageously heavy, and required rocket propellants to obtain the necessary working temperatures. Yet there are ways to bootstrap a gas stream into conductive plasma, including previously stored electrical energy and seeding the gas stream with chemicals. If the vehicle needs a lot of electrical energy and operates in a chemically active medium—air will do handily—then a turbine or motor-driven impeller of some kind may be with us for a long time to come.

Chemically fueled rockets are made to order for MHD. If the vehicle is to operate in space, an MHD unit could be coupled to a rocket exhaust to power all necessary electrical systems. The problem with chemical rockets, as everybody knows, is their ferocious thirst. If a vehicle is to be very energetic for very long using chemical rockets, it will consist chiefly of propellant tanks. And it will require careful refueling, unless the idea is to junk the craft when its tanks are empty. Refueling with cryogenic propellant—liquid hydrogen and liquid fluorine are good bets from the stored-energy standpoint—tends to be complicated and slow. By the end of this century, rocket-turbine hybrids could be used for vehicles that flit from atmosphere to vacuum and back again. The turbine could use atmospheric oxidizer while the vehicle stores its own in liquid form for use in space. The hybrid makes sense because, when oxidizer is available in the atmosphere, the turbine can use it with reduced propellant expenditure. Besides, the turbine is very dependable and its support equipment relatively cheap.

Some cheap one-shot vehicles, designed to use minimum support facilities, can operate with power plants of simple manufacture. When their backs neared the wall in World War II, the Japanese turned to very simple techniques in producing their piloted "Baka" bomb. It was really a stubby twin-tailed glider, carried aloft by a bomber and released for a solid rocket-powered final dash onto our shipping. The Nazis didn't deliberately opt for suicide aircraft, but they managed something damned close to it with the Bachem "Natter". Bachem hazarded a design that could be produced in under 1,000 man-hours per copy, a manned, disposable flying shotgun featuring rocket ascent and parachute recovery. 'Hazard' was the operative word—or maybe they started with factory seconds. On its only manned ascent, the Natter began to shed parts and eventually blended its pilot with the rest of the wreckage. Yet there was nothing wrong with the basic idea and a nation with low industrial capacity can be expected to gobble up similar cheapies in the future using simple, short-life power plants.

There's reason to suspect that simple air-breathing jet engines such as the Schmidt pulsejet can also operate as ramjets by clever modifications to pulse vanes and duct inlet geometry. In this way, sophisticated design may permit a small have-not nation to produce air-breathing power plants to challenge those of her richer neighbors, in overall utility if not in fuel consumption. A pulsejet develops thrust at rest, and could boost a vehicle to high subsonic velocity where ramjets become efficient. Supersonic ramjets need careful attention to the region just ahead of the duct inlet, where a spike-like cowl produces exactly the right disturbance in the incoming air to make the ramjet efficient at a given speed. A variable-geometry spike greatly improves the efficiency of a ramjet over a wide range of airspeeds, from sonic to Mach five or so. We might even see pulse-ram-rocket tribrids using relatively few moving parts, propelling vehicles from rest at sea level into space and back.

For a nation where cost-effectiveness or material shortages overshadow all else, then, the simplicity of the pulse-ram-rocket could make it popular. A turbine-rocket hybrid would yield better fuel economy, though. The choice might well depend on manufacturing capability; and before you can complain that rockets absolutely demand exacting tolerances in manufacturing, think about strap-on solid rockets.

MHD is another possible power source as we develop more lightweight MHD hardware and learn to use megawatt quantities of electrical energy directly in power plants. An initial jolt from fuel cells or even a short-duration chemical rocket may be needed to start the MHD generator. Once in operation, the MHD unit could use a combination of electron beams and jet fuel to heat incoming air in a duct, and at that point the system could reduce its expenditure of tanked oxidizer. We might suspect that the MHD system would need a trickle of chemical, such as a potassium salt, to boost plasma conductivity especially when the MHD is idling. By the year 2050, MHD design may be so well developed that no chemical seeding of the hot gas would be necessary at all. This development could arise from magnetic pinch effects, or from new materials capable of withstanding very high temperatures for long periods while retaining dielectric properties.

It almost seems that an MHD power plant would be a perpetual motion machine, emplaced in an atmosphere-breathing vehicle that could cruise endlessly. But MHD is an energy-conversion system, converting heat to electricity as the conductive plasma (*i.e.*, the hot gas stream) passes stationary magnets. The vehicle would need its own compact heat generator, perhaps even a closed-loop gaseous uranium fission reactor for large craft. A long-range cruise vehicle could be managed this way, but eventually the reactor would need refueling. Still, it'd be risky to insist that we'll *never* find new sources of energy which would provide MHD power plants capable of almost perpetual operation.

Whether or not MHD justifies the hopes of power plant people, other power sources may prove more compact, lighter, and—at least in operation—

simpler. Take, for example, a kilogram of Californium 254, assuming an orbital manufacturing plant to produce it. This isotope decays fast enough that its heat output is halved after roughly two months; but initially the steady ravening heat output from one kilo of the stuff would be translatable to something like 10,000 horsepower! No matter that a kilo of Californium 254 is, at present, a stupefyingly immense quantity; ways can probably be found to produce it in quantity. Such a compact heat source could power ramjets without fuel tanks, or it could vaporize a working fluid such as water. In essence, the isotope would function as a simple reactor, but without damping rods or other methods of controlling its decay. Like it or not, the stuff would be cooking all the time. Perhaps its best use would be for small, extended-range, upper-atmosphere patrol craft. There's certainly no percentage in letting it sit in storage.

For propulsion in space, several other power plants seem attractive. Early nuclear weapon tests revealed that graphite-covered steel spheres survived a twenty kiloton blast at a distance of ten meters. The Orion project grew from this datum, and involved nothing less in concept than a series of nukes detonated behind the baseplate of a large vehicle. As originally designed by Ted Taylor and Freeman Dyson, such a craft could be launched from the ground, but environmentalists quake at the very idea. The notion is not at all farfetched from an engineering standpoint and might yet be used to power city-sized space dreadnaughts of the next century if we utterly fail to perfect more efficient methods of converting matter into energy. Incidentally, the intermittent explosion rocket drive was tested by Orion people, using conventional explosives in scale models. Wernher von Braun was evidently unimpressed with the project until he saw films of a model in flight.

This kind of experiment goes back at least as far as Goddard, who tested solid-propellant repeater rockets before turning to his beloved, persnickety, high-impulse liquid fuels. No engineer doubts there'll be lots of glitches between a small model using conventional explosives, and a megaton-sized version cruising through space by means of nuke blasts. But it probably will work, and God knows it doesn't have a whole slew of moving parts. Structurally, in fact, it may be a more robust solution for space dreadnaughts than are some other solutions. It seems more elegant to draw electrical power from the sun to move your space dreadnaught, for instance—until we realize that the solar cell arrays would be many square kilometers in area. Any hefty acceleration with those gossamer elements in place would require quintupling the craft's weight to keep the arrays from buckling during maneuvers. The added weight would be concentrated in the solar array structure and its interface with the rest of the craft.

On the other hand, there's something to be said for any system that draws its power from an inexhaustible source—and the Orion system falls short in that department since it must carry its nukes with it. The mass driver is something else again. It can use a nearby star for power, though it must be supplied with some mass to drive. Lucky for dwellers of this particular star system: we can always filch a few megatons of mass from the asteroid belt.

The mass driver unit is fairly simple in principle. It uses magnetic coils to hurl small masses away at high speed, producing thrust against the coils. Gerard O'Neill has demonstrated working models of the mass driver. In space, a mass driver could be powered by a solar array or a closed-cycle reactor, and its power consumption would not be prohibitively high. The thrust of the device is modest—too low for planetary liftoff as currently described. Its use in an atmosphere would be limited, power source aside, by aerodynamic shock waves generated by the mass accelerated to hypersonic velocity within the acceleration coils.

For fuel mass, O'Neill suggests munching bits from a handy asteroid—though almost any available mass would do. The mass need not be magnetic since it can be accelerated in metal containers, then allowed to continue while the metal 'buckets' are decelerated for re-use.

In case you're not already ahead of me, notice that the mass driver offers a solution to the problem of 'space junk' that already litters orbital pathways. The mass-driver craft can schlep around until it locates some hardware nobody values anymore, dice and compact it into slugs, feed it into the mass driver buckets, and hurl the compacted slugs away during its next maneuver. Of course, the craft's computer will have to keep tabs on whatever is in line with the ejected masses, since the slugs will be potentially as destructive as meteorites as they flee the scene. Imagine being whacked by a ten-kilogram hunk of compacted aluminum garbage moving at escape velocity!

Solar plasma, the stream of ionized particles radiated by stars, has been suggested as a 'solar wind' to be tapped by vast gossamer sails attached to a space vehicle—with the pressure of light radiation adding to the gentle 'wind'. Carl Wiley, writing as 'Russell Saunders', outlined the space windjammer proposal in 1951. His sail was envisioned as a parachute-like arrangement of approximately hemispherical shape, made of lithium, many square kilometers in area. Wiley argued that, while such a craft could hardly survive any environment but space, it could be made to revolve with its sail as it circles a planetary mass. By presenting a profile view of the sail as it swings toward the sun, and the full circular view as it swings away again, the craft could gradually build up enough velocity to escape the planet entirely. Even granting this scheme a sail which can be quickly deflated or rearranged into windsock proportions, it seems unlikely that a starsailer could move very effectively into a solar wind in the same way that a boat tacks upwind. The interstellar yachtsman has an advantage, though: he can predict the sources of his winds. He cannot be sure they won't vary in intensity, though; which leads to scenarios of craft becalmed between several stars until one star burns out, or becomes a nova.

It takes a very broad brush to paint a military operation of such scale that solar sails and mass drivers would be popular as power plants. These prime movers are very cost-effective, but they need a lot of time to traverse a lot of space. By the time we have military missions beyond Pluto, we may also have devices which convert matter completely into photons, yielding a photon light drive. In the meantime, nuclear reactors can provide enough heat to vaporize fuel mass for high-thrust power plants in space. So far as we know, the ultimate space drive would use impinging streams of matter and antimatter in a thrust chamber. This is perhaps the most distant of far-out power plants, and presumes that we can learn to make antimatter do as we say. Until recently, there was grave doubt that any particle of antimatter could be stable within our continuum. That doubt seems to be fading quickly, according to reports from Geneva. Antiprotons have been maintained in circular paths for over eighty hours. The demonstration required a nearly perfect vacuum, since any contact between antimatter and normal matter means instant apocalypse for both particles. And as the particles are mutually annihilated, they are converted totally into energy. We aren't talking about your workaday one or two percent conversion typical of nuclear weapon, understand: total means *total.* A vehicle using an antimatter drive would be able to squander energy in classic military fashion!

The power plants we've discussed so far all lend themselves to aircraft and spacecraft. Different performance standards apply to land—and water-based vehicles, which must operate quietly, without lethal effluents, and slowly at least during docking stages. Turbines can be quiet, but they produce strong infrared signatures and they use a lot of fuel, limiting their range somewhat. When you cannot be quick, you are wise to be inconspicuous. This suggests that electric motors might power wheeled transports in the near future, drawing power from lightweight storage batteries or fuel cells. The fuel cell oxidizes fuel to obtain current, but the process generates far less waste heat than a turbine does. The fuel cell also permits fast refueling—with a hydride, or perhaps hydrogen—which gives the fuel cell a strong advantage over conventional batteries. However, remember that the fuel cell 'burns' fuel. No fair powering a moonrover or a submarine by fuel cells without an oxidizer supply on board.

When weight is not a crucial consideration, the designer can opt for heavier power plants that have special advantages. The flywheel is one method of storing energy without generating much heat as that energy is tapped. A flywheel can be linked to a turbine or other drive unit to provide a hybrid engine. For brief periods when a minimal infrared signature is crucial, the vehicle could operate entirely off the flywheel. Fuel cells and electric motors could replace the turbine in this hybrid system. Very large cargo vehicles might employ reactors; but the waste heat of a turbine, reactor, or other heat engine is always a disadvantage when heat-seeking missles are lurking near. It's likely that military cargo vehicles will evolve toward sophisticated hybrid power plants that employ heat engines in low-vulnerability areas, switching to flywheel, beamed power, or other stored-energy systems producing little heat when danger is near. As weapons become more sophisticated, there may be literally almost no place far from danger—which implies development of hybrid power plants using low-emission fuel cells and flywheels for wheeled vehicles.

MATERIALS

Perhaps the most direct way to improve a vehicle's overall performance is to increase its payload fraction, *i.e.,* the proportion of the system's gross weight that's devoted to payload. If a given craft can be built with lighter materials, or using more energetic material for fuel, that craft can carry more cargo and/or can carry it farther, faster.

Many solids, including metals, are crystalline masses. Entire journals are devoted to the study of crystal growth because, among other things, the alignment and size of crystals in a material profoundly affect that material's strength. Superalloys in turbine blades have complex crystalline structures, being composed of such combinations as cobalt, chromium, tungsten, tantalum, carbon, and refractory metal carbides. These materials may lead to hyperalloys capable of sustaining the thermal shock of a nuke at close range.

As we've already noted, graphite-coated steel objects have shown some capacity to survive a nuke at close quarters. There may be no alloy quite as good as the old standby, graphite, especially when we note that graphite is both far cheaper and lighter in weight. Superalloys aren't the easiest things to machine, either. Anybody who's paid to have superalloy parts machined risked cardiac arrest when he saw the bill. Graphite is a cinch to machine; hell, it even lubricates itself.

More conventional alloys of steel, aluminum, and titanium may be around for a long time, with tempering and alloying processes doubling the present tensile strengths. When we begin processing materials in space, it may be possible to grow endless crystals which can be spun into filament bundles. A metal or quartz cable of such stuff may have tensile strength in excess of a million pounds per square inch. For that matter, we might grow doped crystals in special shapes to exacting tolerances, which could lead to turbine blades and lenses vastly superior to anything we have today. Until fairly recently, quartz cable had a built-in limitation at the point where the cable was attached to other structural members. Steel cable terminals can simply be swaged—squeezed—over a steel cable, but quartz can't take the shear forces; you can cut through quartz cable with a pocketknife. This problem is being solved by adhesive potting of the quartz cable end into specially formed metal terminals. Your correspondent was crushed to find himself a few months behind the guy who applied for the first patents in this area. The breakthrough takes on more importance when we consider the advantages of cheap dielectric cable with high flexibility and extremely high tensile strength at a fraction of the weight of comparable steel cable. Very large structures of the future are likely to employ quartz cable tension members with abrasion-resistant coatings.

Vehicles are bound to make more use of composite materials as processing gets more sophisticated. Fiberglass is a composite of glass fibers in a resin matrix; but sandwich materials are composites too. A wide variety of materials can be formed into honeycomb structures to gain great stiffness-to-weight characteristics. An air-breathing hypersonic craft might employ molybdenum honeycomb facing a hyperalloy inner skin forming an exhaust duct. The honeycomb could be cooled by ducting relatively cool gas through it. On the other side of the honeycomb might be the craft's outer skin; say, a composite of graphite and high-temperature polymer. Advanced sandwich composites are already in use, and show dramatic savings in vehicle weight. The possible combinations in advanced sandwich composites are almost infinite, with various layers tailored to a given chemical, structural, or electrical characteristic. Thirteen years ago, an experimental car bumper used a composite of stainless steel meshes between layers of glass and polymer to combine lightness with high impact resistance. A racing car under test that year had a dry weight of just 540 lb., thanks to a chassis built up from sandwich composite with a paper honeycomb core. The writer can vouch for the superior impact and abrasion resistance of this superlight stuff, which was all that separated his rump from macadam when the little car's rear suspension went gaga during a test drive. The vehicle skated out of a corner and spun for a hundred meters on its chassis pan before coming to rest. The polymer surface of the pan was scratched up a bit, yet there was no structural damage whatever. But we considered installing a porta-potty for the next driver . . .

Today, some aircraft use aluminum mesh in skins of epoxy and graphite fiber. The next composite might be titanium mesh between layers of boron fiber in a silicone polymer matrix. The chief limitation of composites seems to be the adhesives that bond the various materials together. It may be a long time before we develop a glue that won't char, peel, or embrittle when subjected to temperature variations of hypersonic aircraft. The problem partly explains the metallurgists's interest in welding dissimilar metals. If we can find suitable combinations of inert atmosphere, alloying, and electrical welding techniques, we can simply (translation: not so simply) lay a metal honeycomb against dissimilar metal surfaces and zap them all into a single piece.

Several fibers are competing for primacy in the search for better composites; among them boron, graphite acetal homopolymer, and aramid polymers. Boron may get the nod for structures that need to be superlight without a very high temperature requirement, but graphite looks like the best bet in elevated temperature regimes. Sandia Laboratories has ginned up a system to test graphite specimens for short-term high temperature phenomena including fatigue, creed, and stress-rupture. The specimens are tested at very high heating rates. It's easy to use the report of this test rig as a springboard for guessing games. Will it test only graphite? Very high heating rates might mean they're testing leading edges intended to survive vertical re-entry at orbital speeds. Then again, there's a problem with the heat generated when an antitank projectile piles into a piece of Soviet armor. Do we have materials that can punch through before melting into vapor? And let's not forget armor intended to stand up for a reasonable time against a power laser. For several reasons, and outstanding heat conductivity is only one of them, graphite looks good to this guesser. If the Sandia systems isn't looking into laser armor, something like it almost certainly will be—and soon.

Before leaving the topic of materials, let's pause to note research into jet fuels. A gallon of JP-4 stores roughly 110,000 Btu. Some new fuels pack an additional 65,000 Btu into a gallon. Even if the new fuels are slightly heavier, the fuel tank can be smaller. The result is extended range. It seems reasonable to guess that JP-50, when it comes along, will double the energy storage of JP-4.

VEHICLE CONFIGURATIONS

Now that we're in an age of microminiaturization, we have a new problem in defining a vehicle. We might all agree that a vehicle carries something, but start wrangling over just how small the 'something' might be. An incendiary bullet carries a tiny blazing chemical payload; but does that make the bullet a vehicle? In the strictest sense, probably yes. But a bullet is obviously not a limiting case—leaving that potential pun unspent—when very potent things of almost *no* mass can be carried by vehicles of insect size.

Payloads of very small vehicles could be stored information, or might be a few micrograms of botulism or plutonium, perhaps even earmarked for a specific human target. Ruling out live bats and insects as carriers, since they are normally pretty slapdash in choosing the right target among possibly hundreds of opportunities, we could develop extremely small rotary-winged craft and smarten them with really stupendous amounts of programming without exceeding a few milligrams of total mass. A swarm of these inconspicuous mites would be expensive to produce, but just may be the ultimate use for 'clean room' technology in which the U.S. has a temporary lead.

The mites would be limited in range and top speed, so that a hypersonic carrier vehicle might be needed to bring them within range of the target like a greyhound with plague fleas. The carrier would then slow to disgorge its electromechanical parasites. One immediately sees visions of filters to stop them; and special antifilter mites to punch holes in the filters; and sensors to detect antifilter mite action; and so on.

It's hard to say just how small the mites could be after a hundred years of development. One likely generalization is that the smaller the payload, the longer the delay before the payload's effect will be felt. Take the examples of plutonium or botulism: a human victim of either payload can continue performing his duties for a longer time—call it mean time before failure—if he is victimized by a tinier chunk of poison. Some canny theorists will be chortling, about now, at the vision of a billion mites slowly building a grapefruit-sized mass of plutonium in some enemy bunker. That's one option, for sure. But the blast, once critical mass is reached, would be ludicrously small when compared with other nuke mechanisms.

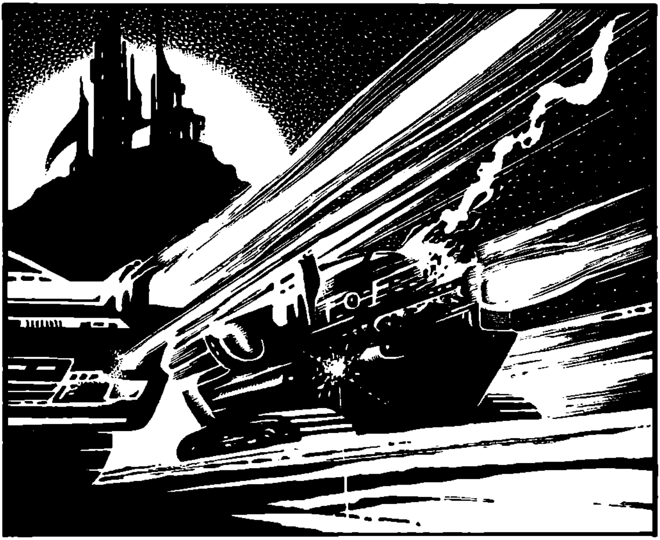
The best use of mites might be as spies, storing data while hunkered down in an inconspicuous corner of the enemy's war room, scaring the bejeezus out of the local spiders. Or would the enemy's spiders, too, be creatures of the clean room? Pick your own scenario . . .

There is no very compelling reason why mites couldn't actually resemble tiny flies, with gimbaled ornithopter wings to permit hovering or fairly rapid motion in any direction. There may be a severe limitation to their absolute top speed in air, depending on the power plant. Partly because of square/cube law problems, a mite could be seriously impeded by high winds or rain. A device weighing a few milligrams or less would have the devil's own time beating into a strong headwind. Perhaps a piezoelectrically driven vibrator could power the tiny craft; that might be simpler than a turbine and tougher to detect. Whatever powers the mite, it would probably not result in cruise speeds over a hundred miles an hour unless an antimatter drive is somehow shoehorned into the chassis. Even with this velocity limitation, though, the mites could probably maneuver much more quickly than their organic counterparts—which brings up a second dichotomy in vehicles.

Information storage is constantly making inroads into the need for human pilots, as the Soviets proved in their unmanned lunar missions. A military vehicle that must carry life-support equipment for anything as delicate as live meat, is at a distinct disadvantage versus a similar craft that can turn and stop at hundreds of g's. Given a human cargo, vehicle life-support systems may develop to a point where bloodstreams are temporarily thickened, passengers are quick-frozen and (presumably) harmlessly thawed, or some kind of null-inertia package is maintained to keep the passenger comfortable under five-hundred-gravity angular acceleration. During the trip, it's a good bet that the vehicle would be under computer guidance, unless the mission is amenable to very limited acceleration. It also seems likely that women can survive slightly higher acceleration than men—an old s.f. idea with experimental verification from the people at Brooks AFB. Women's primacy in this area may be marginal, but it's evidently true that Wonder Woman can ride a hotter ship than Superman. It's also true that your picket calculator can take a jouncier ride than either of them. In short, there will be increasing pressure to depersonalize military missions, because a person is a tactical millstone in the system.

Possibly the most personalized form of vehicle, and one of the more complex per cubic centimeter, would be one that the soldier wears. Individualized battle armor, grown massive enough to require servomechanical muscles, could be classed as a vehicle for the wearer. The future for massive man-amplifying battle dress doesn't look very bright, though. If the whole system stands ten meters tall it will present an easier target; and if it is merely very dense, it will pose new problems of traction and maneuverability. Just to focus on one engineering facet of the scaled-up bogus android, if the user hurls a grenade with his accustomed arm-swing using an arm extension fifteen feet long, the end of that extension will be moving at roughly Mach 1. Feedback sensors would require tricky adjustment for movement past the trans-sonic region, and every arm-wave could become a thunderclap! The user will have to do some fiendishly intricate re-thinkingwhen he is part of this system—but then, so does a racing driver. Man-amplified battle armor may pass through a certain vogue, just as moats and tanks have done. The power source for this kind of vehicle might be a turbine, until heat-seeking missiles force a change to fuel cells or, for lagniappe, a set of flywheels mounted in different parts of the chassis. The rationale for several prime movers is much the same as for the multi-engined aircraft: you can limp home on a leg and a prayer. Aside from the redundancy feature, mechanical power transmission can be more efficient when the prime mover is near the part it moves. Standing ready for use, a multiflywheel battle dress might even sound formidable, with the slightly varying tones of several million-plus RPM flywheels keening in the wind.

For certain applications including street fighting,



there may be a place for the lowly skateboard. It's a fact that the Soviets have bought pallet loads of the sidewalk surfers, ostensibly to see if they're a useful alternative to mass transit. It's also true that enthusiasts in the U.S. are playing with motorized versions which, taking the craze only a step further, could take a regimental combat team through a city in triple time. But if two of those guys ever collide at top speed while carrying explosives, the result may be one monumental street pizza.

No matter how cheap, dependable, and powerful, a military vehicle must be designed with an eye cocked toward enemy weapons. Nuclear warheads already fit into missiles the size of a stovepipe, and orbital laser-firing satellites are only a few years away. A vehicle that lacks both speed and maneuverability will become an easier target with each passing year. By the end of this century, conventional tanks and very large surface ships would be metaphors of the Maginot Line, expensive fiascos for the users.

The conventional tank, despite its popularity with the Soviets, seems destined for the junk pile. Its great weight limits its speed and maneuverability, and several countries already have antitank missile systems that can be carried by one or two men. Some of these little bolides penetrate all known tank armor and have ranges of several kilometers. Faced with sophisticated multi-stage tank killer missiles, the tank designers have come up with layered armor skirts to disperse the fury of a high-velocity projectile before it reaches the tank's vitals. Not to be outdone, projectile designers have toyed with ultrahigh-velocity projectiles that are boosted almost at the point of impact. It may also be possible to develop alloy projectile tips that won't melt or vaporize until they've punched through the tank's skirt layers. Soon, the tanks may employ antimissile missiles of their own, aimed for very short-range kills against incoming antitank projectiles. This counterpunch system would just about *have* to be automated; no human crew could react fast enough. The actual mechanism by which the counterpunch would deflect or destroy the incoming projectile could be a shaped concussion wave, or a shotgun-like screen of pellets, or both. And it's barely possible that a tank's counterpunch could be a laser that picks off the projectile, though there might not be time to readjust the laser beam for continued impingement on the projectile as it streaks or jitters toward the tank.

Given the huge costs of manufacturing and maintaining a tank, and the piddling costs of supplying infantry with tank-killing hardware, the future of the earthbound battle tank looks bleak. It's wishful thinking to design tanks light enough to be ACV's. Race cars like the Chaparral and the formidable Brabham F 1, using suction for more traction, are highly maneuverable on smooth terrain. Still, they'd be no match for homing projectiles; and with no heavy armor or cargo capacity for a counterpunch system, they'd almost surely be gallant losers.

All this is not to suggest that the tank's missions will be discarded in the future, but those missions will probably be performed by very different craft. We'll take up those vehicles under the guise of scout craft.

More vulnerable than the tank, an aircraft carrier drawing 50,000 tons on the ocean surface is just too easy to find, too sluggish to escape, and too tempting for a nuclear strike. It's more sensible to build many smaller vessels, each capable of handling a few aircraft—a point U.S. strategists are already arguing. Ideally the aircraft would take off and land vertically, as the Hawker Harrier does. Following this strategy, carriers could be spread over many square kilometers of ocean reducing vulnerability of a squadron of aircraft.

A pocket aircraft carrier might draw a few hundred tons while cruising on the surface. Under battle conditions the carrier could become an ACV, its reactor propelling it several hundred kilometers per hour with hovering capability and high maneuverability. Its shape would have to be clean aerodynamically, perhaps with variable-geometry catamaran hulls.

Undersea craft are harder to locate. Radar won't reveal a submerged craft, and sonar—a relatively short-range detection system unless the sea floor is dotted with sensor networks—must deal with the vagaries of ocean currents, and temperature and pressure gradients as well as pelagic animals. There may be a military niche for large submersibles for many years to come, perhaps as mother ships and, as savant Frank Herbert predicted a long time ago, cargo vessels.

A submerged mother ship would be an ideal base for a fleet of small hunter-killer or standoff missile subs. These small craft could run at periscope depth for a thousand miles on fuel cells, possibly doubling their range with jettisonable external hydride tanks. A small sub built largely of composites would not be too heavy to double as an ACV in calm weather, switching from ducted propellers to ducted fans for this high-speed cruise mode. From this, it is only a step to the canard swing-wing craft shown opposite. Schnorkel and communication gear are mounted on the vertical fin, and the sub packs a pair of long-range missiles on her flanks just inside the ACV skirt. The filament-wound crew pod could detach for emergency flotation. High-speed ACV cruise mode might limit its range to a few hundred kilometers. The swing wings are strictly for a supersonic dash at low altitude, using ducted fan and perhaps small auxiliary jets buried in the aft hull, drawing air from the fan plenum.

Heavy seas might rule out the ACV mode, but if necessary the little sub can broach vertically like a POSEIDON before leveling off into its dash mode. With a gross weight of some thirty tons it would require some additional thrust for the first few seconds of flight—perhaps a rocket using hydride fuel

and liquid oxygen. The oxygen tank might be replenished during undersea loitering periods. Since the sub would pull a lot of g's when re-entering the water in heavy seas, the nose of the craft would be built up with boron fibers and polymer as a composite honeycomb wound with filaments. The idea of a flying submersible may stick in a few craws, until we reflect that the SUBROC is an unmanned flying submersible in development for over a decade.

On land, military cargo vehicles will feature bigger, wider, low-profile tires in an effort to gain all-terrain capability. Tires could be permanently inflated by supple closed-cell foams under little or no pressure. If the cargo mass is distributed over enough square meters of tire 'footprint', the vehicle could challenge tracked craft in snow, or churn through swamps with equal aplomb. The vehicle itself will probably have a wide squat profile (tires may be as high as the cargo section) and for more maneuverability, the vehicle can be hinged in the middle. All-wheel drive, of course, is *de rigeur*.

It's a popular notion that drive motors should be in the wheels, but this adds to the unsprung portion of the vehicle's weight. For optimal handling over rough terrain, the vehicle must have a minimal unsprung weight fraction—which means the motors should be part of the sprung mass, and not in the wheels which, being between the springing subsystem and the ground, are unsprung weight.

Relatively little serious development has been done on heavy torque transmission via flexible bellows. When designers realize how easily a pressurized bellows can be inspected, they may begin using this means to transmit torque to the wheels of cargo vehicles.

The suspension of many future wheeled vehicles may depart radically from current high-performance practice. Most high-performance vehicle suspensions now involve wishbone-shaped upper and lower arms, connecting the wheel's bearing block to the chassis. A rugged alternative would be sets of rollers mounted fore and aft of the bearing block, sliding vertically in chassis-mounted tracks. The tracks could be curved, and even adjustable and slaved to sensors so that, regardless of surface roughness or vehicle attitude above that surface, the wheels would be oriented to gain maximum adhesion. Turbines, flywheels, fuel cells and reactors are all good power plant candidates for wheeled vehicles.

The bodies of these vehicles will probably be segments of smooth-faced composite, and don't be surprised if two or three segment shapes are enough to form the whole shell. This is cost-effectiveness with a vengeance: one mold produces all doors and hatches, another all wheel and hardware skirts, and so on. On the other hand, let's not forget chitin.

Chitin is a family of chemical substances that make up much of the exoskeletons of arthropods, including insects, spiders and crabs. The stuff can be flexible or inflexible and chemically it is pretty inert. If biochemists and vehicle designers get together, we may one day see vehicles that can literally grow their skins and repair their own prangs. As arthropods grow larger, they often have to discard their exoskeletons and grow new ones; but who's betting the biochemists won't find ways to teach beetles some new tricks about body armor?

Some cargo—including standoff missiles, supplies, and airborne laser weapons—will be carried by airborne transports. In this sense a bomber is a transport vehicle. Here again, advanced composite structures will find wide use, since a lighter vehicle means a higher payload fraction. Vertical takeoff and landing (VTOL), or at least very short takeoff and landing (VSTOL), will greatly expand the tactical use of these transports which will have variable-geometry surfaces including leading and trailing edges, not only on wings but on the lifting body. Page 267 shows a VSTOL transport. With its triple-delta wings fully extended for maximum lift at takeoff, long aerodynamic 'fences' along the wings front-to-rear guide the airflow and the lower fences form part of the landing gear fairings. Wing extensions telescope rather than swing as the craft approaches multi-mach speed, and for suborbital flight the hydrogen-fluorine rocket will supplant turbines at around thirty kilometer altitude. In its stubby double-delta configuration the craft can skip-glide in the upper atmosphere for extended range, its thick graphite composite leading surfaces aglow as they slowly wear away during re-entry. During periodic maintenance, some of this surface can be replaced in the field as a polymer-rich putty.

As reactors become more compact and MHD more sophisticated, the rocket propellant tanks can give way to cargo space although, from the outside, the VSTOL skip-glide transport might seem little changed. Conversion from VSTOL to VTOL could be helped by a special application of the mass driver principle. In this case the aircraft, with ferrous metal filaments in its composite skin, is the mass repelled by a grid that would rise like scaffolding around the landing pad. This magnetic balancing act would be reversed for vertical landing—but it would take a lot of site preparation which might, in turn, lead to inflatable grid elements rising around the landing site.

Once an antimatter drive is developed, cargo transports might become little more than streamlined boxes with gimbaled nozzles near their corners. Such a craft could dispense with lifting surfaces, but would still need heat-resistant skin for hypersonic flight in the atmosphere. But do we have to look far ahead for cargo vehicles that travel a long way? Maybe we should also look back a ways.

For long-range transport in the lower atmosphere, the dirigible may have a future that far outstrips its past. Though certainly too vulnerable for deployment near enemy gunners, modern helium-filled cargo dirigibles can be very cost-effective in safe zones. Cargo can be lifted quietly

and quickly to unimproved dump areas, and with a wide variety of power plants. The classic cigar shape will probably be lost in the shuffle to gain more aerodynamic efficiency, if a recent man-carrying model is any guide. Writer John McPhee called the shape a deltoid pumpkin seed, though its designers prefer the generic term, *aerobody*. So: expect somebody to use buxom, spade-nosed aerobodies to route cargo, but don't expect the things to fly very far when perforated like a collander from small-arms fire. The aerobody seems to be a good bet for poorer nations engaged in border clashes where the fighting is localized and well-defined. But wait a minute: what if the gasbags were made of thin, self-healing chitin? Maybe the aerobody is tougher than we think.

Among the most fascinating military craft are those designed for scouting forays: surveillance, pinpoint bombing sorties, troop support, and courier duty being only a few of their duties. The Germans briefly rescued Mussolini with a slow but superb scout craft, the Fieseler Storch. Our SR-71 does its scouting at Mach 3, while the close-support A-10 can loiter at a tiny fraction of that speed. Now in development in the U.S., Britain, and Germany is a family of remotely piloted scout craft that may be the next generation of scout ships, combining the best features of the Storch and the SR-71. Figure 3 is a rough cut at a fourth generation scout.

The general shape of the scout ship is that of a football flattened on the bottom, permitting high-speed atmospheric travel and crabwise evasive action while providing a broad base for the exhaust gases of its internal ACV fans. The ship is MHD powered, drawing inlet air from around the underlip of the shell just outboard of the ACV skirt. The skirt petals determine the direction of deflected exhaust for omnidirectional maneuvers, though auxiliary jets may do the job better than skirt petals.

The scout uses thick graphite composite skin and sports small optical viewing ports for complete peripheral video rather than having a single viewing bubble up front. The multiple videos offer redundancy in case of damage; they permit a stiffer structure; and they allow the occupant, if any, maximum protection by remoting him from the ports.

The question of piloting is moot at the moment. Gruman, Shorts, and Dornier are all developing pilotless observation craft for long-range operations, but a scout craft of the future would probably have a life support option for at least one occupant.

The design above has an ovoid hatch near its trailing edge. For manned missions, an occupant pod slides into the well-protected middle of the ship, and could pop out again for emergency ejection. For unmanned missions the occupant pod might be replaced by extra fuel, supplies, or weapons. Some version of this design might inherit the missions of the battle tank, but with much-improved speed and maneuverability.

Well, we've specified high maneuverability and a graphite composite skin. Given supersonic speed and automated evasion programs, it might be the one hope of outrunning an orbital laser weapon!

Of course the scout doesn't exceed the speed of light. What it might do, though, is survive a brief zap long enough to begin a set of evasive actions. Let's say the enemy has an orbital laser platform (OLP) fairly near in space, not directly overhead but in line-of-sight, four hundred miles from the scout which is cruising innocently along at low altitude at a speed of Mach 1. The laser is adjusted perfectly and fires.

What does it hit? A thick polished carapace of graphite composite, its skin filaments aligned to conduct the laser's heat away from the pencil-wide target point. Sensors in the scout's skin instantly set the craft to dodging in a complex pattern, at lateral accelerations of about 10 g's. At this point the occupant is going to wish he had stayed home, but he should be able to survive these maneuvers.

Meanwhile the OLP optics or radar sense the change of the scout's course—but this takes a little time, roughly two millisec, because the OLP is four hundred miles away. Reaiming the laser might take only ten millisec, though it might take considerably longer. Then the OLP fires again, the new laser burst taking another two millisec to reach the target.

But that's fourteen thousandths of a second! And the scout is moving roughly one foot per millsec, and is now angling to one side. Its change of direction is made at well over three hundred feet per sec, over four feet of angular shift before the second ('corrected') laser shot arrives. The scout's generally elliptical shell is about twenty feet in length by about ten in width. Chances are good that the next laser shot would miss entirely, and in any case it would probably not hit the same spot, by now a glowing scar an inch or so deep on the scout's shell.

Discounting luck on either side, the survival of the jittering scout ship might depend on whether it could dodge under a cloud or into a steep valley. It might, however, foil the laser even in open country by redirecting a portion of its exhaust in a column directly toward the enemy OLP. The destructive effect of a laser beam depends on high concentration of energy against a small area. If the laser beam spreads, that concentration is lost; and beam spread is just what you must expect if the laser beam must travel very far through fog, cloud, or plasma. If the scout ship could hide under a tall, chemically seeded column of its own exhaust for a few moments, it would have a second line of defense. And we must not forget that the laser's own heat energy, impinging on the target, creates more local plasma which helps to further spread and attenuate the laser beam.

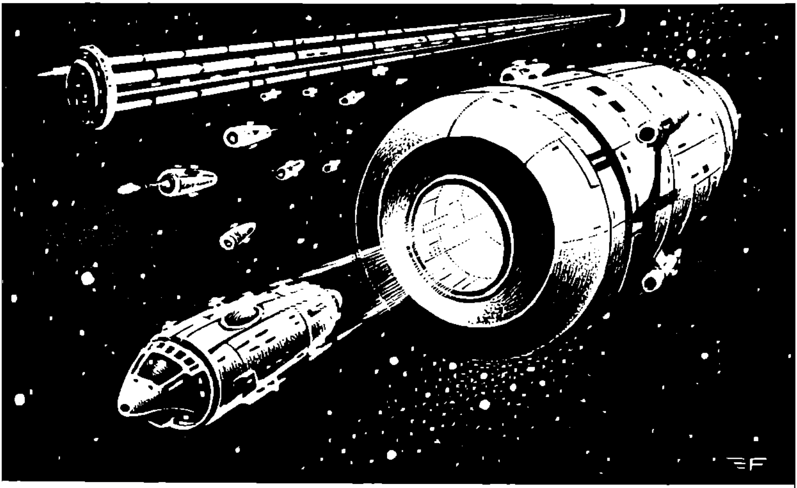
One method of assuring the OLP more hits on a scout ship would be to gang several lasers, covering all the possible moves that the scout might make. The next question would be whether all that fire-power was worth the trouble. The combination of high-temperature composites, MHD power, small size, and maneuverability might make a scout ship the same problem to an OLP that a rabbit is to a hawk. All the same,the hawk has the initial advantage. The rabbit is right to tremble.

An unmanned scout ship, capable of much higher rates of angular acceleration, would be still more vexing to an OLP. If the OLP were known to have a limited supply of stored energy, a squadron of unmanned scouts could turn a tide of battle by exhausting the OLP in futile potshots. It remains to be seen whether the jittering scout craft will be able to dodge, intercept, or just plain outrun a locally-fired weapon held by some hidden infantryman. But given a compact reactor or an antimatter drive, the scout ship could become a submersible. In that even the scout craft could escape enemy fire by plunging into any ocean, lake, or river that's handy. The broad utility of such a craft might make obsolete most other designs.

But what of vehicles intended to fight in space? As colonies and mining outposts spread throughout our solar system, there may be military value in capturing or destroying far-flung settlements—which means there'll be military value in intercepting such missions. The popular notion of space war today seems to follow the Dykstra images of movies and TV, where great whopping trillion-ton battleships direct fleets of parasite fighters. The mother ship with its own little fleet makes a lot of sense, but in sheer mass the parasites may account for much of the system, and battle craft in space may have meter-thick carapaces to withstand laser fire and nuke near-misses.

Let's consider a battle craft of reasonable size and a human crew, intended to absorb laser and projectile weapons as well as some hard radiation. We'll give it reactor-powered rockets, fed with pellets of some solid fuel which is exhausted as vapor.

To begin with, the best shape for the battle craft might be an elongated torus; a tall, stretched-out doughnut. In the long hole down the middle we install the crew of two—if that many—weapons, communication gear, life support equipment, and all the other stuff that's most vulnerable to enemy weapons. This central cavity is then domed over at both ends, with airlocks at one end and weapon pods at the other. The crew stays in the very center where protection is maximized. The fuel pellets, comprising most of the craft's mass, occupy the



main cavity of the torus, surrounding the vulnerable crew like so many tons of gravel. Why solid pellets? Because they'd be easier than fluids to recover in space after battle damage to the fuel tanks. The rocket engines are gimbaled on short arms around the waist of the torus, where they can impart spin, forward or angular momentum, or thrust reversal. The whole craft would look like a squat cylinder twenty meters long by fifteen wide, with circular indentations at each end where the inner cavity closures meet the torus curvatures.

The battle craft doesn't seem very large but it could easily gross over 5,000 tons, fully fueled. If combat accelerations are to reach 5 g's with full tanks, the engines must produce far more thrust than anything available today. Do we go ahead and design engines producing 25,000 tons of thrust, or do we accept far less acceleration in hopes the enemy can't do any better? Or do we redesign the cylindrical crew section so that it can eject itself from the fuel torus for combat maneuvers? This trick—separating the crew and weapons pod as a fighting unit while the fuel supply loiters off at a distance—greatly improves the battle craft's performance. But it also means the crew pod must link up again very soon with the torus to replenish its on-board fuel supply. And if the enemy zaps the fuel torus hard enough while the crew is absent, it may mean a long trajectory home in cryogenic sleep.

Presuming that a fleet of the toroidal battle craft sets out on an interplanetary mission, the fleet might start out as a group of parasite ships attached to a mother ship. It's anybody's guess how the mother ship will be laid out, so let's make a guess for critics to lambaste.

Our mother ship would be a pair of fat discs, each duplicating the other's repair functions in case one is damaged. The discs would be separated by three compression girders and kept in tension by a long central cable. To get a mental picture of the layout, take two biscuits and run a yard-long thread through the center of each. Then make three columns from soda straws, each a yard long, and poke the straw ends into the biscuits near their edges. Now the biscuits are facing each other, a yard apart, pulled toward each other by the central thread and held apart by the straw columns. If you think of the biscuits as being a hundred meters in diameter with rocket engines poking away from the ends, you have a rough idea of the mother ship.

Clearly, the mother ship is two modules, upwards of a mile apart but linked by structural tension and compression members. The small battle craft might be attached to the compression girders for their long ride to battle, but if the mother ship must maneuver, their masses might pose unacceptable loads on the girders. Better by far if the parasites nestle in between the girders to grapple onto the tension cable. In this way, a fleet could embark from planetary orbit as a single system, separating into sortie elements near the end of the trip.

Since the total mass of all the battle craft is about equal to that of the unencumbered mother ship, the big ship can maneuver itself much more easily when the kids get off mama's back. The tactical advantages are that the system is redundant with fuel and repair elements; a nuke strike in space might destroy one end of the system without affecting the rest; and all elements become more flexible in their operational modes just when they need to be. Even if mother ships someday become as massive as moons, my guess is that they'll be made up of redundant elements and separated by lots of open space. Any hopelessly damaged elements can be discarded, or maybe kept and munched up for fuel mass.

Having discussed vehicles that operate on land, sea, air, and in space, we find one avenue left: within the earth. Certainly a burrowing vehicle lacks the maneuverability and speed of some others—until the burrow is complete. But under all that dirt, one is relatively safe from damn-all. Mining vehicles already exist that cut and convey ten tons of coal a minute, using extended-life storage batteries for power. One such machine, only 23 inches high, features a supine driver and low-profile, high traction tires. Perhaps a future military 'mole' will use seismic sensors to find the easiest path through rocky depths, chewing a long burrow to be traversed later at high speed by offensive or defensive vehicles, troop transports, and supply conduits. Disposal of the displaced dirt could be managed by detonating a nuke to create a cavern big enough to accept the tailings of the mole. The present plans to route ICBM's by rail so that enemies won't know where to aim their first strike, may shift to underground routing as the subterranean conduit network expands.

AN ALTERNATIVE TO VEHICLES?

A vehicle of any kind is, as we've asserted, essentially a means to carry something somewhere. So it's possible that the vehicle, *as a category,* might be obsolete one day. The matter transmitter is a concept that, translated into hardware, could obsolete almost any vehicle. True, most conceptual schemes for matter transmitters posit a receiving station—which implies that some vehicle must first haul the receiving station from Point A to Point B. But what if the transmitter needed no receiving station? A device that could transmit people and supplies at light speed to a predetermined point without reception hardware, would instantly replace vehicles for anything but pleasure jaunts. The system would also raise mirthful hell with secrecy, and with any armor that could be penetrated by the transmitter beam. If the beam operated in the electromagnetic spectrum, vehicles might still be useful deep down under water, beneath the earth's surface, or inside some vast Faraday cage.

But until the omnipotent matter transmitter comes along, vehicle design will be one of the most pervasive factors in military strategy and tactics. ●

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But We Try Not To Act Like It

by Orson Scott Card

Illustrated by Steve Fabian

Any organism, including government, will grow until such time as it is successfully resisted or there is nothing left to feed on.

There was no line. Hiram Cloward commented on it to the pointy-faced man behind the counter. "There's no line."

"This is the complaint department. We pride ourselves on having few complaints." The pointy-faced man had a prim little smile that irritated Hiram. "What's the matter with your television?"

"It shows nothing but soaps, that's what's the matter. And asinine gothics."

"Well—that's programming, sir, not mechanical at all."

"It's mechanical. I can't turn the damn set off."

"What's your name and social security number?"

"Hiram Cloward. 528-80-693883-7."

"Address?"

"ARF-487-U7b."

"That's singles, sir. Of course you can't turn off your set."

"You mean because I'm not married I can't turn off my television?"

"According to congressionally authorized scientific studies carried out over a three-year period from 1989 to 1991, it is imperative that persons living alone have the constant companionship of their television sets."

"I like solitude. I also like silence."

"But the Congress passed a *law*, sir, and we can't disobey the *law*—"

"Can't I talk to somebody intelligent?"

The pointy-faced man flared a moment, his eyes burning. But he instantly regained his composure, and said in measured tones, "as a matter of fact, as soon as any complainant becomes offensive or hostile, we immediately refer them to section A-6."

"What's that, the hit squad?"

"It's behind that door."

And Hiram followed the pointing finger to the glass door at the far end of the waiting room. Inside was an office, which was filled with comfortable, homey knick-knacks, several chairs, a desk, and a man so offensively nordic that even Hitler would have resented him. "Hello," the Aryan said, warmly.

"Hi."

"Please, sit down." Hiram sat, the courtesy and warmth making him feel even more resentful—did they think they could fool him into believing he was not being grossly imposed upon?

"So you don't like something about your programming," said the Aryan.

"Your programming, you mean. It sure as hell isn't mine. I don't know why Bell Television thinks it has the right to impose its idea of fun and entertainment on me twenty-four hours a day, but I'm fed up with it. It was bad enough when there was some variety, but for the last two months I've been getting nothing but soaps and gothics."

"It took you two months to notice?"

"I try to ignore the set. I like to *read.* You can bet that if I had more than my stinking little pension from our loving government, I could pay to have a room where there wasn't a TV so I could have some *peace.*"

"I really can't help your financial situation. And the law's the law."

"Is that all I'm going to hear from you? The law? I could have heard that from the pointy-faced jerk out there."

"Mr. Cloward, looking at your records, I can certainly see that soaps and gothics are not appropriate for you."

"They aren't appropriate," Hiram said, "for anyone with an IQ over eight."

The Aryan nodded. "You feel that people who enjoy soaps and gothics aren't the intellectual equals of people who don't."

"Damn right. I have a Ph.D. in *literature,* for heaven's sake!"

The Aryan was all sympathy. "Of *course* you don't like soaps! I'm sure it's a mistake. We try not to make mistakes, but we're only human—except the computers, of course." It was a joke, but Hiram didn't laugh. The Aryan kept up the small talk as he looked at the computer terminal that he could see and Hiram could not. "We may be the only television company in town, you know, but—"

"But you try not to act like it."

"Yes. Ha. Well, you must have heard our advertising."

"Constantly."

"Well, let's see now. Hiram Cloward, Ph.D. Nebraska 1981. English literature, twentieth century, with a minor in Russian literature. Dissertation on Dostoevski's influence on English-language novelists. A near-perfect class attendance record, and a reputation for arrogance and competence."

"How much do you *know* about me?"

"Only the standard consumer research data. But we do have a bit of a problem."

Hiram waited, but the Aryan merely punched a button, leaned back, and looked at Hiram. His eyes were kindly and warm and intense. It made Hiram uncomfortable.

"Mr. Cloward."

"Yes?"

"You are unemployed."

"Not willingly."

"Few people are willingly unemployed, Mr. Cloward. But you have no job. You also have no family. You also have no friends."

"That's consumer research? What, only people with friends buy Rice Krispies?"

"As a matter of fact, Rice Krispies are favored by solitary people. We have to know who is more likely to be receptive to advertising, and we direct our programming accordingly.

Hiram remembered that he ate Rice Krispies for breakfast almost every morning. He vowed on the spot to switch to something else. Quaker Oats, for instance. Surely they were more gregarious.

"You understand the importance of the Selective Programming Broadcast Act of 1985, yes?"

"Yes."

"It was deemed unfair by the Supreme Court for all programming to be geared to the majority. Minorities were being slighted. And so Bell Television was given the assignment of preparing an individually selected broadcast system so that each individual, in his own home, would have the programming perfect for him."

"I know all this."

"I must go over it again anyway, Mr. Cloward, because I'm going to have to help you understand why there can be no change in your programming."

Hiram stiffened in his chair, his hands flexing. "I knew you bastards wouldn't change."

"Mr. Cloward, we bastards would be delighted to change. But we are very closely regulated by the government to provide the most healthful programming for every American citizen. Now, I will continue my review."

"I'll just go home, if you don't mind."

"Mr. Cloward, we are directed to prepare programming for minorities as small as ten thousand people—but no smaller. Even for minorities of ten thousand the programming is ridiculously expensive—a program seen by so few costs far more per watching-minute to produce than one seen by thirty or forty million. However, you belong to a minority even smaller than ten thousand."

"That makes me feel so special."

"Furthermore, the Consumer Protection Broadcast Act of 1989 and the regulations of the Consumer Broadcast Agency since then have given us very strict guidelines. Mr. Cloward, we cannot show you any program with overt acts of violence."

"Why not?"

"Because you have tendencies toward hostility that are only exacerbated by viewing violence. Similarly, we cannot show you any programs with sex."

Cloward's face turned red.

"You have no sex life whatsoever, Mr. Cloward. Do you realize how dangerous that is? You don't even masturbate. The tension and hostility inside you must be tremendous."

Cloward leaped to his feet. There were limits to what a man had to put up with. He headed for the door.

"Mr. Cloward, I'm sorry." The Aryan followed him to the door. "I don't make these things up. Wouldn't you rather know *why* these decisions are reached?"

Hiram stopped at the door, his hand on the knob. The Aryan was right. Better to know why than to hate them for it.

"How," Hiram asked. "How do they know what I do and do not do within the walls of my home?"

"We don't *know*, of course, but we're pretty sure. We've studied people for years. We know that people who have certain buying patterns and certain living patterns behave in certain ways. And, unfortunately, you have strong destructive tendencies. Repression and denial are your primary means of adaptation to stress, that and, unfortunately, occasional acting out."

"What the hell does all that mean?"

"It means that you lie to yourself until you can't anymore, and then you attack somebody."

Hiram's face was packed with hot blood, throbbing. I must look like a tomato, he told himself, and deliberately calmed himself. I don't care, he thought. They're wrong anyway. Damn scientific tests.

"Aren't there any movies you could program for me?"

"I am sorry, no."

"Not all movies have sex and violence."

The Aryan smiled soothingly. "The movies that don't wouldn't interest you anyway."

"Then turn the damn thing off and let me read!"

"We can't do that."

"Can't you turn it *down?*"

"No."

"I am so sick of hearing all about Sarah Wynn and her damn love life!"

"But isn't Sarah Wynn attractive?" asked the Aryan.

That stopped Hiram cold. He dreamed about Sarah Wynn at night. He said nothing. He had no attraction to Sarah Wynn.

"Isn't she?" the Aryan insisted.

"Isn't who what?"

"Sarah Wynn."

"Who was talking about Sarah Wynn? What about documentaries?"

"Mr. Cloward, you would become extremely hostile if the news programs were broadcast to you. You know that."

"Walter Cronkite's dead. Maybe I'd like them better now."

"You don't care about the news of the real world, Mr. Cloward, do you?"

"No."

"Then you see where we are. Not one iota of our programming is really appropriate for you. But ninety percent of it is downright harmful to you. And we can't turn the television off, because of the Solitude Act. Do you see our dilemma?"

"Do you see mine?"

"Of course, Mr. Cloward. And I sympathize completely. Make some friends, Mr. Cloward, and we'll turn off your television."

And so the interview was over.

For two days Cloward brooded. All the time he did, Sarah Wynn was grieving over her three-days' husband who had just been killed in a car wreck on Wiltshire Boulevard, wherever the hell that was. But now the body was scarcely cold and already her old suitors were back, trying to help her, trying to push their love on her. "Can't you let yourself depend on me, just a little?" asked Teddy, the handsome one with lots of money.

"I don't like depending on people," Sarah answered.

"You depended on George." George was the husband's name. The dead one.

"I know," she said, and cried for a moment. Sarah Wynn was good at crying. Hiram Cloward turned another page in *The Brothers Karamazov.*

"You need friends," Teddy insisted.

"Oh, Teddy, I know it," she said, weeping. "Will you be my friend?"

"Who writes this stuff?" Hiram Cloward asked aloud. Maybe the Aryan in the television company offices had been right. Make some friends. Get the damn set turned off whatever the cost.

He got up from his chair and went out into the corridor in the apartment building. Clearly posted on the walls were several announcements:

Chess club 5-9 wed

Encounter groups nightly at 7

Learn to knit 6:30 bring yarn and needles

Games games games in game room (basement)

Just want to chat? Friends of the Family 7:30 to 10:30 nightly

Friends of the Family? Hiram snorted. Family was his maudlin mother and her constant weeping about how hard life was and how no one in her right mind would ever be born a woman if anybody had any choice but there was no choice and marriage was a trap men sprung on women, giving them a few minutes of pleasure for a lifetime of drudgery, and I swear to God if it wasn't for my little baby Hiram I'd ditch that bastard for good, it's for your sake I don't leave, my little baby, because if I leave you'll grow up into a macho bastard like your beerbelly father.

And friends? What friends ever come around when good old Dad is boozing and belting the living crap out of everybody he can get his hands on?

I read. That's what I do. The Prince and the Pauper. Connecticut Yankee. Pride and Prejudice. Worlds within worlds within worlds, all so pretty and polite and funny as hell.

Friends of the Family. Worth a shot, anyway.

Hiram went to the elevator and descended eighteen floors to the Fun Floor. Friends of the Family were in quite a large room with alcohol at one end and soda pop at the other. Hiram was surprised to discover that the term *soda pop* had been revived. He walked to the cola sign and asked the woman for a coke.

"How many cups of coffee have you had today?" she asked.

"Three."

"Then I'm so sorry, but I can't give you a soda pop with caffeine in it. May I suggest Sprite?"

"You may not," Hiram said, clenching his teeth. "We're too damn overprotected."

"Exactly how I feel," said a woman standing beside him, Sprite in hand. "They protect and protect and protect, and what good does it do? People still die, you know."

"I suspected as much," Hiram said, struggling for a smile, wondering if his humor sounded funny or merely sarcastic. Apparently funny. The woman laughed.

"Oh, you're a gem, you are," she said. "What do you do?"

"I'm a detached professor of literature at Princeton."

"But how can you live *here* and work *there?"*

He shrugged. "I don't work there. I said detached. When the new television teaching came in, my PQ was too low. I'm not a screen personality."

"So few of us are," she said sagely, nodding and smiling. "Oh, how I long for the good old days. When ugly men like David Brinkley could deliver the news."

"You remember Brinkley?"

"Actually, no," she said, laughing. "I just remember my mother talking about him." Hiram looked at her appreciatively. Nose not very straight, of course—but that seemed to be the only thing keeping her off TV. Nice voice. Nice nice face. Body.

She put her hand on his thigh.

"What are you doing tonight?" she asked.

"Watching television," he grimaced.

"Really? What do you have?"

"Sarah Wynn."

She squealed in delight. "Oh, how wonderful! We must be kindred spirits then! I have Sarah Wynn, too!"

Hiram tried to smile.

"Can I come up to your apartment?"

Danger signal. Hand moving up thigh. Invitation to apartment. Sex.

"No."

"Why not?"

And Hiram remembered that the only way he could ever get rid of the television was to prove that he wasn't solitary. And fixing up his sex life—*i.e.*, having one—would go a long way toward changing their damn profiles. "Come on," he said, and they left the Friends of the Family without further ado.

Inside the apartment she immediately took off her shoes and blouse and sat down on the old-fashioned sofa in front of the TV. "Oh," she said, "so many books. You really are a professor, aren't you?"

"Yeah," he said, vaguely sensing that the next move was up to him, and not having the faintest idea of what the next move was. He thought back to his only fumbling attempt at sex when he was (what?) thirteen? (no) fourteen and the girl was fifteen and was doing it on a lark. She had walked with him up the creekbed (back when there were creeks and open country) and suddenly she had stopped and unzipped his pants (back when there were zippers) but he was finished before she had hardly started and gave up in disgust and took his pants and ran away. Her name was Diana. He went home without his pants and had no rational explanation and his mother had treated him with loathing and brought it up again and again for years afterward, how a man is a man no matter how you treat him and he'll still get it when he can, who cares about the poor girl. But Hiram was used to that kind of talk. It rolled off him. What haunted him was the uncontrolled shivering of his body, the ecstacy of it, and then the look of disgust on the girl's face. He had thought it was because—well, never mind. Never mind, he thought. I don't think of this anymore.

"Come *on,*" said the woman.

"What's your name?" Hiram asked.

She looked at the ceiling. "Agnes, for heaven's sake, come *on.*"

He decided that taking off his shirt might be a good idea. She watched, then decided to help.

"No," he said.

"What?"

"Don't touch me."

"Oh, for pete's sake. What's wrong? Impotent?"

Not at all. Not at all. Just uninterested. Is that all right?

"Look, I don't want to play around with a psycho case, all right? I've got better things to do. I make a hundred a whack, that's what I charge, that's standard, right?"

Standard what? Hiram nodded because he didn't dare ask what she was talking about.

"But you obviously, heaven knows how, buddy, you sure as hell obviously don't know what's going on in the world. Twenty bucks. Enough for the ten minutes you've screwed up for me. Right?"

"I don't have twenty," Hiram said.

Her eyes got tight. "A fairy *and* a deadbeat. What a pick. Look, buddy, next time you try a pickup, figure out what you want to do with her first, right?"

She picked up her shoes and blouse and left. Hiram stood there.

"Teddy, no," said Sarah Wynn.

"But I need you. I need you so desperately," said Teddy on the screen.

"It's only been a few days. How can I sleep with another man only a few days after George was killed? Only four days ago we—oh, no, Teddy. Please."

"Then when? How soon? I love you so much."

Drivel, George thought in his analytical mind. But nevertheless obviously based on the Penelope story. No doubt her George, her Odysseus, would return, miraculously alive, ready to sweep her back into wedded bliss. But in the meantime, the suitors: enough suitors to sell fifteen thousand cars and a hundred thousand boxes of tampax and four hundred thousand packages of Cap'n Crunch.

The nonanalytical part of his mind, however, was not the least bit concerned with Penelope. For some reason he was clasping and unclasping his hands in front of him. For some reason he was shaking. For some reason he fell to his knees at the couch, his hands clasping and unclasping around *Crime and Punishment,* as his eyes strained to cry but could not.

Sarah Wynn wept.

But she can cry easily, Hiram thought. It's not fair, that she should cry so easily. Spin flax, Penelope.

The alarm went off, but Hiram was already awake. In front of him the television was singing about Dove with lanolin. The products haven't changed, Hiram thought. Never change. They were advertising Dove with lanolin in the little market carts around the base of the cross while Jesus bled to death, no doubt. For softer skin.

He got up, got dressed, tried to read, couldn't, tried to remember what had happened last night to leave him so upset and nervous, but couldn't, and at last he decided to go back to the Aryan at the Bell Television offices.

"Mr. Cloward," said the Aryan.

"You're a psychiatrist, aren't you?" Hiram asked.

"Why, Mr. Cloward, I'm an A-6 complaint representative from Bell Television. What can I do for you?"

"I can't stand Sarah Wynn anymore," Hiram said.

"That's a shame. Things are finally going to work out for her starting in about two weeks."

And in spite of himself, Hiram wanted to ask what was going to happen. It isn't fair for this nordic uberman to know what sweet little Sarah is going to be doing weeks before I do. But he fought down the feeling, ashamed that he was getting caught up in the damn soap.

"Help me," Hiram said.

"How can I help you?"

"You can change my life. You can get the television out of my apartment."

"Why, Mr. Cloward?" the Aryan asked. "It's the one thing in life that's absolutely free. Except that you get to watch commercials. And you know as well as I do that the commercials are downright entertaining. Why, there are people who actually choose to have double the commercials in their personal programming. We get a thousand requests a day for the latest McDonald's ad. You have no idea."

"I have a very good idea. I want to read. I want to be alone."

"On the contrary, Mr. Cloward, you long not to be alone. You desperately need a friend."

Anger. "And what makes you so damn sure of that?"

"Because, Mr. Cloward, your response is completely typical of your group. It's a group we're very concerned about. We don't have a budget to program for you—there are only about two thousand of you in the country—but a budget wouldn't do us much good because we really don't know what kind of programming you *want*."

"I am not part of any group."

"Oh, you're so much a part of it that you could be called typical. Dominant mother, absent and/or hostile father, no long-term relationships with anybody. No sex life."

"I have a sex life."

"If you have in fact attempted any sexual activity it was undoubtedly with a prostitute and she expected too high a level of sophistication from you. You are easily ashamed, you couldn't cope, and so you have not had intercourse. Correct?"

"What are you! What are you trying to do to me!"

"I *am* a psychoanalyst, of course. Anybody whose complaints can't be handled by our bureaucratic authority figure out in front obviously needs help, not another bureaucrat. I want to help you. I'm your friend."

And suddenly the anger was replaced by the utter incongruity of this nordic masterman wanting to help little Hiram Cloward. The unemployed professor laughed.

"Humor! Very healthy!" said the Aryan.

"What is this? I thought shrinks were supposed to be subtle."

"With some people—notably paranoids, which you are not, and schizoids, which you are not either."

"And what am I?"

"I told you. Denial and repression strategies. Very unhealthy. Acting out—less healthy yet. But you're extremely intelligent, able to do many things. I personally think it's a damn shame you can't teach."

"I'm an excellent teacher."

"Tests with randomly selected students showed that you had an extremely heavy emphasis on esoterica. Only people like you would really enjoy a class from a person like you. There aren't many people like you. You don't fit into many of the normal categories."

"And so I'm being persecuted."

"Don't try to pretend to be paranoid." The Aryan smiled. Hiram smiled back. This is insane. Lewis Carroll, where are you now that we really need you?

"If you're a shrink, then I should talk freely to you."

"If you like."

"I don't like."

"And why not?"

"Because you're so godutterlydamn Aryan, that's why."

The Aryan leaned forward with interest. "Does that bother you?"

"It makes me want to throw up."

"And why is that?"

The look of interest was too keen, too delightful. Hiram couldn't resist. "You don't know about my experiences in the war, then, is that it?"

"What war? There hasn't been a war recently enough—"

"I was very, very young. It was in Germany. My parents aren't really my parents, you know. They were in Germany with the American embassy. In Berlin in 1938, before the war broke out. My real parents were there, too—German Jews, or half Jews, anyway. My real father—but let that pass, you don't need my whole genealogy. Let's just say that when I was only eleven days old, totally unregistered, my real Jewish father took me to his friend, Mr. Cloward in the American embassy, whose wife had just had a miscarriage. 'Take my child,' he said.

" 'Why?' Cloward asked.

" 'Because my wife and I have a perfect, utterly foolproof plan to kill Hitler. But there is no way for us to survive it.' And so Cloward, my adopted father, took me in.

"And then, the next day, he read in the papers about how my real parents had been killed in an 'accident' in the street. He investigated—and discovered that just by chance, while my parents were on their way to carry out their foolproof plan, some brown shirts in the street had seen them. Someone pointed them out as Jews. They were bored—so they attacked them. Had no idea they were saving Hitler's life, of course. These nordic mastermen started beating my mother, forcing my father to watch as they stripped her and raped her and then disemboweled her. My father was then subjected to experimental use of the latest model testicle-crusher until he bit off his own tongue in agony and bled to death. I don't like nordic types." Hiram sat back, his eyes full of tears and emotion, and realized that he had actually been able to cry—not much, but it was hopeful.

"Mr. Cloward," said the Aryan, "you were born in Missouri in 1951. Your parents of record are your natural parents."

Hiram smiled. "But it was one hell of a Freudian fantasy, wasn't it? My mother raped, my father emasculated to death, myself divorced from my true heritage, etc., etc."

The Aryan smiled. "You should be a writer, Mr. Cloward."

"I'd rather read. Please, let me read."

"I can't stop you from reading."

"Turn off Sarah Wynn. Turn off the mansions from which young girls flee from the menace of a man who turns out to be friendly and loving. Turn off the commercials for cars and condoms."

"And leave you alone to wallow in cataleptic fantasies among your depressing Russian novels?"

Hiram shook his head. Am I begging? he wondered. Yes, he decided. "I'm begging. My Russian novels aren't depressing. They're exalting, uplifting, overwhelming."

"It's part of your sickness, Mr. Cloward, that you long to be overwhelmed."

"Every time I read Dostoevski, I feel fulfilled."

"You have read everything by Dostoevski twenty times over. And everything by Tolstoy a dozen times."

"Every time I read Dostoevski is the first time!"

"We can't leave you alone."

"I'll kill myself!" Hiram shouted. "I can't live like this much longer!"

"Then make friends," the Aryan said simply. Hiram gasped and panted, gathering his rage back under control. This is not happening. I am not angry. Put it away, put it back, get control, smile. Smile at the Aryan.

"You're my friend, right?" Hiram asked.

"If you'll let me," the Aryan answered.

"I'll let you," Hiram said. Then he got up and left the office.

On the way home he passed a church. He had often seen the church before. He had little interest in religion—it had been too thoroughly dissected for him in the novels. What Twain had left alive, Dostoevski had withered and Pasternak had killed. But his mother was a passionate Presbyterian. He went into the church.

At the front of the building was a huge television screen. On it a very charismatic young man was speaking. The tones were subdued—only those in the front could hear it. Those in the back seemed to be meditating. Cloward knelt at a bench to meditate, too.

But he couldn't take his eyes off the screen. The young man stepped aside, and an older man took his place, intoning something about Christ. Hiram could hear the word *Christ,* but no others.

The walls were decorated with crosses. Row on row of crosses. This was a Protestant church—none of the crosses contained a figure of Jesus bleeding. But Hiram's imagination supplied him nonetheless. Jesus, his hands and wrists nailed to the cross, his feet pegged to the cross, his throat at the intersection of the beams.

Why the cross, after all? The intersection of two utterly opposite lines, perpendiculars that can only touch at one point. The epitome of the life of man, passing through eternity without a backward glance at those encountered along the way, each in his own, endlessly divergent direction. The cross. But not at all the symbol of today, Hiram decided. Today we are in spheres. Today we are curves, not lines, bending back on ourselves, touching everybody again and again, wrapped up inside little balls, none of us daring to be at the outside. Pull me in, we cry, pull me and keep me safe, don't let me fall out, don't let me fall off the edge of the world.

But the world has an edge now, and we can all see it, Hiram decided. We know where it is, and we can't bear to let anyone find his own way of staying on top.

Or do I want to stay on top?

The age of crosses is over. Now the age of spheres. Balls.

"We are your friends," said the old man on the screen. "We can help you."

There is a grandeur, Hiram answered silently, about muddling through alone.

"Why be alone when Jesus can take your burden?" said the man on the screen.

If I were alone, Hiram answered, there would be no burden to bear.

"Pick up your cross, fight the good fight," said the man on the screen.

If only, Hiram answered, I could find my cross to pick it up.

Then Hiram realized that he still could not hear the voice from the television. Instead he had been supplying his own sermon, out loud. Three people near him in the back of the church were watching him. He smiled sheepishly, ducked his head in apology, and left. He walked home whistling.

Sarah Wynn's voice greeted him. "Teddy. Teddy! What have we done? Look what we've done."

"It was beautiful," Teddy said. "I'm glad of it."

"Oh, Teddy! How can I ever forgive myself?" And Sarah wept.

Hiram stood transfixed, watching the screen. Penelope had given in. Penelope had left her flax and fornicated with a suitor! This is wrong, he thought.

"This is wrong," he said.

"I love you, Sarah," Teddy said.

"I can't bear it, Teddy," she answered. "I feel that in my heart I have murdered George! I have betrayed him!"

Penelope, is there no virtue inthe world? Is there no Artemis, hunting? Just Aphrodite, bedding down every hour on the hour with every man, god, or sheep that promised forever and delivered a moment. The bargains are never fulfilled, never, Hiram thought.

At that moment on the screen, George walked in. "My dear," he exclaimed. "My dear Sarah! I've been wandering with amnesia for days! It was a hitchhiker who was burned to death in my car! I'm home!"

And Hiram screamed and screamed and screamed.

The Aryan found out about it quickly, at the same time that he got an alarming report from the research teams analyzing the soaps. He shook his head, a sick feeling in the pit of his stomach. Poor Mr. Cloward. Ah, what agony we do in the name of protecting people, the Aryan thought.

"I'm sorry," he said to Hiram. But Hiram paid him no attention. He just sat on the floor, watching the television set. As soon as the report had come in, of course, all the soaps—especially Sarah Wynn's—had gone off the air. Now the game shows were on, a temporary replacement until errors could be corrected.

"I'm so sorry," the Aryan said, but Hiram tried to shrug him away. A black woman had just traded the box for the money in the envelope. It was what Hiram would have done, and it paid off. Five thousand dollars instead of a donkey pulling a cart with a monkey in it. She had just avoided being zonked.

"Mr. Cloward, I thought the problem was with you. But it wasn't at all. I mean, you were marginal, all right. But we didn't realize what Sarah Wynn was doing to people."

Sarah schmarah, Hiram said silently, watching the screen. The black woman was bounding up and down in delight.

"It was entirely our fault. There are thousands of marginals just like you who were seriously damaged by Sarah Wynn. We had no idea how powerful the identification was. We had no idea."

Of course not, thought Hiram. You didn't read enough. You didn't know what the myths do to people. But now was the Big Deal of the Day, and Hiram shook his head to make the Aryan go away.

"Of course the Consumer Protection Agency will pay you a lifetime compensation. Three times your present salary and whatever treatment is possible."

At last Hiram's patience ended. "Go away!" he said. "I have to see if the black woman there is going to get the car!"

"I just can't decide," the black woman said.

"Door number three!" Hiram shouted. "Please, God, door number three!"

The Ayran watched Hiram silently.

"Door number two!" the black woman finally decided. Hiram groaned. The announcer smiled.

"Well," said the announcer. "Is the car behind door number *two?* Let's just see!"

The curtain opened, and behind it was a man in a hillbilly costume strumming a beat-up looking banjo. The audience moaned. The man with the banjo sang "Home on the Range." The black woman sighed.

They opened the curtains, and there was the car behind door number three. "I knew it," Hiram said, bitterly. "They never listen to me. Door number three, I say, and they never do it."

The Aryan turned to leave.

"I told you, didn't I?" Hiram asked, weeping.

"Yes," the Aryan said.

"I knew it. I knew it all along. I was *right."* Hiram sobbed into his hands.

"Yeah," the Aryan answered, and then he left to sign all the necessary papers for the commitment. Now Cloward fit into a category. No one can exist outside one for long, the Aryan realized. We are creating a new man. *Homo categoricus.* The classified man.

But the papers didn't have to be signed after all. Instead Hiram went into the bathroom, filled the tub, and joined the largest category of all.

"Damn," the Aryan said, when he heard about it. ●

science fiction and science,

part four

the science fiction in science

by poul anderson

"WHAT OBSERVATIONS ARE WE FAILING TO MAKE TODAY, OR MAKING BY CHANCE AND DISMISSING, BECAUSE THEY DON'T CONFORM TO OUR THEORIES?"

"The Lord whose is the oracle at Delphi neither reveals nor hides but gives tokens."

Thus wrote Heraclitus, two and a half millennia ago: a sentence which Hermann Weyl chose as an epigraph for the second part of his profound *Philosophy of Mathematics and Natural Science.* The universe is basically mysterious, and not only in the sense that we don't know everything about it that we might. Einstein remarked once that perhaps its strangest feature is that we can come to some understanding of it. There is no *a priori* reason why an animal which spent nearly its whole evolutionary history as a primitive hunter and gatherer should be able to conceive of the atom or the galaxies.

Indeed, we aren't sure of what we know, how we have come to know it, or what our knowledge signifies. The last sentence in the paragraph above is full of typical ambiguities. In order to question the ways in which we make scientific findings, it presupposes concepts of evolution and anthropology which are themselves scientific findings. It implies that atoms and galaxies exist independently of us and were, so to speak, always waiting to be discovered—that none of our information about them was inevitably generated by ourselves. This is the normal scientific assumption, but it isn't logically necessary and, anyhow, we were asking about the validity of scientific assumptions!

Yet science does work. We can make predictions about atoms and galaxies and see them verified. For instance, the possibility of creating plutonium in the laboratory, eventually on an industrial scale, was established before anybody observed the slightest amount of that metal: established exactly enough for the necessary apparatus to be designed. Light from the most remote sources displays the familiar spectra of the elements.

Often something that looked like a discrepancy has turned out to add confirmation. Thus, our own galaxy appeared to be larger than any other, which didn't quite make sense. Then Baade got data which showed that the other galaxies are farther off than earlier, less exact observations had indicated. Hence they must be correspondingly bigger, and ours therefore an average specimen.

Likewise, for many years Piltdown man was an embarrassment to paleoanthropologists. That combination of jaw and skull would not fit into any reasonable evolutionary tree of the hominid family. At last chemical analysis proved it was a hoax. This not only helped strengthen the claim of the usual evolutionary tree to being reasonable, it illustrated the fact that chemistry and evolution are two aspects of the same reality.

So it would appear the epistemological questions are mere quibbles. Most educated people today take for granted that the universe has a completely objective existence; that it is orderly, i.e. governed by unchanging natural laws; that those laws and the ways in which they manifest themselves are discoverable by the scientific method.

Of course, everybody agrees that in practice we'll probably never ferret out all the details. For instance, it's unlikely we'll ever know what most of the soft-bodied organisms were which swam in the pre-Cambrian seas, they having left almost no fossil traces, or that we will ever visit every last planet in the cosmos and see exactly what's there. Moreover, again and again we'll be surprised. For instance, recent discoveries have forced us drastically to modify that human family tree and to push its separation from the apes far back, perhaps to as much as five million years ago.

If they are slightly more sophisticated than this, our educated people are aware that (in the present scheme of physics) there are certain limits on what we can possibly learn. The position and momentum of a small particle such as an electron cannot be determined exactly. The closer we have one quantity pegged, the less we can tell about the other. This is a very rough rendition of Heisenberg's famous uncertainty principle. That is often explained in terms of interaction between observer and observed: to take a measurement on the particle, we must do things like bouncing another particle off it, which changes the values we are trying to measure. In fact, though, the principle is a mathematical consequence of wave mechanics. That's important, because theoretically we could make our measurements *almost* non-disturbing, by making them extremely delicate . . . except that Heisenberg found that no matter what we do, we cannot increase our accuracy beyond a certain point.

With these reservations in mind, none of which appear superficially to be of a fundamental nature, and with the prodigious success of science before them, our educated people do, then, take for granted the orderliness of the universe and the validity of the scientific method as the means of finding out how that universe works. A few physicists—including Milton Rothman, One of Us since he has long been interested in science fiction and written some himself—go so far as to suggest we may be close to having discovered all the basic laws. More precisely, we may formulate the one basic law, a unified field theory from which everything else flows in a logically inevitable fashion.

If so, then we'll be able to demonstrate that atoms have the characteristics they do because these are the only possible ones. Likewise for energy in its many forms, space-time, the cosmos as a whole; we'll find out for certain whether the universe is open or closed, eternal or finite or cyclical, whether other universes exist, what we can and cannot hope to achieve with any imaginable technology. (Needless to say, nobody believes that this would put an end to research in other areas. Biology would take a long time to become an exact, mathematical science, because it involves vast complexities; this is still more true of psychology, while disciplines like archeology and paleontology would doubtless always remain largely empirical. The point is that we would make no further discoveries which could not readily be fitted into the scheme of our physics.)

Yet to many thinkers, this confidence in the scientific method seems premature, at least. To some, it seems altogether unjustified.

Various prominent scientists have denied that there is any such thing as the scientific method. It's usually described about as follows. The scientist gathers exact observations—or, more commonly, generations of scientists do. This is either by means of careful measurements, as in physics, or by carefully controlled experiments, as in biology, where one tries to vary a single factor at a time. Now as Henri Poincaré, himself a distinguished philosopher of science, remarked, a mere heap of facts is no more a science than a heap of bricks is a house. They must form a pattern, they must make sense. Somewhere along the line, somebody does find such a pattern, of which the individual facts are specific cases. This is not the end, for what we have here is essentially a *description* of how things are, and we want an *explanation*. We want to know why. To create a true explanation requires genius of a rare order. Once this has been done, however, we have a theory, which we can use for a guide in making new discoveries.

The classic example is from astronomy and physics. Through centuries, astronomers had collected ever more precise information about the motions of the heavenly bodies. This effort culminated, for the time being, with Tycho Brahe. Although he himself clung to a version of the old geocentric pattern, Copernicus showed that his figures could not be reconciled with it in any way that wasn't hopelessly complicated. Earth must move around the sun like the rest of the planets. Kepler then worked out the three rules by which they do move: a neat mathematical summation of countless individual data.

Meanwhile Galileo had been studying the behavior of bodies as they fell, rolled, or flew on various trajectories. A lifetime afterward, Newton provided the explanation, in his laws of motion and of gravitation. He showed that Kepler's rules and Galileo's findings were straightforward consequences of these. Newton's principles were everywhere triumphant; among other things, they were used to find hitherto unknown planets, Neptune and Pluto.

A few small discrepancies remained. By the early twentieth century it became clear that these were not due to inexact measurements, but represented something fundamental. Einstein produced his theory of relativity, which explained the awkward facts—to a first approximation—and of which Newton's laws were a special case. Relativity in its turn made predictions that experiment was to confirm; the best known is $e = mc^2$.

Thus the scientific method as commonly described. I have simplified the account a good deal, some would say oversimplified. Still, the complications are precisely what raise questions about the method.

To start with, in practice it is nowhere near as neat and rational as it's supposed to be. Kepler, who was quite a mystic, began by attempting to create a numerological astronomy, in which the spatial configuration of the planets was determined by properties of the regular solids. Newton had his insight about the inverse-square nature of gravitation early in his life, but must wait long to publish it. First, he needed to develop an entire new branch of mathematics, the calculus, in order to prove that he was right (and not until the nineteenth century was the calculus put on a mathematically sound basis). Second, the Moon's motion couldn't be fitted into the scheme until better information about it became available. And third, it's lately been shown that he fudged his figures anyway!

At its most creative, science is also at its most intuitive. Thus, de Broglie proposed that matter has a wave as well as a particle character, years before anyone had found experimental evidence for this, on grounds of symmetry; he felt that it ought to be the case. Einstein was never reconciled to the indeterminacy implied by wave mechanics, as in the Heisenberg principle. Darwin did not really prove that natural selection is the driving force of evolution. Freud originally, before he grew old and dogmatic, looked on his concept of the psyche as a set of metaphors, a stopgap until a chemical theory of mental illness could be worked out. The list might go on at great length.

Even at a lower level, what we do, what we observe is conditioned by our preconceptions. For example, Carl Sagan has remarked that the ancient Greeks could have gotten a pretty good idea of the distances of the stars, if they'd assumed that these are like the sun and had measured the brightnesses. (They'd have been in error, because most visible stars are intrinsically brighter than Sol, but it would not have been by a factor as high as ten.) As was, though, nobody did this until the Copernican-Newtonian revolution had given rise to the idea that the stars *are* suns. (To measure the distances exactly was an epic of patience and ingenuity; it used a different method.)

What observations are we failing to make today, or making by chance and dismissing as wrong, because they don't conform to our theories?

We simply cannot give equal weight to everything. Once in a high school laboratory I got results which appeared to show that the conservation-of-energy law wasn't operative that day. However, it was more plausible to assume that my experimental technique was poor. More seriously, chemical tests were made on the Piltdown remains, when they became possible to make, precisely because it seemed Piltdown might be a fake. If Velikovsky's notions about interplanetary catastrophes are correct, then we need a whole new physics, because the events he describes cannot happen within the scheme of the physics we know. This is a major reason for discounting them and looking for alternative explanations of the facts he deals with. Already in the Middle Ages, William of Occam enunciated the principle since known as Occam's razor: that that hypothesis is most likely to be right which makes the fewest postulates of a basic nature.

As a homely example, from time to time I have had things disappear, and occasionally reappear, in mysterious ways. The most intriguing case may be when the latest chapter of a book, which was in the first-draft stage of writing, vanished. I'd finished it the day before. Next morning it wasn't on the heap of manuscript, nor did it ever turn up in spite of diligent search. I finally had to write it over.

If I must try to account for this, it's simpler to suppose that I suffered a lapse of memory, or a one-shot burglar with peculiar tastes came in during the night, or something comparable, than it is to suppose the chapter was stolen by a collector who lives in hyperspace. After all, we have no other reason to believe in an inhabited hyperspace, and much reason not to.

In practice, what I have said is: "Insufficient data. It is impossible to form a hypothesis which I'd have any chance of testing."

Testability, also called verifiability and confirmability, is a basic criterion which did not become explicitly accepted until this century, when revolutionary new theories forced an examination of the foundations of science itself. Thinkers had always agreed that we can never establish a final proof of a scientific idea; nature may always surprise us. (So observation and Einstein showed that Newton hadn't been quite right, Pioneer flybys showed Jupiter is hot rather than cold, recent finds cast doubt on the "African genesis" of man, the thymus gland turns out to have a function after all, etc., etc., etc.) The new requirement was that, to be meaningful, an idea must be capable of being *disproven.*

For instance, in the nineteenth century a "luminiferous ether" was postulated as the medium which conveys electromagnetic waves such as light or radio. Michelson and Morley then tried to detect Earth's motion through the ether. They should have; their apparatus was sensitive enough. But they failed. Numerous attempts followed to explain this. The upshot was that the ether, if it exists, must have such properties that there is no possible way to detect its presence. In that case, what does it matter whether it exists or not? As William James had already said, "A difference must make a difference to be a difference." According to the new criterion, "ether" was not just a concept proven false by experiment, as "phlogiston" had been. It was a concept devoid of meaning, like "the blueness of sideways."

The application of the testability principle is reasonably clear in physics, though some ambiguities remain and, as we shall see, some of these are crucial. It is not at all clear in the less exact sciences.

For example, while we're reasonable to suppose that Neanderthal man had a well-developed language, since he made tools and buried his dead with some ceremony, how can we ever prove or disprove it—and what about more primitive predecessors, Homo erectus or Pithecanthropus? How can you show that psychoanalytical entities like the ego and id are real, not mere figures of speech? More importantly, how can you show that they are not real? What kind of evidence could you produce which a psychiatrist could not explain away? (This is not to denigrate psychiatrists, who are doing the best they can in a field where little is known. It's only to suggest that what they employ may be less a science than an art . . . and certainly man does not live by science alone.)

The issue becomes acute when we examine claims made under names like "ESP" and "psionics." Some enthusiasts insist that these involve phenomena which can never be manifest under controlled conditions. Does this statement have any content or is it empty noise?

Suspicious though it makes me of these particular assertions, I cannot deny that there are real things aplenty about which it is probably inherently impossible for us to learn anything. What sound did a certain proto-man utter when he first deliberately kept a fire going for his own use, if that is what he did? Or was it a proto-woman, or a group, or what? The list of such questions is endless. Either we refuse to admit they are genuine questions—which brings us dangerously close to Bishop Berkeley's world-in-your-head; indeed, it was radical empiricism which forced him to that position—or else we confess that the verifiability rule has its own limitations.

Returning to the realm of science, I've already mentioned that Heisenberg's uncertainty principle never felt right to Einstein. Here we get down to philosophical bedrock. If there is *in principle* no way for us to determine exactly what a particle is doing, and hence calculate what it will do, how can we speak of it as being governed by natural law? Can't we just as well say that what it does is random (within limits) and that cause-and-effect doesn't apply? If so, the very basis of science breaks down, the axiom that the same kind of conditions always has the same kind of consequences and that we can discover the relationship.

Conventionally, those who accepted quantum uncertainty nevertheless felt that it was strictly a subatomic phenomenon. While we may not be able to predict how a given particle will behave, we can ascertain what the odds are that it will do this or do that. Accordingly, given a very large number of particles—which is always the case in the "macroscopic" world—the statistics guarantee that a particular state of affairs will be followed by another which is predictable.

Chance had already been subsumed into classical physics. We can't tell what a single gas molecule is going to do; too many other molecules and energies are acting upon it. However, given multiple trillions of molecules, their collective behavior becomes quite orderly, and we can design steam engines or airplanes with confidence that the atmosphere will perform as it is supposed to.

There is a negligibly small, yet finite chance that a lot of molecules will simultaneously fly off in a given direction or something like that. In such a case, we'd get a curious event like a kettle of water, set on a fire, freezing rather than boiling. The odds against it are more than astronomical. Besides, if it did come to pass, this wouldn't prove that natural law was invalid, only that an extraordinary set of circumstances had occurred. As a rough analogy, if you tossed a coin you might by sheer happenstance get fifty heads in a row. This would not indicate that each individual toss wasn't governed by the various forces of your hand, the air, and other environmental factors. It would only show how little you really knew about these. To be sure, you might suspect the coin was biased, and on examination you might find this was correct; but that simply makes the determinism more obvious.

The trouble is, gas dynamics or coin tossing offer no real analogies to quantum physics. "Chance," in the sense of unpredictability because of lack of complete knowledge, is not the same as "chance" in the sense of unpredictability because it is forever impossible to have complete knowledge. Repeat: on the subatomic level, there is absolutely no way to trace cause and effect, nor can there be.

Nor can we take refuge in the statistics of large numbers, at least not philosophically. As a melodramatic illustration, consider an atom of a radioactive element. At an unknowable time it is going to emit a charged particle in an unknowable direction. Given a great many similar atoms, we can tell exactly what the rate of decay will be and that—unless prevented—the decay particles will radiate outward spherically, as the light of a star does. Now, though, we are talking about a single atom. Its fate may seem insignificant. Ah, but let's surround it with Geiger counters. (This is technologically possible nowadays; we could use a mass spectrograph to isolate it and place it onto a surface.) Some of these counters will emit harmless clicks if the decay particle passes through them, but some are wired to amplifiers which will, in turn, detonate an atomic bomb planted beneath Washington, D.C.

Whether we get a click or a devastating explosion becomes a matter of pure chance, in the sense that nothing predetermines what will happen. Also, of course, the time is undetermined. If Washington is destroyed, it might occur when the President and Congress are on hand, or it might when they aren't, or it might not happen for another million years . . . and so on and on, with obvious human consequences in every case.

Einstein had subtler and more fundamental things in mind than this, but our scenario does perhaps suggest why he insisted to the end of his life that indeterminism could not be real, that "God does not play dice with the world."

Now, ironically, his own relativity, as developed further by others, gives cause to think that indeterminism, raw chance, may operate on the cosmic scale too, and that even among the stars there may be things we will never know because there is no possible way we can know them.

Most science fiction readers have learned something about black holes. When a star of sufficiently large mass—the minimum is, roughly, three times the mass of Sol—collapses after its death as a supernova, the gravitational field gets ever more intense. At last, as collapse continues, gravity becomes so strong that light itself cannot escape. In the relativity scheme, it then becomes inherently impossible to observe what is going on within the "event horizon," the volume out of which nothing can come.

Well, almost nothing. Some particles can emerge by "tunneling" through the "potential well"—which is to say that, precisely because its position is not governed by causal laws, a particle has a finite chance of being outside the region which it was in before. This process is important in nuclear physics and has found commercial application in the tunnel diode. It would cause the gradual melting away of small black holes, if any were formed in the early stages of cosmic expansion, as Hawking has suggested. It would be measurable around large black holes, though not significant. In either case, being random, it would tell us nothing about their interiors.

These objects seem to violate several key conservation laws. Worse, as densities within them get higher and higher with further collapse, less and less of what we know remains true, conditions are so enormously alien. At last they reach a state of affairs known as a singularity, which our very mathematics cannot handle. This is the worst of all.

It is conceivable that naked singularities exist: regions where such anarchy lacks a surrounding black hole mass to shield the rest of the universe from it. In that case, as Heinlein put it long ago in *Waldo,* "Chaos is King, and Magic is loose in the world!"

Even if this is not so, the situation is bad enough for the determinist. Relativity theory leads to the conclusion that extremely dense, extremely fast-rotating masses generate forces of peculiar kinds. Some of these act in a straightforward fashion, e.g., like an odd kind of gravitation. Others don't. Kerr has shown that they may open the way to a sort of spacewarp which might even permit faster-than-light travel. Tipler has shown that they may open the way to a sort of time travel.

I should emphasize that neither of these men, nor any other serious worker, says that this *is* true. They're quite properly cautious. For instance, Tipler has demonstrated that time travel cannot happen under any conditions of spin and density that we know to be possible.

Yet, speaking for myself, I might remark that conditions in the near neighborhood of a singularity are special, and we know little more than that. . . .

Maybe science is not at the point of discovering the basic limitations of nature. Maybe, instead, it's at the point of discovering its own basic limitations. If so, that could bring about a revolution in human thought as thoroughgoing as science itself did during the last three centuries. It might also, imaginably, open capabilities to us of which we have hardly dared dream—or lead us into strange experiences—

Too long has science fiction confined itself to a standardized set of concepts. The time is overpast for us to widen our horizons, and to think what this could mean. ●

BOOKS

Here is not a formal bibliography of the philosophy of science, which has an enormous literature, but a list of a few more or less popular treatments which I have found especially readable.—P.A.

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