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Destinies

Edited by JAMES BAEN

THE PAPERBACK MAGAZINE OF SCIENCE FICTION AND SPECULATIVE FACT

POURNELLE
SHEFFIELD
ING
ANDERSON
BENFORD

WELCOME

to this the final issue of *Destinies*. As promised we lead off with a double barreled offering from Charles Sheffield: the cover story, "Summertide", is a fictional extension of the skyhook concept, told, if you will, in a psycho-adventure motif; then, with fellow astro-physicist Yoji Kondo, Charles examines the theoretical limits of orbital astronomy. You will be amazed. Next Dean Ing, in the culmination of his Nuclear Survival series, shows how life can be made livable after WWIII. The first step is "Stocking Your Tenacity Chest." In the event that we avoid a nuclear exchange, nuclear wastes will remain an issue, or "Waste Not, Want Not," as Karl Pflock puts it. Fred Pohl takes the guessing out of guesswork in "Programming the Future", and as a grand finale Poul Anderson reflects on being a science fiction writer, and on being Poul Anderson, in "Ramblings."

On the fiction side, as well as the cover story we have "Slices," in which Gregory Benford, this year's Nebula winner for best novel, speculates on high-tech pornography; we have Davide Drake on location in the Upper Cretaceous in "Time Safari"; David Langford looks at the possible meanings of "Sacrifice"; and in "Where Thy Treasure Is" Fred Saberhagen considers what's worth sacrificing for.

At this point I have always in the past slid into a teaser for the next issue. But there is no next issue. This is it.

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In all pieces of fiction in this book, all characters are fictitious. Any resemblance to actual persons, living or dead, is purely coincidental.

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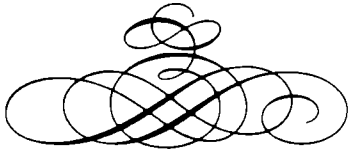
SLICES

Gregory Benford



In the end, it was just another ...job.

I.

Even though he has learned it by now, the seeping sensation, the rich tingling comes to him each time: *something more.* No mere bauble, no toy, but the real thing: experience. They will give it to him again. He feels his mind drift to the subject this time and, yes, there it is, something he wants, something—yes, a woman. Again, a woman. Soft and with the by-now-familiar black hair, coming toward him with hips weaving that certain way, eyes intent and flickering with concern (there must always be concern) and the round enveloping fullness, the breasts, all that is there. She swarms over him, without his beckoning, without really even willing it. She is a fog of sensation and he feels her filling him, fluid up his nostrils, clotting in his eyes, piercing his anus *yes she does that* and more, onward, fibers lancing into him, his nerves giving back a smooth chorus of caressing pleasure as he enters her in turn, *yes,* this is it, this is

what he wanted, how like them to know it.

2.

In the silent drifting times he wonders. There are not many such times but, almost pedantically, he times them by the thumping of his heart—at least he thinks that it is his heart—and deduces that they allow him only a few black spots in a day, a mere handful, and yet in time he has come to treasure them more than the—

3.

This one is scarlet, flesh aflame, he sees her by a riveting light that seems to make her face distort, stretching until he cannot be sure it is an optical effect—they use those often—or whether in fact the women are now becoming more distorted, grotesque. Or is it his taste that is changing?

4.

The jokes go on and on, each one better than the last and yet strangely all the same. First small quips, and then one-liners that seem to come from Wilde or Noel Coward, all good but not gut-busters as his father used to say, and then on to the situation jokes, even ethnic jokes (how did they know?), odd stories that seem to mean nothing until the end and then he finds him rocking back and forth in his chair, when moments before he did not even know he was sitting, had no sensation at all, but now feels himself convulse with laughter and curl up, clenched—

5.

Pressed duck, thick with the burnished sauce; gauzy flavors from southeast Asia (strange, he

thought all that fell long ago); slick fish that goes down easily; cloying scent of garlic in the fat noodles; deeply marbled steaks, glowing red, quick with juice; warm and aromatic sauces slathered over the half-open carapace of the blue-armored thing—it tastes gooey, rich, with a coolness behind the first spicy rush that comes exploding into the mouth, almost drowning the palate; bitter, like old beer, flat but pungent and he cannot get it out of his mouth; the slitted gut of the cow is swarming with maggots but he dips in, choosing carefully among the moving white things, the brown matter coming up on his spoon; dry but light, quenching, quite a nice wine overall when you considered—but he stopped at the thought, did not consider, and ate on; on.

6.

He knows now why they do it, why there are the drifting silent times to let him rest, but he cannot remember from one intense time to the next what the answer is, what they—

7.

The woman is fat and he cannot go on with her. He rolls off her slipperyness, though until this moment there has not been any gravity, feeling her softness yield under him, no this is not it, a failure, he hopes they know that this was not his fault, she was not the right kind.

8.

Yes, that must be it, these are the reward sessions, they are paying him off for some enormous and complex job he does for them. He feels this is right, feels a sudden certainty that burns away all that has happened before, all the gushing stuff that filled him

up, all the gut-deep sensations that he thought he could not hold but always finally did. Yes: he cannot remember the job, does not know what it is, and that is precisely why these hammering long sensations, these dreams at last come home, are so effective. These slabs of excess release him. He feels himself set free by them and thus, the logic is immutable, thus he is fully free when his real self goes back to the job, whatever it is, that they press him to do. He must be very valuable and the job must be of that dark kind he has heard whispered about for years, heard mention of across tables in restaurants but never any details, it must be that. And this is his time off, the moments when the psyche is launched so that the upper mind can go on, yes.

9.

It is a man this time. He comes into the booth where the pictures are showing on the big flat screen, the playlet just starting after the quarter has dropped in, clinking in the stillness. There is the usual conversation, a few words, and then the loosening of the belt and he feels himself nod, the hand on him, and the screen seems to fill his eyes. The soft sound comes up to him, the oval into which he is falling, he is becoming harder because they both know that this is what he really wanted all along, as the flesh forms move and slide on each other before him, he feels the strength and swelling energy of himself about to do what he always—

10.

Running, sheer empty running, on the beach, the quick clench of the calves as he digs into the sand and the air cuts deeply into his lungs, a simple moment when he hangs suspended at the top of an arc,

the stride tilted forward and forever coming into completion.

11.

Soft fragrant matting, he glides over it and lets it fill his nostrils, the silky radiance of it becoming the air around him, penetrating him, ass and nose and mouth, streaming, as he slips down a stream bed of fur.

12.

He tries to hold onto the information about the tasks he performs. As the long spaces of sensation get longer, seeming to stretch out as he enters them and cannot escape, he struggles for a strand of memory. The job. Pilot, yes, pilot, on harrowing and lonely missions, seeking some electronic solace on the long flights between planets which must have some relief or else he would go mad.

13.

He breathes in the coiling acrid smoke and finds it good. The long pipe, the oily sensation of fullness, the cushions under him, yes, it is all very pleasurable, very Asian, he thinks, and he knows this is another way they have of distracting him from the enormity of his tasks, of what destiny calls him to do daily, leaving only these obliterating sessions when he is released of the burden. He thinks of this and has to be distracted again by the smoke.

14.

Water, washing away all the memories, waves breaking over him until he learns to ride them, to match velocities with the looming mountains of toppling water and pick up energy from their headward

lunge, struggling to stay on top of the foaming white. It fills him with zest and he lances an arm through the wave to vector left, feeling the wind blow stinging salt into his brimming eyes.

15.

Computer specialist, that is it, it would explain the recurrent dreams of cascading mathematics that he sees at—but no, not dreams, there are no nights, so they must be a memory, something from the job. Unless they were a pleasure in themselves. Could it be that anyone got something out of those lattices of symbols? No, it seems improbable (and he is a believer in probabilities). The busy squiggles of the equations must be part of the job.

16.

This one is fat, conical. He thrusts himself in viciously. A wracking pain fills him, swells into his throat, and brings him to a curious, lurching orgasm.

17.

As he gives the speech beneath the hot, glowing lights he feels the power surge through him knows that he can turn this crowd any way he likes, senses their need of him, and beneath the immediate sensation the thought comes: this is it, a true memory, the thing they seek to ease him of. This is the task that he must flee, in these dark times. This is the job.

18.

She thrusts it into him and he curls about it, taking it, slippery but welcoming, moist, knowing that this must be part of it, too, as she lunges into him again and he spreads for it, willing.

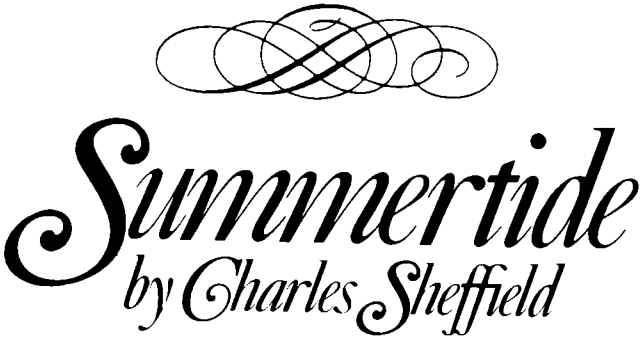
19.

Falling, cutting through the billowy moist stuff, carving the clouds, he is at last free, knows this will help him when he returns to his rightful place at the center of the vast and complex enterprises which spin about him when he is fully conscious, when he is at his job.

20.

He feels the seeping back of consciousness like burning fog, and then swarming damp sheets, rumpled and disturbed from a long sleep, and then there comes the bright cutting light, lamps—*you have a break coming up*—so he relaxes on the bed, not daring to open his eyes, because the excitement is welling in him, he knows that he will come into his real world when he opens the eyes, he will be at his job and everything will clarify—*might as well take it* —and in a burst of energy he opens them, sees the cheap pasteboard walls and the tangle of wires and cables like thick ropes, all winding around the narrow bed—*hey you know you got another coming up in fifteen minutes, might as well get up an' walk aroun' a little*—and sees his friend, the other hourly employee who occupies the next telemetery-studded bed, and knows that whoever used his body as somofilter for the canned sensations is gone, the customer is already paying up at the cashier outside, probably a session caught on a stopoff during commuter hours, fifty bucks to tap into someone who can take the shadowy contexts that the senso tapes provide and transform those one-dimensional echoes into vivid life, into someone who really knows how to feel and does it by instinct, can give them the intensity that most of them never know. *Hey you're lookin' kinda worn down* and he grins wryly. *Well the money's good*

anyway, and indeed it is, far better than he could get otherwise, without this talent. He presses his face into his hands, not minding any of it, really, because in earlier days he would have been dismissed as a useless manic type, blown helpless before whatever emotional winds prevailed, but still—He had hoped the riveting moments would release him, as well as the passing customers. He rubs his eyes, feeling the grit in them, and marvels that the customers can be so easily satisfied by these mirages, no more lurid than the world he ordinarily inhabits. What he wants is in the dreams, too, but now he sees that it cannot ever be satisfied, he is transfixed in worlds that others lust for but now imposes on them his own fantasy, and thus has become a customer, too, seeking what is impossible: the pride, the job.


Summertide
by Charles Sheffield

The more you have, the more you have to lose...

"Genocide?" My tone showed my disbelief.

Governor Wethel shrugged his shoulders at me in an embarrassed way and turned to his companion without trying to answer me.

"Perhaps you should explain this, Dr. Rebka."

"I intend to." Rebka was a small, thin man, with sharp grey eyes and a long, mournful mouth. His voice was dry and even, with just a trace of accent to reveal that he had not been raised in our System. "Cooperation from both of you will be essential, and I know that I could not command it here for any ordinary crime. Did Governor Wethel tell you where this journey began?"

I nodded. Wethel had time for that and for little else when he had linked through from Cloudside, to tell me that he was flying over, top priority, with a visitor.

"I understand that you were on Lasalle—Delta

Pavonis Four. I wondered what a Section Moderator could be doing there. All it has are marshes and Zardalu."

"Not quite right." Moderator Rebka's voice had become flatter yet. "All that Lasalle has now are marshes. The Zardalu are extinct. The last surviving members—two lodges—died two Earth-months ago. The people who killed them escaped from the Pavonis System long before I got there, but I have been able to trace them through four jumps. To here."

I took another look at Sector Moderator Rebka. For the first time, I stared hard at the symbols on the gold cluster fixed to the sleeve of his black jacket. Inside the main pattern was a tiny seven-pointed star. Why hadn't Wethel told me that Rebka belonged to the Species Protection Council? He might be polite enough to ask for our cooperation, but if Rebka wanted to he could do just about anything he liked—including taking over my job or Governor Wethel's.

I looked again at him, but I could see little sign of the exceptional qualities that his position suggested. He was still the same short, thin stranger, with an unimpressive voice and carriage. Now for the real question: what could Rebka's visit here, over on Quakeside, have to do with his search? All the administration of Dumbbell was back over on Cloudside, where he had just come from. They had the police headquarters, the inter-system coordination, and the only interstellar spaceport. I began to feel uneasy. It was less than twenty Days to summertide maximum, and I had no time to spare for visitors, no matter what their mission.

The other two were still looking at me, waiting for my response to Rebka's information. I shrugged.

"I'm shocked to hear about the Zardalu, but I don't see how I can help you. The people who killed them came to Dumbbell, I'm prepared to believe that. But they'll be over on Cloudside, not here. As Governor Wethel could have told you, we have no place for them to hide on Quakeside—all our towns are too small, and the land is all monitored. Are you sure that they landed on Egg at all? Suppose they took off again and were hiding out near Perling?"

Looking at Rebka's baffled expression, I realized my mistake. His accent was slight, but it was clear that he didn't know this System—the names were missing him completely.

All the reference texts outside the System tell the inquirer that Eta Cassiopeiae A has the double planet, Dobelle. It was named after the captain of the ship that made the first scout survey. The components of Dobelle, the twins of the planetary doublet, were logically named Ehrenknechter and Castelnuovo-Kryszkoviak, after the other two men on the scout ship. The records don't tell us how long the first settlers struggled with those jaw-breakers, but well before I was born the two components had been renamed Quake and Egg, and no one in the System ever used their official names—except for formal outside communications. And as soon as the connecting umbilical went in between the two, the name of the planet pair, Dobelle, had naturally slid over into Dumbbell. Only Perling, the gas-giant planet that circled Eta-Cass A seven hundred million kilometers out, had managed to hold on to its original name—probably because no one ever went there.

Governor Wethel jumped into the conversation again, putting all the names I had used back into their official forms. When he had finished, I got an-

other hard look from Rebka and a shake of the head.

"No. They did not go to Perling." He sat down in the chair over by the curved window, his manner stiff and serious. "Please assume that I know how to do at least a part of my job, Captain Mira. Before I came to Dobelle I checked that the fugitives were neither near Perling, nor out by the dwarf companion."

I nodded. I couldn't see anybody trying to hide near Eta-Cass B, there was nothing there but a few orbiting chunks of rock. "But what makes you think they landed here on Egg?"

"No doubt about it," chipped in Wethel. "I looked at the landing records when Moderator Rebka called me. I found we had a jump ship land at Cloudside, twenty Days ago—and it's still there."

"But its passengers are not," said Rebka. "They landed on the other side of this planet—Cloudside?—and they are not there now."

He reached into his pocket and pulled out an ID pack. "Two people were involved in the death of the Zardalu. They were visitors to Delta Pavonis Four, first-time visitors on their way from Peacock A to Sol. They stayed there only one day. Have you seen anyone who looks like this over here in your area? Within the past twenty Days?"

I flicked on the ID pack and looked into it. I had a sudden shock of false recognition. For the first moment, the young woman who smiled at me from the pack was Amy—my Amy.

I looked on, and the thrill faded. The obvious differences were there—how had I failed to see them at once?—and they brought me back to normal. The young woman I was looking at was older than Amy, and she wore a deep tan that no one ever acquired

on the cloudy side of Egg. It must have been her clothes—clothes that matched Amy's preference exactly. Dark green and russet, cut low off the smooth shoulders and matching her auburn hair. That, and perhaps something in the smiling eyes, a message of life and laughter that carried through the impersonality of the ID display.

After a few seconds I realized that I had to speak. Rebka was looking at me, and into me, in a way that had to be avoided. I stared back into his eyes and shook my head.

"I don't know her—but if she had been here, I assure you that I would have noticed. Surely this isn't one of the criminals?"

He nodded his head slowly, eyes still locked on mine. "I am afraid that she is. You are looking at Elena Carmel. She, together with her sister, killed the Zardalu."

I couldn't imagine it. Not someone who looked so young and vulnerable herself.

"Could it have been an accident?" I peered again into the depths of the ID image. "I thought that the Zardalu were still in a probationary state—marginally intelligent."

"They were. It could well have been an accident."

"But you still accuse them of genocide—when the Zardalu may not have even been covered by the Species Protection Act."

"Of course." He sighed. "Isn't my position obvious to you? Most of the Zardalu were killed before their potential intelligence was recognized. Killed by humans. A human Moderator is assigned to this investigation—perhaps that was a wrong decision, but it was made. Don't you see that I am obliged to assume the worst? There must be no suspicion on the part of any other Council Member that I sought to

cover a crime—even a potential crime—by one of my own species. That would mean the end of the Council. But apart from that, I would pursue them anyway. The death of the Zardalu must be investigated, even though nothing that I do can ever bring them back. They are gone forever."

Rebka's voice was bitter. He was that rarest of all humankind, a man who felt as strongly about the protection of non-humans as he did about his own kind. I was beginning to realize what it took to be a member of the Species Protection Council.

"Do you have an ID pack for the other sister?" I said, breaking a long silence that made us all uncomfortable, but which no one seemed willing to end.

"Of course." Rebka shrugged. "I will show it to you, but it will do no good. If you did not recognize Elena Carmel, you will not recognize Jilli Carmel. They are identical twins."

He handed me a second ID pack. The features were identical, that was undeniable. Yet there were differences, ways in which I thought I would know them apart—and I don't mean the superficial things, such as the styling of the auburn hair. Jilli Carmel had a slightly different expression, a trifle less confident and extrovert than her sister. Reluctantly, I handed it back to him.

"I don't know her. You and Governor Wethel seem confident that they are not on Cloudside. I'm at least as sure that they aren't here, on Quakeside. So where does that leave us? Wherever they are, it's not anywhere on Egg."

"He means anywhere on Ehrenknechter," explained Wethel, then bit his lip.

Rebka had frozen him with a look. Wethel passed it on to me, as a grimace of disgust—self-disgust. He had already explained once to Rebka that the twin

planets had been re-named, and the Moderator was not wearing an Ampak at wrist or throat. That meant that he was undoubtedly a mnemonist, with perfect recall—but Klaus Wethel had unfortunately made that deduction a fraction of a second *after* he had spoken.

I gave him a consoling wink, as Rebka went on, "I agree with you. They are not here on Egg. Six Days ago—two Earth-days—they left this planet and went across to your companion world. They are now on Castelnuovo-Kryszkoviak—if you prefer it, on Quake."

He smiled this time at Wethel, to take the edge off his words.

"Never," I said abruptly. Klaus Wethel looked horrified, that I should be so terse with a Sector Moderator, but Rebka did not seem at all perturbed.

"And why not?" he said. "I had a good look at the other component of this doublet as we were flying in for our approach to the Dobelle System. It is almost wholly undeveloped, is it not? I have no doubt that the Carmel sisters believe that they can hide there safely, perhaps until I am called away for other duties."

I looked over at my calendar and shook my head. Eighteen Days—six Earth-days—to summer maximum. I felt sick inside, a heavy feeling of nausea that the situation could not justify. The ID packs had upset me more than I would have thought possible. I looked back at Rebka, sitting upright and serious in my visitor's chair.

"What is the Species Protection Council punishment for genocide?"

He looked uncomfortable. No one with his degree of empathy for other beings could feel happy at the discussion of penalties.

"The maximum punishment?" he said at last. "For proven intent, which I hope we will not find to be the case here, it would be third level rehabilitation."

He caught my questioning look.

"Erasure," he went on. "In a bad case, of all adult memories."

I nodded. "But never death, even in the worst cases? Even if they acted with full knowledge of their crime?"

Now he looked as sick as I felt. He swallowed and stared off into space, unable to meet my gaze. Klaus Wethel gave me an angry glare.

"No," said Rebka at last. "Excuse me. I had forgotten that many things are different on the frontier planets. The idea of death as punishment is not completely unfamiliar to me, but it is still not something that I can regard without discomfort. It has not been practised in—other places"—I felt that he had almost said civilized places—"for many years."

"Then I'm afraid I must give you information that will make you unhappier yet," I said. I pressed the button that would make the big dome above our heads move to transparency. "Elena and Jilli Carmel must have had the same impression of Quake as you did, that it is an undeveloped area where they could remain in safe seclusion. But if they are on Quake now, and stay there, then it doesn't matter if they are guilty of genocide, or as innocent as you are—they're dead, both of them, within a few Days."

The dome had become completely transparent. I felt sorry for Wethel, with his severe agoraphobia and acrophobia—I was hitting him with both of them at once, but I had to do it. I saw him, as though against his will, slowly turning his head to look upward. He knew what he was going to see, but

he couldn't force himself not to look.

It was just past the middle of the Second-night on Egg, and as usual at this time of the year the night sky over Quakeside was clear. Directly above us, fully illuminated, hung the bright orb of Quake itself. The building we were in was not far from the center of Quakeside, at the pole of Egg closest to Quake. We were only about twelve thousand kilometers away from the other planet's surface. From where we sat it filled more than thirty-five degrees of the sky, like a great mottled fruit, purple-grey and overripe. It was easy to imagine that it was ready to fall on us. I saw Rebka follow Governor Wethel's reluctant upward look, and flinch when he saw our sister planet.

"Steady," I said. "Don't get alarmed by the way it looks. You know the dynamics as well as I do." I was really speaking for Rebka's benefit—nothing I said could make it any easier for Wethel, he had heard all the logical arguments before and they hadn't helped. "Remember, sir," I went on. "Quake and Egg have been playing roundabouts like this, circling each other this way, for nearly half a billion years. They won't decide to collide tonight for your benefit."

It helped me to know that Rebka had something else on his mind other than seeing through my own psychological defenses. And it said something for the man that he didn't let that first sight of Quake in the sky unnerve him for more than a few seconds. He seemed to focus himself inwards, then dragged his eyes back from the zenith and frowned at me.

"That's an impressive sight. No wonder you keep the dome opaque most of the time. But what do you mean, the Carmel sisters are dead?" He couldn't be distracted from his main interest for long. "I looked

at Quake through high power scopes," he went on, "as we were flying in. It didn't just look undeveloped, it looked like a garden planet. Are you telling me that there are dangerous life forms there?"

"Nothing that you couldn't handle with a hand weapon—and nothing that's dangerously poisonous, either. But Quake's a death trap at this time of the year." I swung the big telescope across towards us and switched on the viewing screen. "Take a look at it for yourself. Compare it with what you saw when you looked a few days ago. Can you see any differences?"

Under a 1000X magnification, it was as though we were hovering a little more than ten kilometers above the surface of the planet. We could see all the rivers and plains of Quake, even the larger of the mines that provided Egg with most of its metals.

Rebka leaned forward and frowned at the screen, while Klaus Wethel did his best not to look at anything—fear of falling was even more intense from ten kilometers than it had been from twelve thousand. It had been a bad thing to do, opening the dome on him. Now I'd have even more trouble than usual to get him to ever come back to Quakeside.

Rebka nodded. "It looks different," he admitted at last. "I have no idea why, but the colors all seem to have changed since we came past it on the way in, more than I would expect from a change in viewing angle or sun angle. How could it have changed so quickly?"

"Did you look at all at Dumbbell's orbit before you came here?" I asked. "I thought not. We're less than six Earth-days from perihelion—from midsummer. Our seasons here on Egg, and on Quake, are caused by distance from Eta-Cass A, not by axial tilt the way they are on Earth. Dumbbell sweeps in

pretty close—the orbit has an eccentricity better than 0.3. Here on Egg we have good protection from the cloud cover, but Quake doesn't have that. Right now all the vegetation there is getting ready for the summer. The plants die off above the ground, and all the root systems dip deeper for the cooler layers. They go down twenty meters or more."

Rebka was looking sicker than ever. "Are you telling me that the Carmel twins will die of the heat there? What do the native animals do in the summer?"

"They dig deep down, and they estivate."

"Then the Carmel sisters will dig deep down, too. They probably have a good refrigeration pack with them." His expression was now relieved—genocide or not, his first worry at the moment was the survival of his quarry. "They only need to survive a few Earth-days of heat."

"True enough, and they may have counted on that." I hated to do this to him, but he had to know the truth. "It gets really hot there on Quake, but it's not the heat that will get them."

We had seen enough of the other planet, and I cut the transparency of the dome back to full opaqueness. Klaus Wethel drew in a long breath, and began to take an interest in the discussion for the first time in the past ten minutes.

"The heating of the surface goes up like the inverse square of the distance from Eta-Cass A," I went on. "But the tidal forces go up like the inverse *cube*. Quake is smaller and heavier than Egg, and has much more of a liquid core—the radioactives keep it that way. At summer maximum, when the tides hit their peak, the whole surface shakes like a jelly. Why did you think that the first settlers called it Quake? It's the 'quakes and volcanoes that will kill the Carmel sisters."

It took Rebka less than a minute to digest this new information, and factor it into his main objective. The conclusion he drew was one that I was most afraid of.

"So we have very little time before Quake becomes uninhabitable," he said. "We can't leave them there—they obviously don't know any of this."

"But are you sure they *are* there?" I was really playing for time, and Rebka saw right through me.

"I am convinced of it. How difficult would it have been for them to obtain passage along the umbilical?"

"Not difficult at all." I shrugged. "We don't check the outgoing pods, and if a couple of people climbed on board an empty cargo container we would never know it."

"So they are there." He obviously was not prepared to discuss that issue further. "We have six Earth-days to summer maximum, you said. That ought to give a party ample time to go up the umbilical, locate the Carmel sisters on the surface of Quake, and bring them back here. I assume that you have no bad tidal problems here, even at midsummer?"

"Slight tides," I said. "Nothing to worry about."

My mind was still engaged on Rebka's last words. Up the umbilical, cross to Quake, pick up the girls and back over to Egg—just like that! He had no idea what he was proposing. I had been there, and I knew. He saw my expression, but he misinterpreted it.

"We do have sufficient time, don't we?" he said.

"If we start at once, we may," I replied. "Even so, it would be touch and go. Quake gets less and less predictable the closer we get to summertide maximum. This is the busiest time of the year for me,

trying to make sure that we get the mining operations all closed down and packed up the umbilical for the summer."

He ignored that, too. "The party ought to be a small one," he said. "It must have an experienced man, someone who has been on Quake before for the summer."

He turned to Wethel, who was looking at him with horror. "Governor, do you know anyone on the planet who has had summer experience of Quake?"

Klaus Wethel's face turned red—he had never learned how to lie, which is curious when you think that he had reached the position of Governor.

"I'm afraid not, Dr. Rebka," he said, looking anywhere except in my direction. "No one makes summer trips to Quake."

"Thanks, Klaus," I said. "But it's not necessary." I thought again of the happy young faces in the ID packs, and the images of the Carmel twins were overlain with Amy's smile. I turned to Rebka.

"So far as I am aware, Councilman, only one person on Egg has made more than one trip to Quake during summer maximum."

I suppose you don't get to be Sector Moderator without a lot of brains, and you don't get on the Species Protection Council without other qualities as well. Rebka was too sharp for his own good, and he had read something else out of my tone of voice that I didn't know had been in there. He gave me a strange look from those steady grey eyes.

"And how many times have you made that trip, Captain Mira?"

"Three." I took a deep breath. I don't think that I looked down at my hands, but maybe I moved them or something. Rebka was staring at them, at

the shiny pink of rebuilt skin and scar tissue. I wanted to put them behind my back.

"I was there five years ago," I said at last. "And I also made visits there four years ago and three years ago."

And since then, I felt like saying, with the help of people like Klaus Wethel I have managed to find other ways to control my misery. But I didn't say that—I had never said it to anyone. In Rebka's case, I'm not sure that it mattered. He had such strong antennae for other people's emotions that I felt he was reading everything out of me anyway.

"I think perhaps you have been there too much already," he said after a few moments. He looked across at Wethel. "Wouldn't you agree, Governor?"

Klaus looked at him gratefully. "I agree completely, Councilman. I do not think that Captain Mira ought to risk another trip. Last time he was very lucky to escape with his life."

That was a matter of opinion.

"I'm going," I said. I stood up. "There will be danger on Quake, and I at least have a good idea where it will come from. But the party should be kept small: I, and my second-in-command. He has not been there at midsummer maximum, but he knows Quake well."

Rebka stood up too. I should have known what was coming.

"No," he said simply. "I cannot permit anyone else to usurp my duties. I must go also." He turned to Wethel. "Captain Mira and I will make the trip. I know you are feeling that you must volunteer too, but I will not accept that. When we return, you and I must spend more time together. The fears you felt when Captain Mira opened the dome are curable. I will show you how to do it."

So he had seen that too, despite his own instinctive reaction to the first sight of Quake in the sky. I wondered how much else he had seen that I thought was hidden.

"I will need a few minutes to prepare myself," went on Rebka. "Then we can go as soon as you like. No arguments," he added, seeing that I was about ready to speak again. "It is my duty, remember, to follow the Carmel sisters, *wherever* that may happen to lead."

I suddenly realized that Rebka was also a driven man. Into the jaws of Death, into the mouth of Hell —it didn't matter where, if his duty told him to go there. I nodded without speaking, and he turned and walked quickly from the dome.

Klaus Wethel was still sitting in his chair. He showed no sign of leaving with Rebka.

"No need to stick around here, Klaus." I knew he would rather be back on Cloudside. "Why don't you head back?"

He stood up and came over to stand directly in front of me. "Marco, you have a chance that you may never get again. Don't miss it."

That was a bad sign. Klaus Wethel never called me by my first name unless he was feeling very uncomfortable. I looked up at him—he was about five centimeters taller than me—and tried to look puzzled.

"Chance for what?"

"Don't act dumb, Marco." His face was getting red again. "You'll probably not meet another Sector Moderator—especially one who is on the Protection Council—in your life. If anybody can sort you out, he can."

"Sorry." I turned around and started out of the room. "There's nothing that Rebka can do for me.

Nothing that I want him to do for me, either."

I don't think I lie any better than Klaus Wethel. But I'm not the Governor of Egg, so I don't usually need to. And if I do lie, I hope that my face doesn't go red. I wondered how skilled a Sector Moderator had to be at carefully calculated misstatement. From the look of Rebka, he could do anything that he chose to.

I resolved to watch myself very closely in the Days ahead.

There was more preparation than Rebka had expected. It took nearly two Days—fifteen Earth hours—before we were ready to go over to the foot of the umbilical. Even on Quakeside, the heat was steadily rising. Not enough to be more than slightly uncomfortable, but it was a taste of what was coming.

We took a hover-car over to the umbilical. It would have been quicker to use an air-car, but I wanted Rebka to get used to piloting the hovercraft. I didn't think he would need that skill when we were on Quake, but it's better to prepare for everything.

As we were on our way, noon of the third Day arrived. Rebka watched in fascination as Eta-Cass A swept behind Quake for the midday eclipse, then back out again about forty minutes later.

"Why doesn't it get dark?" he asked. "There can't be much refraction from Quake's atmosphere. It ought to be like another night, but a short one."

"Not at this time of year." I pointed over to the west, which was the first side of Egg to come back to sunlight after the noon eclipse. "You can't see it now because of the cloud cover over there, but Eta-Cass B is above the horizon. Almost ten billion kilometers away from here, but it gives off plenty

enough light to throw a shadow when the weather is clear. It never gets dark on Quakeside at this time of year. It won't be dark on Quake, either—there's not much cloud there, except for ash and smoke at midsummer max."

Rebka nodded and continued his tentative manipulation of the car controls. While he did so, I had a chance to look over the records that he had handed to me. They showed the reconstruction of the sequence of events on Delta Pavonis Four that had led to the deaths of the last two lodges of Zardalu—part facts, part Rebka's own deductions.

The more I saw, the less likely it seemed that the Carmel sisters had committed an intentional crime. The Zardalu were big, slow amphibians. They looked like scaly beavers, and they spent their whole lives down by the rivers, damming them and making their complex lodges. From the look of some of the structures, they had a good claim to intelligence. I could recognize cantilevered bridges, all made from the native wood.

That seemed to be part of the problem. With its high silicon content, the xylem of the trees of Delta Pav Four was more like tough, sandy rock than the woods we have on Egg. To chew through that, the Zardalu had developed big, strong teeth, which from the position in their heavy jaws gave them an aggressive, savage look. All human experience with them suggested that they were gentle and herbivorous. But they certainly looked fierce.

According to Rebka's analysis, the Carmel twins had landed very close to the Zardalu colony, and settled in for the night. The Zardalu had come over to look at them, out of sheer curiosity. That was the other problem. The Zardalu were nocturnal—and the Carmel sisters must have awakened to the sight

of a circle of grinning jaws, with those grey, razor-edged teeth.

I could imagine that might produce a strong reaction in anyone, even if they had been assured by the life-forms directory that Delta Pav Four had no species dangerous to humans. But it ought not to have led to a blind use of the construction laser, blamed by Rebka as the instrument for the killing. I rubbed at my chin and laid the report down on the hover-car seat.

"I can see how your reconstruction might work, but I still don't understand what put the two women into such a blind panic. Surely they would have come to their senses after a second or two?"

Rebka did not answer for a moment. He was staring out of the front of the car, to where the umbilical was now rising ahead of us. I have grown used to it, but I can still remember my own first sight of it.

From the pole of Egg, it rose vertically upward like the trunk of a giant metal tree. Up to infinity, to the point where it became invisible against the sky. At the base it was about forty meters across, and there was no perceptible taper to it as it disappeared from view. Actually, only the load-bearing cable was tapered, and the drive mechanism and power cables dominated the appearance. Above our heads, at the exact center of the rising umbilical, Quake hung in the sky. I noticed that even at noon eclipse the surface was not dark. Already there were the first signs of volcanic activity there, as the tides rose in strength.

Rebka finally managed to get his attention back to the business of driving the hover-car. He gunned the forward motor and took a second to glance around at me.

"I couldn't understand why the women would have been so panicked, either," he said. "Look farther back—go on through the records, all the way to their childhood. That ought to give you some idea why I'm confident that we are looking at pure accident—and panic. But I can't prove that unless we can get them back to Earth for trial and deep testing."

Puzzled, I began to skim backward, into the earlier records of the Carmel twins' life. I had to go all the way, back to where they were just three years old, before I found it.

Their parents had been archeologists, specializing in the artifacts of the Kaneeli, an ancient space-going race whose relics appear on many planets. Their final fate as a species is still a mystery, and the Carmel parents had been pursuing a promising lead. It took them to a planet of Ross 882, an M-4 type star of little interest to human settlers. It had pre-

viously been the subject of only one survey, and the native life forms had been reported as small and innocuous.

Quite clearly, the earlier survey had landed in only one hemisphere, or had skimped on the detail of their analysis.

On the second night on the planet, the camp of the Carmel family had been attacked by a large native carnivore, a bipedal reptile that was both quick and ferocious. Elena and Jilli's mother had been killed at once, and their father reached the jump ship with one arm torn off at the shoulder. He had died on the way to Peacock A, after using his last strength to initiate a jump exit. The rescue party had found two small girls, unclear about what had happened to them but with certain memories indelibly rooted.

Were the Zardalu similar to the carnivores that had killed their parents? It was an irrelevant question. They were similar enough, and there was no doubt—to me and to Rebka—that the Carmel twins had been reliving a terrible period of their childhood when they awoke on Delta Pav Four and found themselves surrounded.

"But why did they run away?" I asked Rebka. "They must have known they'd made a horrible mistake. There's no way that any Council group would have found them guilty of anything but fear."

Rebka was moving us cautiously in towards the foot of the umbilical, too busy to look around. "You are asking the question that has pursued me as long as I have pursued them," he said quietly. "Why would innocents flee? I can imagine that they might make one jump, in blind panic. But then they should have known why they had acted as they did. Why did they go on running?"

It was some consolation to know that not even

Sector Moderators, with their combination of native talent, high motivation and specialized training, could explain everything. We climbed out of the car and went on over to the foot of the stalk of the umbilical. The hover-car was small enough to fit into the cargo pod, but I wanted to get one from Midway Station, where they had equipment better suited for work down on the surface of Quake.

It took us about twenty minutes to get settled into the passenger car that was waiting for us at the foot of the umbilical. Another five minutes, and the drive train took hold to give us a smooth upward acceleration, away from the surface of Egg.

I had made the trip many times, but Rebka couldn't resist the viewports that showed the scene both ahead and behind the car.

"How long before we can see the whole umbilical?" he asked.

I shook my head. "We never will. It looks thick when we're close to it, but it never gets to be more than about fifty meters wide. And there are twelve thousand kilometers of it, remember, between us and Quake. We won't see more than you can see right now."

In front of us, the umbilical stretched away, thinning out to a fine silver thread that at last vanished into invisibility against the purple backdrop of Quake. Rebka was straining his eyes to follow the silver filament, but it would be hours before we could see it meet the surface of Egg's sister planet.

It was easy to time our progress. Every few minutes there was a vibration and a rumble in the drive train, as a loaded ore car passed us on its trip from Quake to Egg. At this time of year we stopped the transportation of radioactives, even though there were always plenty available on Quake. An ac-

cident in the first days of operation of the umbilical had made the use of the transportation system during summertide an activity that always called for caution.

I looked ahead. Hanging there five thousand kilometers away shone the bright knot of Midway Station, marking our halfway point on the journey along the bar between the two spheres of Egg and Quake—the balanced counterweights of the Dumbbell system. I pointed Midway Station out to Rebka and he spent a long time crouching forward, looking out of the front port.

"I've seen a fair number of Stalks in different Systems," he said. "But this is the first one between two planets. Why don't they do it like this in other places? Say between Earth and Luna."

I was fiddling with the scope, trying to get us a better view of Quake's surface. "You need a pair that are in synchronous lock," I said, only half my attention on Rebka—image motion compensation was a problem for the scope at our speed. "Quake and Egg always present the same face to each other. They're so close together, tidal friction has killed off any relative rotation of the two surfaces. In fact, if they were a bit closer together, they'd break apart—they'd be inside the Roche limit."

I locked in the scope, satisfied that it was as good as I was likely to get. The image was crisp enough to let us see the outward flow of lava from a volcano at the terminator, and clouds of blackish smoke were spreading around the sunward side.

"Even with the planets in synchronous lock, this was a tricky job," I went on. "There was a lot more to it than the usual cables and drive train that you're used to back on Earth. Wait until we get to Midway—you'll see what I mean."

Rebka remained silent, staring out of the front screen. I did the same. Quake approaching summer maximum was something I had seen before but never tired of. Tidal forces on the molten interior were steadily mounting and the surface crust was weakening, unable to hold back the heat dragons that would rule the summer land. Already we could see faint blotches of smoke and heat haze, spreading across the purple-grey sphere.

I should have known better than to sit there, doing nothing. Before I knew it all the old memories were streaming back. I could see Amy's face before me as she nudged me carefully along to her own objectives.

"You're the expert, aren't you?"

I was.

"And you have the whole system under control, don't you? All the tether gear and the movement of the cable?"

I thought I had it all under control—everything except Amy.

"Well, then, why won't you take me with you?"

"It's dangerous."

"Not so dangerous that you *can't go if you want to. You've been there before."*

"I made one trip. I swore I wouldn't make another."

Amy was leaning over me as we lay on the open plain. Above our heads, Quake was still ten Days from midsummer. Even with my eyes shut, I could see its strange beauty. The volcanic action near summertide maximum filled all the upper atmosphere with fine dust and smoke, veiling the surface. The sunsets came every seven and a half hours, and they were a riot of purples, reds and gold. There was nothing like them anywhere else in the known universe—nothing that I had read of or heard rumored.

Amy was watching my expression. She had picked up a piece of fine fern, and was stroking it slowly down my bare chest. She moved in front of my view of Quake, her wide brown eyes unusually serious.

"So you'll take me with you this time?"

I shook my head, rolling it from side to side on the soft earth, too lazy to lift it fully.

"It's not safe there."

"But it would be if you were there with me." She was working on my resistance like an expert climber, sensing and taking advantage of each tiny niche and fractional fingerhold.

"Not at summer maximum," I said at last. "We couldn't stay through that. I left before that myself."

She sensed my weakening resolve even before I knew it myself and moved in on it instantly. I could see a different expression in her face, flushed with a new passion and a gleam of adventure. I was staring into

her eyes when a new face appeared before me and a different voice broke into our private world.

"I wondered if you were having problems. I thought I'd better check."

I was wrenched back across a four-year gulf. I became aware of Klaus Wethel's anxious face looking in at us over the comscreen, and of Rebka sitting quietly watching me.

"Everything's fine," I said. "We'll be at Midway Station soon."

Wethel nodded. "Then I'll go back to Cloudside. Just wanted to check."

He looked reassured by the fact that the scene in the pod was so peaceful. The comscreen is limited in the amount of information that it will transmit. Klaus Wethel couldn't tell that my shirt was soaked with sweat under the armpits and around the collar —despite the accurate temperature control in the passenger pod.

I couldn't hold out that hope for Rebka. To someone with his sensitivity I would be radiating like a supernova, a rank blend of pheromones: lust, fear, excitement, and anguish.

I managed to keep my face and voice under firm control as we said our goodbyes to Wethel and he vanished from the screen. Nothing that Rebka had said to Klaus Wethel revealed that anything unusual was happening in the car—perhaps nothing unusual *was* happening for Rebka. High empaths must be used to a deluge of emotions from those around them.

After a single, calm look at me, Rebka leaned forward again and set the scope to a higher magnification. Midway Station zoomed towards us.

"I was about to ask you about this," he said. "Why such a big station? I have seen nothing like

that structure on other Stalks from surface to orbit."

If he was willing to forget what had been happening to me, I was ready to go along with him. I took in a deep breath and tried to hold my attention firmly in the present. No more trips to the past, until we were safely back on Egg and Rebka had gone on his way, with or without the Carmel sisters.

"That's what I was talking about earlier," I said. "I told you Dumbbell is a tricky system. Midway Station there is four things in one. It's the power center that provides energy all along the umbilical, it's the central maintenance station, plus a very complicated computer system; and it's the Winch, over to the left. Watch as we get closer."

With the scope magnification that Rebka had set we seemed to be only a few hundred meters from Midway. We could see every detail of the Winch's operation. It looked like a flattened disk almost a kilometer in diameter, from which the load cable of the umbilical protruded on both sides, like a thread through a bead of greenish glass. We could follow the cable for the first few meters inside the Winch, then its outline faded to a delicate branching pattern that baffled the eye. I set the zoom higher and moved our view in to the entry point of the cable.

"Look at the movement there."

As we watched, the umbilical on the side facing us was in continuous motion, reeling in meter after meter to the mysterious interior of the Winch. It seemed to be gobbled up endlessly by the dark mouth. Rebka looked at me in alarm.

"I thought the connection between Ehrenknechter and Castelnuovo-Kryszkoviak was a permanent one? Won't we lose contact at the other end if it keeps in reeling in the load cable like that?"

"No. Look." I changed the scope setting, so that

we had a view of the far end of the umbilical. It was still firmly attached to the surface of Quake, six thousand kilometers ahead of us. "See? We're still connected at both ends. The whole assembly is permanently tied—except for a few hours near midsummer maximum. But the length still has to vary, to allow for changes in the distance between the two planets. Their orbits are almost exactly circular about each other—as near as can be. There are still perturbing forces, though. They depend on the distance of Dumbbell from Eta-Cass A, and on the changes in the tidal forces. And don't forget the wobbles in Egg and Quake. Quake is almost a perfect sphere, but Egg fits its name—we have a two hundred kilometer difference between polar and equatorial radius."

Rebka was staring hard. "But how does it do it? How do you know how much load cable has to be picked up or let out?"

"All computer-controlled. I told you we have a fancy set-up at Midway Station. The Winch is programmed to allow for all the perturbing effects—otherwise we could never hold a connection between Quake and Egg for more than a few minutes. We'd break the cable, or have it flopping loose between the planets."

As we were speaking, we had swept closer and closer to Midway Station. Just before we came to the Winch, our car was detached from the load cable and followed the drive train around the outside of the Winch. After a couple of minutes, we re-connected at the other side, and began the long fall towards Quake, once more securely attached to the drive—which soon had to slow our fall rather than driving us upward away from Egg. Midway Station was set at the mean center of mass of the Dumbbell

system. A point of equilibrium, but an unstable one. Only the tension in the umbilical kept the whole assembly in overall balance.

The complexity of the mechanical structure we had just passed seemed to have quietened Rebka. I felt that he was perhaps beginning to realize that a trip to Quake, for any reason, was not the same as taking a simple air-car flight. The umbilical was as simple as it could be—but that didn't make it simple. We settled into an uneasy silence, and watched the steady approach of the surface of Quake.

In the two days since Rebka had first looked at it from my office, there had been changes. It was now daytime below us, and the purple-grey-green of our earlier view had dimmed to a general subdued grey. The plants were diving deeper, letting the top foliage die off and dry out. That would be sacrificed to the summer heat and widespread brush-fires.

As the vegetation retreated from the surface, the scabs of recent wounds were revealed on Quake. I pointed to the long rifts and cuts that marked the planet beneath us.

"See those? When we get a couple of hundred kilometers closer you'll see more of them."

"Lava flows?" Rebka's voice was calm. I wondered what he had seen already, in his years as Sector Moderator. Whole planets wasted, and star-going civilizations wiped out? Probably. The Council was reluctant to tell of the worst side of its work. Perhaps Quake at summertide maximum was something he would take in his stride. In that case, I hoped he could teach me the trick. I zoomed the screen in on one of the longer rifts.

"Lava, and fractures in the rock," I said. "Every year at perihelion, about two percent of Quake's

surface gets covered with lava and hot ashes. That may not sound like a lot, but even the parts that don't get covered are affected by the eruptions. What you're looking at is one of last year's, or maybe the year before. The plants haven't had time to grow back yet. They'll do it all right, and they find rich soil there when the lava decomposes, but it takes a few years to do it. Come back in ten years and there'll be a whole new set of scars, in many different places. That's one of the problems with Quake. The eruptions seem to come in different places each year."

Rebka was looking suitably chastened. "What's the radius of Quake?"

"About fifty-four hundred kilometers—the Carmel sisters could be anywhere in three hundred and fifty million square kilometers."

"Yet you are still convinced that you can find them?"

"We have a good chance. I'm betting that they have stayed within hover-car range of the foot of the umbilical. And they will want to be near water. I think that tells us where to look—if we can look there in time."

He nodded thoughtfully. "You were quite right. This would be impossible without someone who knows the summer surface of the planet. I would be useless alone."

So he had considered that option. That proved he was either braver or more foolish than anyone else I knew—perhaps both.

"Suppose we don't get to them," he went on. "There must still be a chance that they would survive perihelion. How good would that chance be?"

I had to think hard about that one. Could they survive summertide maximum? I had, in a manner

of speaking, but that could be put down to blind fortune.

I shrugged. "I'd give them maybe five percent. Not more, and probably less. What will you do if they get killed there?"

I should have realized that my question would upset him as much as my answer. Rebka winced at the thought.

"I will blame myself," he said. "I am the one who has pursued them across four systems. If I had been less clumsy in pursuit—in signalling my approach—perhaps they would not have fled to Dobelle. We must save them, if they cannot save themselves. How do the native animals survive—can you give me any details?"

No comfort for him there. "Most of them don't," I said. "They all dig deep down, but the biologists who've looked at the fauna here reckon that at least half of the animals are killed off each year. They can breed fast enough to keep up, but overpopulation doesn't ever seem to be a problem on Quake."

He nodded again and fell silent. He was acting more like the guardian of the Carmel sisters than their pursuer, but it suited me fine if he would keep his mind on them. In a miserable silence, we approached the foot of the umbilical. When we got near enough to see clearly where it joined the surface of Quake, Rebka saw something that brought him out of his introspection.

"What's going on there?" he said, as we reached the end of the drive train and prepared to descend to the surface.

He was pointing off to one side, where the first stage of loosening of the tether had begun. The heavy cables had already been deployed around the tether end, as it lay like a broad inverted mushroom on the surface.

"They're getting the tether loose, ready for midsummer."

"I thought you said that the connection with the planet was permanent?"

"It is. It always provides the tension we need to stabilize the load cable. But at midsummer maximum we can't risk a simple mechanical contact, the way we have over on Egg. In a few more Days we'll draw the end of the umbilical up to about three thousand meters from the surface, well away from danger of real damage during the eruptions at tidal maximum. We have to be back here long before that happens."

"So you are telling me that there is no permanent coupling?"

I shrugged, and opened the door of the passenger car. We had reached the end of the line, the surface of Quake. So far, everything about us looked peaceful, with no obvious signs of seismic activity. We had to get the hover-car ready and be on our way as soon as possible.

"It depends what you call a coupling," I replied. "We keep the tension in the cable through midsummer with a magnetic hold. Quake is full of ferromagnetics, and the umbilical has a generator in its tether. We just use Quake as a big lump of iron. The bond is as strong as a mechanical one, and it doesn't need a contact with the surface. You'll see, it works fine."

"And how do you get off the surface when the umbilical is drawn up?"

I looked back at him before I set my foot down onto Quake's surface. "That's what I've been trying to say. You don't. That's why we have to be back here in twenty hours or less."

I was getting through to him. It was no good get-

ting back to this point, unless we could do it in time. I went on with the unshipping of the hovercraft from the cargo pod that had followed us down, while Rebka walked over to the cables that hung loosely by the edge of the tether. He was inspecting them closely.

"We could still use one of those, couldn't we?" he said. "It looks as though they will still be hanging down to the surface. Couldn't they serve as an emergency hoist to the bottom of the umbilical?"

I went over and took a look for myself. He was right, the cables would hang down to the surface, even when the umbilical was high in the sky. I looked at their size and weight, then went back to the hover-car.

"Rather you than me, but I suppose you're right. In fact, I think that if you look at the specifications on the umbilical, you'll find a statement that says the cables can form an emergency system."

"I gather that you do not regard them as such."

I shrugged and climbed into the driver's seat on the hovercraft. "It all depends what you define as an emergency system. If I open my shirt and look at my chest I find I've got two nipples, and I guess they're my emergency system in case I ever get pregnant. I'm hoping the idea that we'll have to shinny up those cables is somewhere about the same level of probability. I never thought of using them before, and I handle all the shipment of materials from here to Egg and back."

"Do you like your work?"

I didn't care for his change of subject.

"It's a good job. It passes the time."

Since we had nothing else to do for a couple of hours while we drove off towards the lake side, it looked as though Rebka was proposing to try his

hand on me. I felt I had to improve on my last answer.

"I wouldn't change it for any job on Egg or Quake, so I guess I like it."

Leave me alone, Rebka, my tone said. Not a chance.

"Do you realize how fond Governor Wethel is of you, Captain Mira?"

"Wethel? I always thought he felt uncomfortable with me." I had set the speed to forward maximum, and was skimming us across the quiet surface of Quake. It was hard to believe that all this peace would soon be broken.

"He is uncomfortable with you. Most uncomfortable. Do you know why?"

Wethel wasn't any more uncomfortable than I was. How rude could I be to a Sector Moderator?

"No, I have no idea why."

"Then I will tell you. He is uncomfortable because he is convinced that you could do his job much better than he can."

I was tempted to look round at him, but at the speed we were going it could be fatal.

"I couldn't do his job at all. I couldn't stand it. In fact, if you want to know the truth I once refused it."

"I know. Three and a half years ago, after your second visit to Quake in summer, and before your third visit."

Damn the man. I didn't know just how long he had been in the Dumbbell system, but he seemed to have found out everybody's whole life history.

"And that's exactly why Wethel feels it's really your job," went on Rebka calmly. "You refused it—so he feels like a second choice, with the first choice there to prove it."

I was holding the controls so hard that I thought they ought to snap off in my hands. This type of conversation may be nothing to Rebka, but I couldn't take it—and where it was leading. The sudden orange glow in the sky ahead of us was exactly what I needed. I switched the screen to maximum transparency.

"See that?" As I spoke, the tremor shook the car. We were travelling on a meter-deep cushion of air, but we were also skimming forward at forty kilometers an hour. The ground ahead was moving in smooth, linear waves, rippling out from the quake center. Driving the hover-car over them was like sitting in a power boat and shooting the Grand Rapid on Egg's eastern limb.

Ten seconds after the land waves we heard the deep rumble of the eruption. Rebka had moved forward to sit next to me, craning closer to the front screen.

"Is that a big one?"

"Medium size. I'd say it's fifteen kilometers away. You'll see breakouts ten times that big in another five hours, when we're really getting in to the maximum tidal force. Hold tight now. We'll hit the secondary wave front in a second, and that'll be choppy."

As we came to the region where surface and body waves had created their complicated interference pattern I had to slow our speed. The hover-car was rolling and yawing, even when I cut us to walking pace. It wasn't a bad quake—for Quake—but it had given Rebka something else to think about. We were going to see more and worse before we reached the Carmel twins.

The early records of the Dumbbell System make interesting reading. The first settlement party had

arrived at Eta-Cass A in the winter months of Dumbbell, and had the choice of landing on Egg or on Quake. It looked like an easy decision. Quake was more fertile, it had lots of metals and available radioactives, and it was less humid and muggy than Egg. I'm used to the Egg climate, but I must say I wouldn't care to live over on Cloudside.

The settlers put small camps on both planets, but they made it clear that Egg would be a temporary facility, only to be used for general exploration.

The tone of the old records on Quake gradually changes as their first summer approached. They knew it would be hot, because the orbit of Dumbbell had been known since the first scout ship came through. What worried them was something else. They could see recent evidence of widespread vulcanism, even though there had been no signs of volcanic activity when they landed.

Dumbbell swept in closer to the sun. The temperature shot up, all the plants began to die off and root deeper, and the earth tremors began. Even then, no one seemed to realize how bad it would get.

One colony camp stuck it out until three Days before summer maximum, before they finally gave up and ran over to Egg for shelter under the clouds.

Reading between the lines, you can detect another tone in those old records. It is almost one of disbelief. If Quake is as inhospital to life as this, they seem to say, how could life ever have arisen here in the first place?

It took several hundred years before anyone could definitively answer that old question. The gas-giant, Perling, orbiting Eta-Cass A seven hundred million kilometers farther out, emerged as the villain of the story. Dumbbell had circled its sun peacefully for several billion years, not changing much in climate

or distance. Life had emerged and developed on both Quake and Egg. It had been a tranquil environment on both members of the planet pair, until a third component of the planetary system, perturbed by the gravitational forces of the dwarf sun Eta-Cass B, had suffered a close encounter with Perling, two hundred times its mass. The giant had thrown it into a close swing-by of Eta-Cass A, from which it should have emerged with an eccentric but stable orbit. But Dumbbell lay in its path.

The stranger had done a complex dance about the doublet, moving the components closer together and changing their combined orbit to one that now skimmed much nearer to Eta-Cass A at perihelion—the present orbit. And the other planet had been slung clear out of the system by the encounter. Somewhere in interstellar space there was a solitary planet on an endless journey, waiting for encounter with and possible capture by another sun.

I couldn't help wondering about the old Quake, the planet before the encounter that gave it its present orbit and unruly surface. Had it been a true garden planet, with tranquil streams and clean, fragrant air? The present atmosphere was breathable, but near summer there was always a faint sulphurous smell to the air, a reminder that new eruptions were on the way to buckle and scar the face of Quake. I didn't mind it, but Rebka had reacted strongly when we first encountered that faint smell. He was sitting near a side window that had been left cracked open—everything would have to be closed as the sun rose, so that the air-cooler could do its job, but near dawn the temperature was still tolerable.

When the breeze carried in its trace of sulphur, Rebka had stiffened and sniffed. He seemed like a

hunting animal, turning to track a scent. It took his mind off the thought of the eruptions ahead of us.

"You all right?" I asked. He was acting strangely, head rigid and cocked to one side.

He leaned back, and nodded. "That smell brings back old memories too clearly. I had an experience on Luytens, a long time ago. Curious, how strongly the stimulus of smells can affect our recall."

So I was not the only one who could be troubled by my memories. I didn't know if I was pleased or worried. It was easy to think of Rebka as a superman, the image that the words 'Sector Moderator' carried with them. If he was as frail and human as I was, it was good to know that. We might need a superman in the hours ahead, but if we didn't have one it was better to know it ahead of time.

Rebka reached out and closed the side window. The thermometer was beginning to show a rapid rise outside the car, and we might as well enjoy cool air while we could—I knew that soon enough we would have to go outside.

We were travelling now across a sea of dry spiky plants that cracked and powdered beneath the skirts of the hover-car. It was hard to believe that the brittle stems had been healthy and growing less than ten Days before.

"I don't understand how life survived here," said Rebka, peering out at the dead landscape. "After the orbit changed, everything else must have changed too. Temperatures, seasons, even the atmosphere. How could the life forms have endured?"

"I'm sure most of them didn't." I was skimming us along into a dry ravine, where we could make better speed. It was going slower than I had hoped. "Look at the plants that you'll see in a few minutes in the valley bottoms. Most of them are primitive

forms, nothing like as complex as you'd expect on a planet this old. And there are a lot fewer species than you find on Egg. It must have been touch and go here. Egg was lucky, it had more water and it's less dense."

"You think it was simple adaptation of existing forms?"

"What else could it be?" I skirted us around a smoking patch of black rock. We could probably have gone over it without damage, but the underside of the hover-car was its most vulnerable part.

"Talk to the biologists when we get back to Egg," I went on. (If we got back?) "The forms that were already here and adapted to summer inactivity and deep rooting took that trend further. You won't see any animals at all at midsummer—they've found their hideaways. Quake has no viviparous forms, and all the eggs are tucked away ten meters down. Some of those will survive almost any violence on the surface."

While we were talking, the face of the land around us had been changing, slowly becoming flatter and less dried-out. There was only one body of water of decent size within two hundred kilometers of the foot of the umbilical, and we were getting close to it. Even in the worst earthquakes, I had never known it to dry up. I had come here on each of my summer visits to Quake. The first time had been pure exploration. On my second trip, Amy had wanted to see everything, but I had carefully chosen areas that I already knew, where the dangers would be reduced. I was sure that she would behave in her usual way, dancing on ahead of me and revelling in every new sight. I couldn't control her, had never been able to. Now we were tracing back over the same familiar ground, heading for the side of the lake. As

we curved around a deep caldera, I halted our craft completely and let us settle to the ground. I remembered this spot from my previous visits—it had been inactive for at least five years, and that was unusual for Quake.

I opened the door. The heat sprang in at us, as though it had been waiting outside for its chance. We were still many hours from midsummer, and more than that from maximum temperatures. I breathed shallowly, reluctant to impose that sulphurous hotblast on my unprepared lungs.

"See those, Councilman?" I pointed down the steep caldera side. "At the bottom there. This is one place that Eta-Cass never shines. You might expect it to, at noon, but that's when Egg eclipses it. Those places, the bottoms of the steep craters—that's the coolest place on Quake in midsummer. If anyone wants to survive summertide here, that's where they ought to go."

Rebka peered gingerly down the steep slope. "So you think that's where we'll find the Carmel sisters?"

"Not in this particular one—in one nearer to the lake. We have time to look at maybe three of them before we have to turn back. But it's still our best bet. We have to keep moving and hope that Quake doesn't decide to fill the bottom of the one we want with molten lava."

Now it was Rebka's turn to look anxiously at his watch. He nodded. "We ought to be able to look at more than three, we've done well."

"Less well than you might think. I expect we'll be slower going back. Quake will be a lot livelier then."

I slid the door shut, turned the air-cooler to its maximum setting, and started the lift and forward motors. As we moved closer to the lake, Rebka stud-

ied again the images that we had made from the umbilical. They were high-resolution, and he was looking for any signs of unusual activity in the craters by the lake.

"See anything on those?"

He shook his head. "I'm not used to looking at pictures of Quake. You'd do a better job."

"I think it's better if I stick with the driving. Time is the most important element of all now. Are any of the craters more heavily vegetated than the rest?"

He puzzled over them for a couple more minutes. Outside, it was again growing dark, but we had to press on through the night—not too difficult, thanks to the steady light from Eta-Cass B.

"I think three of them have more growths in the bottom than the others," he said at last.

I shrugged. "That saves any tough decision-making. Mark them up, and pass them over. I'll try and pick us the best path to them."

There was no point in trying to be too fancy. As Quake became more turbulent, we would have to make course changes to accommodate that. With old memories running on ahead of me, I set our speed as fast as I dared and threw the hover-car on and on, across the lava-lit, smoke-veiled landscape. Black and orange-red, heaving and moving like a wounded animal—Quake summer, the season for nightmare.

I was glad to be back.

The Winch controllers had promised me an extra four hours. That was my margin for error, as much as they dared grant us without risking huge damage to the umbilical. Rebka had no idea how much that four-hour dispensation would cost in possible recriminations if things went wrong. I did, and I was horrified at how much the controllers were willing to put on the line for my benefit—I knew it wasn't for Rebka or the Carmel twins, they were strangers. If we got back in one piece, I owed the group of engineers a debt that I would have trouble ever repaying. How much is four hours worth? At midsummer maximum, the price was too high to calculate.

We were approaching the first of our selected craters, moving in on it to the irregular accompaniment of distant thunder. Part weather, part volcanic eruption. As Quake trembled, atmospheric storms grew in intensity.

Our timing was bad. Quake's three-hour night was rushing in on us, and there was no way that Eta-

Cass B could shine into the depths of the crater. I handed the controls of the hover-car over to Rebka, and took a last look at the dark pit-depth in front of us before I opened the door.

"Hold us steady right here. Don't move, unless you have to because you see a lava-flow getting too near. Sound the siren if that happens—I don't want to come back up and find molten rock coming down to meet me."

The air outside was stifling. I guessed that it had heated up another five degrees since we had last opened the door. It took me only a few seconds to walk over to the lip of the crater and begin the slither down its steep sides. In that short time I felt perspiration start out onto my face and arms. It took me another couple of minutes to stumble and scrape my way to the bottom, to the place where the head-high purple ferns marked the area shielded from the direct sun. The flashlight that I carried was not much use. It allowed me to avoid the worst stumbles, but I still had a number of semi-falls on the way down.

After a few minutes of thrashing around in the crater bottom, I was confident that it held nothing but plant life. No one could have forced their way into the ferns without leaving a trail of broken stems behind them.

I turned and began to scramble my way back up the steep sides, noting that the bottom of the ferns had managed to slash through my pants and leave lines of itchy cuts all over my lower calves. I could feel a strong reaction there, a quick swelling caused by the irritant sap. By the time I reached the car the pain and itching were all I could stand.

"Nothing?" said Rebka, as I swung open the door. It was a rhetorical question. I dropped into my

seat and waved at him to get us moving again. While I sprayed my legs with a coagulant and anesthetic, Rebka started us cautiously on our way to the second crater. As soon as I was in reasonable shape I went over and took the controls.

"We have to go faster. I took too long down in that crater." I risked opening the throttle one more notch, remembering that the path towards the lake side held no major rock outcrops that might cripple the hover-car. "Good thing it's getting light again. We'll find the next one easier with the sun shining. I lost time in the bottom of that one splashing in a sort of messy bog. If I could have seen it from above I'd have known ahead of time that we wouldn't find them in that."

After a couple of minutes I had to decrease speed again. Rocks or no rocks, there was no way that I could hold our pace. Quake was feeling the full power of the solar forces. The ground that we moved over was in constant motion, an uneasy, irregular stirring. I increased the pressure of the under-blowers, to move us fifty centimeters higher from the ground, and ran us along as fast as I dared.

Before I went down into the next crater I borrowed Rebka's knee-high boots. They were two sizes too small, but I could stand a couple of blisters and cramped toes better than lacerated calves. Dawn had arrived as we drove. The sun had risen through a red, smoky screen that made everything in the air of Quake diffuse and incredibly beautiful. Dust in the upper atmosphere offered some shielding from the solar rays—not much, but anything was welcome.

This time it took me only a minute to determine that no one was in the crater. All I had to do was make a quick circuit of the stand of vegetation at the

bottom, and confirm that its perimeter was undisturbed. On the way around it I saw a small shape fleeing in front of me. Some native animal had lost the battle with the planet. Something must have gone wrong with its time sense, and now it was too late to estivate. There was a tiny chance that it could survive summertide by crouching deep in the vegetation. I wished it luck as I scrambled back to the car, using my hands to help me in the ascent. The crater walls were perceptibly hotter than the air. That didn't look good for the little animal.

A few more hours, and this pit would probably see a lava breakthrough. The plants and animals would be buried beneath the molten flow. Ten years from now, wind-borne seeds would begin the recolonization, rooting in the mineral-rich surface of hardened lava. Twenty years, and the animals would return.

It occurred to me that we could adapt to life on Quake, if we really wanted to. All it needed was a change in attitude. We would have to accept a more rapid breeding rate, and the idea that we would lose one-fifth of the population each year. Maybe we had just become too soft. Random, violent death had gone from our lives—look at Rebka's reaction to the possible death of the Carmel sisters. We had no plagues, famines, or natural disasters to thin our ranks—unless we chose to seek them out in places like Quake.

Rebka was looking anxiously at his watch when I finally got back to the car. I dropped into my seat and sat, head down, for a full minute while he again got us moving on our way.

"We're going too slowly," he said. "We'll never do it in time. Four more hours, and we have to turn back."

His face was pinched with tension. I at least had the chance to work some of mine off, scrambling around the crater bottoms and burning up the adrenalin.

"One more crater," I said, as soon as I had enough breath to speak. "The next one is closest to the lake. I give it a better chance than the other two we've done."

After the outside heat the inside of the car felt freezing. I gulped down fruit juice and a stimulant and took over the controls again. Now I drove with one eye on the sun—I wanted to reach the final crater in full daylight. Eta-Cass A seemed to be racing across the sky, a reddened, dust-dimmed blur that occasionally broke through to send bright spears of yellow light onto the heaving surface of Quake. I was racing against the sun, and I was losing. Noon eclipse came when we were little more than halfway there.

Close as we were to perihelion, I knew that the outside temperature was still far from its peak. Fractures on the surface of Quake were still releasing the inner fires, at the same time as Eta-Cass A poured in more solar flux.

We came to the third crater as night was again falling. The orange glow around the horizon was continuous now, reflecting from the high dust clouds. As I climbed out of the car there was a violent burst of crimson light directly in front of me, not more than a kilometer from the other side of the crater. As the lava burst from the volcano summit, I saw Amy.

She was watching the eruption, clapping her hands as the crimson was replaced by the glow of white-hot lava. The stream crested the cone and began a quick march towards us, sputtering and sparking where it touched the cooler earth.

I turned and looked closely at her face. There was no fear there, only the rapt entrancement of a child at a fireworks display. The caution had to come from me —there was no place for it in her view of the world.

I tugged at her sleeve. "All right, that's the high spot of the show. We have to start back to the Stalk. It's a five-hour journey, and by the time we get there they'll be thinking about loosening the tether and moving it up."

She turned to me. I knew that pout very well. "Not yet. Let's watch until the lava gets to the water."

"No. I'm not taking more risks. We have got to get out of here. I'm beginning to boil."

I was, too, despite the air curtain that kept a sheath of cool air blowing about us. My heat came from inside, the burning of my own worry.

"In a minute." Amy turned all the way around, looking over the whole horizon. There was, thank God, no new eruption emerging near the lake. "All right, then. Marco, you've got to learn how to have fun. All the time we've been here, you've been sitting there like a block of stone." She took my hand and pulled me closer. "You have to let yourself go and get into things."

I felt relief as we began to walk back to the car. We still had plenty of time. From the lake side, we went back to the high point where we had first parked to overlook the arrival of summertide. I had wanted to stay there, but somehow we had found ourselves outside, halfway to the lake. I didn't want to be too near when the lava met the water behind us.

And now I was again at the same lake—my fourth visit during Quake's summer. This time, I was hurrying into the shaded depths of an old crater, closer to midsummer maximum than ever before. Quake's brief twilight was over and the pit below me was black and unfathomable. I shone my light close to

the ground in front of me and half slipped, half fell down the steep slope.

At the bottom there was no sign of the lava glow, but I could still hear and feel the broken percussion of seismic movement. When I put my hand to it, the ground was at blood heat. This crater too was probably due for drastic change.

Then I shone my torch on the central clump of plants, and knew that our search had changed its character. The stems along a two-meter stretch were broken off at the base.

I knew that no native animal was large enough to make that opening—and such life as there was on Quake should be long since deep down in the cooler earth. I hurried forward. Ten paces in, close to the center of the clump, I found them.

Rebka's description of the twins, added to the ID pack images, should have given me a complete picture of them. But it's always hard to convert meters and kilos to flesh and blood. When I first saw them, sitting back to back in the clearing they had made and touching all the way from hips to shoulders, my first thought was how small they looked. I am not a tall man, but they would not have come higher than my shoulder.

My blundering approach must have been noisy but it had been lost in Quake's summer turmoil. The Carmel twins were unaware of my presence. Rushed as I was, I stood for a second before I entered the air curtain that marked the edge of their camp. Within that two-meter radius I knew that it would be cool and comfortable, even if the temperature outside went up another fifty degrees. The danger came from below. The ground beneath my feet was shaking and trembling, moving every few seconds with

an upward flexing like the clench of a birth contraction.

The girls were twins, and identical twins—but they were not identical in all ways. The moment that I saw them I knew that the one closer to me was Jilli. Some subtle difference—*was* it an air of dependence?—had been captured by the ID pack.

I stood there much too long, mindlessly watching, until finally I forced myself to move forward, in through the air curtain.

Both girls turned in alarm at my sudden appearance. They must have decided that there were no large animals on Quake, but I wasn't risking the beam of a construction laser. I spoke as soon as they saw me.

"Don't panic. I'm here to help you."

I kept my voice calm, but there was no mistaking the terrible fear that showed on both their faces. Elena turned and began to grope in the case by her side. I sighed and lifted the stunner. It wasn't going to be easy.

"Don't move, either of you, or I'll have to put you both to sleep for a while. That won't help anybody —we have to get up that slope and out of here as fast as we can."

While I was speaking I groped in my jacket with one hand and pulled out my official ID pack. I tossed it forward to lie on the ground in front of Jilli. She picked it up.

"Look inside that," I said. "I'm here on official business." Still neither of them spoke. "On behalf of the Government of Dobelle," I went on, "and on behalf of the Office of Species Protection, I arrest you as suspects for the genocide of the Zardalu species. You will be taken to the planetary center on Ehrenknechter, formally charged there, and trans-

ported for testing and interrogation on Sol."

That was the formal piece, but I added, "Unless you both want to die here when summertide hits, we'd better get out of this crater. Let's go, the sooner we do it the better our chances are."

I didn't expect resistance. There was no rational way in which they could hope to disarm me, or if they did there was no chance that they would survive on Quake. But neither girl moved.

Finally Elena spoke. She did not look at me, but she took Jilli's hand.

"We won't go," she said. "Leave us alone here. If we die, that ought to be enough punishment. We'll take our chances here."

I looked at Jilli. She nodded agreement. I was in trouble, and it was of a type that I had never expected. I could make both sisters unconscious easily enough—but could I get them back to the lip of the crater without assistance? The heat was getting worse and worse, even though they were not aware of it inside the conditioned air of their camp. And I was slowly becoming aware of Quake's higher gravity—not much more than Egg, about ten percent, but that would be important if I had to carry anything up the steep slope.

"You don't have the choice," I said. I still kept my voice as gentle and reassuring as I could. "If I have to, I can take you both in unconscious. You know what this is?"

I waved the stunner, and both sisters nodded.

"I don't want to use it unless I have to," I went on. "It would take time to get you up there, and we don't have time. Make me do it that way, and you'll make my chances of living through this a good deal less."

Jilli put one hand up to her face. I couldn't stand

the look in her eyes. It was despair, final and hopeless, the knowledge that something worse than death was coming to her. I swallowed my own bile and stood there, waiting. Around us, frequent thunder marked the passing of precious seconds. Unless they could be persuaded quickly, their final decision would be irrelevant.

Jilli looked around at her sister, questioning. "It's not just us, Ellie," she said. "We can't make it more dangerous for him. He hasn't done anything to us."

I didn't see Elena Carmel's expression change, but her twin could read signs that were invisible to a stranger. She turned back to me.

"You can put away your gun. We'll come with you."

They began to break camp, but I stopped them.

"No time for that. Just bring what you absolutely need."

Two nods, in unison. They picked up one bag each and we stepped outside the air screen.

Away from the protective curtain of cool air, perspiration seemed to burst out of our skins. Static conditioning areas were easy, but we had no way of providing a mobile one that could move along with us. I motioned for them to go ahead of me up the slope. It would have been better if I had led them back along the way I came, but even now I couldn't be sure there would not be a change of heart. Close as we were to our deadline, it was still better to take a few extra minutes to make sure that I reached the hover-car with the Carmel sisters safely in tow. As we climbed the rough slope, I noticed that Jilli and Elena moved side by side, closer together than I would have chosen. If one fell, both might slip back down.

By the time we reached the top I was feeling

crushed. Rebka and I had gone a long time without rest or sleep. The combination of higher gravity, fatigue, heat, tension and troublesome old memories was beating me down. I longed for a chance to collapse into the hover-car chairs. The cuts on my legs had opened again, and I could feel the blood trickling down into Rebka's borrowed boots.

The relief on Rebka's face when we appeared over the top of the crater lip lifted me a little, enough to grin at him as he swung to the ground and helped the two women inside the hover-car. They looked at him, once, then turned their eyes down. He was the Inquisitor, the Tormentor, pursuing them remorselessly across the space between the stars.

If I could read their look, Rebka could analyze it in detail. He was thoughtful for a second.

"Sit there, in the back," he said. "The worst is over now."

He left them to their own thoughts while he secured the door and turned the car around for the return journey—with more experience, he would have done that while I was gone and saved us some precious time. Then he handed the controls over again to me and went to sit opposite the Carmel sisters. I would have preferred to take a few minutes rest, but we had no choice. We were too late already, half an hour past my own mental deadline for the return. I set the forward motor. Too fast for full safety, I hurled us across the heaving, smoldering surface, back towards the foot of the umbilical.

Fatigue and tension; they can combine to produce strange effects. I felt as though there were three of me in the hover-car. One was piloting us back to our starting point, automatically skirting dangerous spots on Quake but still trying to hold as close as

possible to a straight line on the ground. The second man inhabiting my body was listening to the conversation behind me between Rebka and the twins. Their voices seemed to cut in and out, disappearing completely when the way ahead of us required total attention. The crust of Quake was full of new fissures and fractures that had appeared since our outward trip.

Who was the third man? He was a shadow, a pair of eyes and ears looking out on Quake—the Quake of long ago, the garden planet that existed before Perling threw a planetary ball across the inner System. The third man watched and listened, while a young, auburn-haired woman danced and skipped her way across the sunny plains, smiling wide-eyed at the noon eclipse and breathing in the fragrance of dawn and evening. By careful concentration, he could banish the drab reality of the present.

I would like to have stayed with the third man, but the other two intruded. First it was a stream of lava, dull black-red across our path. I had to swing a kilometer left to clear it. Four more minutes had been lost. And I had to hear what was being said behind me, because part of the young woman that danced across my sight was Jilli Carmel, the happy Jilli who had looked at me from the ID pack.

"There is nothing that I can do about that part of it," Rebka was saying. Somehow or other he had broken through the dark despair that had climbed out of the crater. The two women were talking to him, low-voiced and intense.

"You must go back to Earth with me," he said. "I have no latitude in that area. Perhaps if you were not human, or I were not human, I could take greater risks. But we must let you prove conclusively, to every species on the Council, that you were

controlled only by fear and early experience when you killed and fled on Lasalle. I have seen the record of your childhood. I know what drove you to act as you did."

Not true, said a small part of me. You told me that you couldn't understand why they fled, any more than I could. Rebka was playing his own game, making the conversation behind me follow some predetermined pattern that he had established.

"We were terrified," said Jilli Carmel softly. "They came so quietly. I had the beam disperser close to me, and I fired it without thinking. There was nothing that Ellie could do to stop me—it was all done in a second."

"But I would have done just the same," said her sister. "I woke up a second after you, that was all."

"And then we ran," said Jilli simply, as though she and her sister were one person continuing a monolog. "We ran away, and jumped to Kirsten."

"But we knew someone would be pursuing us," said Elena. "Someone from the Council. So we kept going until we reached Dobelle. This planet seemed safe, there was no one here to betray us to you."

There was a long silence. In front of us we faced the long, slow hill that led to the foot of the umbilical. I strained my eyes through the smoke, but we were still too far away to see anything. I did not mention it to anyone behind me, but the deadline had passed fifteen minutes earlier.

"I don't understand," said Rebka at last. "You killed by accident, when you were still half-asleep. You killed beings who looked like those who had killed your own parents. Our tests would have shown that, as soon as we began them. The Council will not offer punishment for an accident. We would have given you a rehabilitation treatment, but only

to cure the things that caused you your fear." His voice was baffled and disturbed. "We are not monsters on the Council. We would never do more rehabilitation than is necessary for your own good."

Another long silence. I concentrated on steering us across a charred and smoking landscape and waited for some response from the Carmel twins. There was no time to spare for my third self. We were just hours away from summertide maximum, and it took full attention to move us safely across the tide-torn, dragon-haunted surface of Quake. The ground moved constantly, hot vapors breathed from fissures in the rock, and the sky above was a rolling mass of fine ash and bright lightning. We skimmed through occasional downpours of warm, sulphur-charged rain that steamed as it touched the hot earth.

"For our own good," said one of the girls at last. Her voice was bitter and accusing. "You'll give us rehabilitation necessary for our own good. That is exactly what we are afraid of. We don't want your treatment, any of it."

I couldn't tell which of the twins had spoken, and I had my hands too full with the controls to risk turning round to look.

"It wouldn't hurt you," said Rebka. I felt sure that he was staring at them with his intense, deep-probe look, trying to see through into the working of their souls, as he had done to me. "How could you think we would hurt you? Doesn't the Council have a good reputation? We want to make you stronger, saner people—you will be much happier after treatment that you could be before it."

"You can't guarantee that." Again, which twin was speaking? I thought it was Elena. "That means you'd remove our problems, doesn't it? Make us

'saner'—but we know what that would include."

"It would mean that you'd remove the thing that is more important to us than anything else," said the other sister. "You wouldn't consider it at all—except as one of our 'problems.' "

"We would remove *nothing* that was right for you," said Rebka. He was beginning to sound baffled—even irritated, which would never do for a member of the Species Protection Council. "We'd make only minor changes, enough to let you live normal balanced lives—without those terrible childhood memories."

"Of course. Normal, balanced lives. We knew that's the way the Council would work." The voice was low and intense.

"But you see, we're *not* normal," said her sister. "Your treatment would make us like other people. Does the Council have other human members?"

"No. We have only one of each species—but every species is represented." Rebka's voice was puzzled now. "Why do you ask that?"

"Because to us there is one species that is not considered by the Council—its needs are ignored. No other species has *twins*—and we are different from you."

"You'd change us"—I felt sure that was Jilli speaking. "You'd make it so we were not dependent on each other, the way that we have been all our lives. Did you know that one other pair of identical twins was given Council treatment? They lost their closeness."

There was a sudden grunt from Rebka, like an indrawn breath of pain. The sisters kept up their attack.

"Can't you see that to twins like us, what you'd do is the worst thing that we can imagine? Worse than

killing us, worse than putting us into a prison—if we were together. But you'd do it to us and think you were helping—and not one of the other species on the Council would help us, because they have no idea what it means to be identical twins."

Rebka grunted again, but he had himself under control. "I've been blind," he said. "Blind for years. I've been conceited enough to think that I can empathize with any creature, from any world. Now I find that I don't understand my own species. No single individual can ever truly understand a compound being, that's obvious. That's why you fled from Delta Pavonis?"

"Of course." Both spoke together.

"We would have treated you," went on Rebka, as though to himself. "We *would* have broken your dependence. Of course we would. All our psych profiles would tell us that it was unnatural. In anyone else, it would be."

"But not for us. We would rather die."

"I understand. Your pain is my pain." Rebka sounded as though he were repeating some familiar litany, some phrase that he had used many times to soothe himself in his work. But it was true, I was sure of it. Their pain *was* his, and he felt it all the more keenly because he had missed seeing it for so long. I knew that the rehab procedures back on Earth were due for a big shake-up as soon as Rebka got back.

If he got back. The view from the front screen grabbed my attention. Ahead of us, dim through the smoke, I could see the great column of the umbilical. It was about a kilometer and a half away—but it was no longer attached to Quake at its base. I looked at my watch. We were more than an hour after our last deadline. The controllers must have waited as long

as they dared, held it well past the promise they had made to me. But at last they had been forced to begin the lift. Worse yet, dead ahead of us I could see a ribbon of red-hot lava, winding between us and the foot of the umbilical stalk. I could find no way around it—the top of the hill that we wanted was surrounded by a moat of fire.

I killed the engine that gave us our forward motion and we remained hovering on the air cushion. I tracked the lava with the scope, confirming that our way ahead was blocked, then turned to the others in the rear of the car.

"Problems," I said. "There's a lava flow ahead, about thirty meters wide. We have to make a choice. I don't see any way across it, but we could look all the way around and see if there's any sort of break. That will cost us a good deal of time—and we'll risk more eruptions here while we do it. We're right at summertide maximum."

Rebka had been sitting with his head down, concentrating on his own problem. He slowly looked up. "And what is our alternative? So far you have offered no choice."

"We can shoot the lava. I think I can get the car across it all right—it's not impossibly wide. But I think the heat will burn through the skirts around the base, and we'll lose all our lift. We might have to get out and go the rest of the way on foot."

He came forward and looked ahead, noting that the umbilical had been raised but apparently seeing no point in mentioning anything that would further worry the Carmel sisters. "It would only be about a kilometer," he said.

"A bit more than that. But take a look at the outside temperature. It's a furnace out there. I don't see how we could take more than ten minutes of it."

"Are you sure that the lava will burn the skirts on the car?"

"No, we might get lucky. But even if we're not, I think it's the best bet we have. Feel that tremor? Quake's getting more restless, will do until we're past summertide. We don't have much time to think about this."

Rebka turned and looked at the twins. He seemed to be able to read their faces and the look that passed between them. I was beginning to feel like a blind man—Elena and Jilli could read each other, and Rebka could read both of them, but I couldn't even track my own emotions. I looked back at him, and he nodded.

"We agree. It's the best hope we have. Let's go over the lava, and hope that we will reach the foot of the Stalk before the skirt burns through."

It was not a time for debate. I nodded, turned, and pushed the forward power control to maximum. We jerked forward, accelerated to our top speed, and lurched up onto the river of lava.

After the first second, I lost sight of the path ahead. The view was blocked by a thick black smoke that rose from the burning skirt of our car. I had no idea what lay in front of us, but I held the speed to maximum—we had nothing to lose. We ploughed on, shaking and swaying, and after a few more seconds there was another lurch, this time downwards. We were over the molten river with no obstacle between us and the foot of the umbilical.

But we were sitting in a dead hover-car. I applied maximum forward power and it produced nothing but a rough grating sound. The under-skirt was gone. I cut all power and stood up.

"Come on. We have to go on foot. The faster we do this, the better."

I swung the door open and stepped out onto the surface. The lava lay behind us, ten meters away. After the cool interior of the car, the air of Quake hit me like a solid wedge of heat. I held the door for the others to step through, as faucets turned on inside my skin. Ten minutes? I doubted that we could stand more than five. Elena came out first, then Jilli. I helped them to the ground—the contact with Jilli's hand made my skin tingle, as though there existed a big potential difference between her skin and mine.

Last of all came Rebka, stumbling down and heading for the base of the stalk at a shambling run. I realized that I had shown more speed than sense. I was still wearing his boots, that he had lent to me when I looked at the second crater, and he was wearing my shoes—two sizes too big for him. We were like a couple of cripples, hobbling and staggering along after the Carmel sisters.

They were making good speed, about forty meters in front of me. They were running side by side, almost holding hands, but as I watched Jilli had to slow a little and turn in her path to avoid a patch of jagged rock. And in that same moment I saw, five meters ahead of Elena, the odd blurring of the flat surface.

It was like a slight shimmer, a hint of loss of focus in my view of the ground. I had seen it once before, four years earlier. I stopped and screamed. Even as I shouted my warning, the scene before me was dimming, over-written by memory so intense that it had never faded.

Amy, laughing and playful in the heat, ran on ahead of me, back to the foot of the umbilical. It was just a few hundred meters away.

"Hey, slow down. I'm the one that has to carry the equipment."

She spun around and laughed at me. "Come on, Marco. Learn to have fun. We don't need all that stuff —leave it here."

Her tone was teasing, making me smile in spite of the heat. "I can't just leave it—it's official property. Wait for me, Amy."

She laughed, and danced on, on into that blurring of the surface, the shimmering ground of summertide.

There was less than a centimeter of solid crust. Beneath it lay boiling, pitch-black slime. The surface bore her weight long enough for her to get beyond my reach, then it broke. While I watched, she plunged screaming into the bubbling mud.

Before I could reach the edge she was gone, down into the seething pitch. I threw myself flat and plunged my hands down into it, up to the elbows in the boiling blackness. I could grasp nothing solid. All that I could take back from Quake was pain, physical and mental. The scars were inside and out. The grafts could replace my skin, but nothing could replace Amy; not work, not sex, not even another visit to Quake at summertide.

I stood, screaming and screaming, as Rebka came alongside me. He looked at me for one split-second, then hit me savagely across my left cheek. I jerked back to the present.

Elena, chest-deep in the boiling pitch, was writhing in agony. Four paces from her was Jilli, running towards her. Rebka and I threw ourselves at her, falling as we did it. I managed to get a hold of her waist and he grabbed the back of her boots. One more step and she would have joined her sister, as Elena disappeared beneath the seething surface.

Whose screams was I hearing? Not Elena's, she was gone. Jilli's, certainly, and probably my own.

Working together, Rebka and I managed to drag Jilli away. She would have gone back, to plunge

herself after her sister, but between us we managed to hold her and work our way along to the foot of the umbilical. The main tether was well above our heads, seven or eight hundred meters and still rising steadily.

I let go of Jilli with one hand, relying on Rebka to stop her pulling free. I took the thick cable that hung from the umbilical, wound it about the three of us, and pressed the activator at the end. We were hauled aloft, crushed together by the tension in the cable—it had been designed to accommodate only one person.

Up we went, into the smoke-filled sky of Quake. All about us, the summer lightning flickered, and the ground beneath swayed and shuddered like a drunkard. Jilli was weeping desperately, and Rebka was beyond tears. The loss of Elena was doubly affecting to him—he felt his own loss, and shared Jilli's.

And I? Selfish as ever, I was back again in my own past, four years gone, watching Amy sink into the boiling mud. But now Amy was Elena, and Amy was Jilli. And I was Amy, sinking forever into the molten interior of Quake, while we slowly ascended swinging and turning, to the safety of the foot of the umbilical.

None of us was aware of our danger, dangling from a system strained beyond its safety limit, five hundred meters above the ground. How could we feel danger, when each of us was ready to welcome death? Perhaps not. Perhaps Rebka's control still existed even then. There are stories about Sector Moderators—perhaps I ought to call them legends—stories of Moderators cut in half by lasers, and still able to discuss terms logically with their attackers. I can't believe those stories—the body control needed

to maintain the blood pressure and keep the heart pumping would be too much. But I do know, from my own observation, how much pain Rebka could stand, and still run, think and work. My proof?

The crew who received us into the Emergency Entrance of the umbilical took one look at us and at once called ahead to Midway Station for complete physical support functions in the hospital. All of us had been burned by hot ash and spatters of boiling mud. Most of Jilli's long hair had been burnt off, and I had plunged one of my legs above the boot top into the molten pitch. But Rebka had fared worst of all.

He had lost both my shoes in our final struggle to the umbilical, and the underside of both his feet had burned through to the bone. I saw them when we reached the umbilical, bloodied slabs of raw meat, oozing lymph and crusted with burnt tissue. Rebka had carried Jilli on those, for more than a kilometer —and was able to comfort Jilli as we were hoisted up by the cable.

That I saw, and nothing more before heavy sedation plunged me into a sleep too deep for dreams.

It took two days to get us back to the hospital on Egg. I drifted, always on the edge of consciousness, as we were carried carefully back along the umbilical. My first real memory came when I awoke in my hospital bed. It was night and the dome was transparent above me. I must have somehow operated the controls myself.

It was after perihelion now, and close to midnight on Egg. The daylit face of Quake hung above me. It was blackened and smoking, with ash clouds hiding most of the surface features. I watched and watched, until the surface lost the sunlight and glowed on, a

dull and savage red. Then I turned my face to the wall and waited for another dawn.

Before it came I awoke again and found Rebka by my bedside. He was a tough specimen. His legs ended in giant swollen balls of padding, but he was up and about and fully alert. He was still a small, thin man with a sad mouth, but I was under no illusions. I watched him warily.

"Jilli is doing well," he said. "I wish I could say the same for you."

"I'm fine."

"No you're not. Did you realize that you had been losing blood ever since you went down into that first crater?"

I shook my head. "No. I put coagulant on my legs. The bleeding didn't begin again until I was climbing out of the crater with the Carmel sisters. There was no time to bother with it after that."

"You were lucky to make it to the umbilical." Rebka smiled. "I suppose I'm lucky too. I don't think I could have handled Jilli on my own."

He sat down on the end of my bed, watching me with steady eyes. I glowered back at him.

"Jilli and I will be leaving in three more days," he said. "She will be fit enough to travel by then."

"To Earth?"

He nodded. "She'll need more rehab than ever now. For her childhood and for the Zardalu. And for Ellie."

I didn't like to hear that. I began to replay everything again inside my head. Elena and Amy were tangled up there—I could no longer separate the two deaths.

"Can you help her?" I asked after a few seconds.

"Of course. We can help anyone. In her case, the punishment will be waived, but she will badly need

the rehab treatment. The death of the Zardalu is merely my guarantee that she will be obliged to take it. In some cases I have no powers of coercion."

I looked up, out of the transparent dome. "You can only force someone to treatment if there has been a crime."

"It is worse than that." He shrugged his thin shoulders. "There are really two kinds of crime. I can pursue and bring to justice—and to rehab treatment—one type of criminal. The one who commits an act of savagery or injustice against another sentient being. But I am not allowed to do anything about a person who commits a crime against himself."

"It's not easy to rehab a suicide." I said it intentionally, to see if he would wince. He did, but then he smiled. I knew he had seen through me again.

"Not suicide. I didn't mean suicide." (He was proving to me that he was tough enough to use the word.) "What kind of crime is it if a man blights his own great potential? I feel just as badly if a man cripples his own hopes and dreams, as if he does it to another." He leaned forward. "Captain Mira, when Jilli Carmel and I leave for Earth, will you come with me?"

"For rehab?"

He nodded. "First level erasure. You'll lose memories, but little change to your personality. You'll still be you."

I lay back on my pillow and looked up at Quake again. Memories, those I certainly had. Rebka knew his job better than anyone. But it seemed to me that memories were all that I had. Take those away, and what was left? Nothing.

I shook my head. "I need no rehabilitation. I'll stay here on Egg, and keep an eye on the traffic with Quake."

He did not appear at all surprised. "Very well," he said quietly. "I told you, I have no control of that. You have committed no crime that I can document. We will go, Jilli and I."

He stood up, gingerly on his swaddled feet.

"She will be cured?"

He nodded. "She will be in treatment for one hundred Earth-days. When that is complete, she will be very confused about everything. In order for her rehab to succeed completely, she will need help in the year or two after that."

I lifted my head up from the pillow so that I could look at him properly. "I'm sure you will succeed." It was hard to believe that he had given up on me.

"We may succeed with Jilli," he said. "I hope so. But I cannot be involved in that phase of her treatment. I must go to another case on Peacock A—a bad one. I will go with Jilli as far as Earth, for the first rehab phase, then I must leave her."

I looked down at his bandaged feet. "No rest for you, eh? When do you get your own rehab treatment, Councilman? No one is more driven than you."

He smiled. I had tried to get in a low blow, and it had bounced off him. "Drives in a good cause are all right," he said. "In any case, I am not the subject of the discussion. I want to talk about Jilli Carmel. As I told you, I have authority only in certain areas, but one of those is the decision as to where subjects who have been rehabilitated will receive Phase Two of their treatment. On that, I have full authority. I have decided that Jilli will spend that time here, on Quakeside."

"You can't do that," I said. My throat was constricted and I had to choke the words out. I had enough problems already.

"I'm afraid that I can, Captain," he said. "Check

it if you wish, but you'll find that your cooperation is obliged by Sector law."

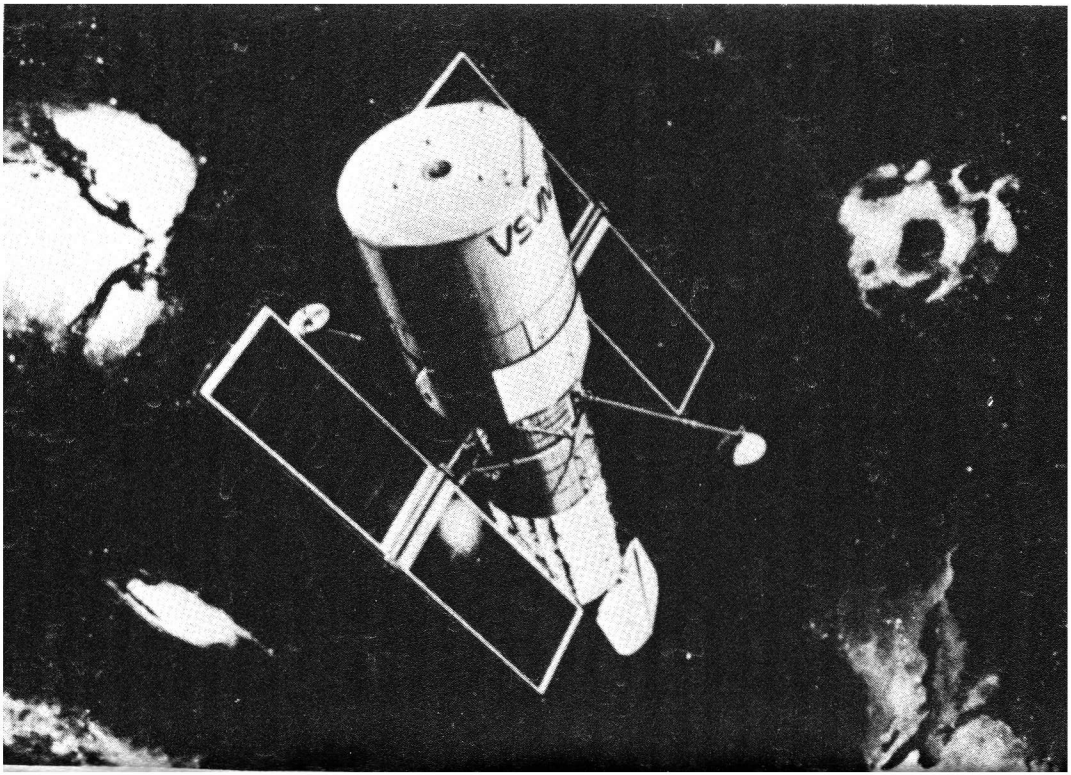
"You can't go away and dump this in my lap," I began, but Rebka had turned and was walking towards the door.

"I can," he said. He turned in the doorway and pulled something from his pocket. "By the way, you might want to keep this." He lobbed it through the air and it landed lightly on my chest as he walked out of the room.

I picked it up. It was the ID pack of Jilli Carmel, smiling as she had been before they had landed on Delta Pavonis. I stared at it for a long time, then put it under my pillow. I wondered just how well Rebka knew his job. Was it possible that he knew it so well that the rehab center on Earth was something that he could dispense with if he had to?

I moved the dome to its opaque setting and the image of Quake slowly dimmed above me and disappeared. I couldn't answer my own question. Not yet. Did Rebka know me, after a few Days, better than I knew myself? Perhaps in another year I might have some kind of answer.

—Charles Sheffield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LOOKING ABOUT IN SPACE

by Dr. Charles Sheffield
and Dr. Yoji Kondo

"How far can an optimist go without crossing the line that stands between intelligent extrapolation and nonsense?"

I. *THE NEXT BEST THING TO BEING THERE.* The pessimists among us predict that a hundred years from now humanity will be extinct, or our descendants will be eking out a subsistence-level existence on a planet that is polluted, overcrowded, and depleted of natural resources. It is easy to reach this conclusion; you suppose that Mankind will remain earth-bound, and you do a linear extrapolation of present trends.

The optimists point out that history is nonlinear. No linear model would predict the emergence of life from the oceans or the discovery of sex (the biological discovery, not the personal one—though both constitute nonlinear changes). No linear prediction allows us to deduce the effects on history of the discovery of fire, or the invention of language, of the wheel, or of electricity. These all came as discontinuous changes from everything that preceded them.

There will be inventions and discoveries just as startling in the future. The optimists see us, a hundred years from now, using those new inventions to explore the solar system in manned and unmanned spacecraft, and watching the flare as the first long-range probes set off to our stellar neighbors.

The real optimists expect they will still be around to witness all this, a century from now.

How far can an optimist go without crossing the fine line that stands between intelligent extrapolation and nonsense? Well, few writers are willing to suggest that a century from now Earthlings will be exploring the center of the Galaxy, or that we will be colonizing planets in the Andromeda Galaxy or the Virgo Cluster. Thirty thousand light-years, or two million light-years, or forty million light-years—they are not that much different from each other, not to human inch-worms who have struggled no further than the Moon, a light-second or so away from Earth. Even the optimists don't think we'll reach the galactic center in the next century or two.

Perhaps not, but the galactic center will be coming here. Every second of every day we receive visitors from our own and distant galaxies. At this very moment, radiation and particles are completing multi-million light-year journeys and arriving in the atmosphere of Earth. Every light ray, every proton, and every neutrino bears information about its source. If our technology were adequate, we could use these ethereal messengers to tell us about their distant origins, about the stars in the Andromeda Galaxy, the planets circling those stars, and even perhaps the cities on the surface of those planets.

Instead of travelling to distant places, we have an alternative. We can stay here, close to the sun, and *watch*. To do that watching, something like a tele-

scope is needed. A *big* telescope.

II. *TELESCOPES.* At the very beginning lies a mystery. Who invented the telescope? Many books state that it was a Dutch spectacle maker, Hans Lippershey of Middleburg, but no one is really sure. All that is certain is the sudden appearance of telescopes in several different places in Europe, close to the beginning of the seventeenth century.

Its first uses were quite practical, perhaps military. Galileo pointed out that potential in a letter to the Doge of Venice, "At sea, we shall be able to see enemy warships and their flags two hours before they see us . . . on land it should be possible from high places to observe enemy camps and their fortifications. . ." Galileo's letter, coupled with the strange and sudden appearance of the telescope in several different cities, suggests another thought. Perhaps the telescope was invented years earlier but its military value as a 'secret weapon' was so high that the discovery was kept hidden—until somebody leaked it to the world at large. Is it coincidence that between 1585 and 1600 England and Holland enjoyed astonishing military success on sea and land?

Whatever its earliest history, it is clear that Galileo was the first person to make a telescope and point it upwards for intensive study of the heavens. In 1610 and 1611, he discovered the mountainous nature of the Moon's surface, the four biggest satellites of Jupiter, now called the Galilean satellites, sunspots (Very large sunspots had actually been observed with the naked eye by Chinese astronomers, prior to Galileo.), and the phases of Venus, which like the Moon can appear as anything from a crescent to a full disk. Galileo made these discoveries with a small telescope that he had built with his own hands.

What does a telescope do, and why can things be seen with one that are invisible to the unaided eye?

A telescope does two basically different things: it gathers more light than the human eye, because it presents a larger area to incoming light than the pupil of the eye; and it makes things look closer, so that more detail can be distinguished on them. These two functions are quite different, and it is important to keep them separate, because this will lead naturally to the idea that telescopes should be built out in space rather than here on Earth.

The principle of the telescope is simple. Something (a lens or a shaped mirror) intercepts a broad beam of light and makes the rays converge until the whole beam is no wider than the pupil of the eye. A second lens or mirror intercepts this narrow and concentrated beam and converts it back to the near-parallel beam that the eye can accept and interpret.

The pupil of the human eye under moderate lighting is about a tenth of an inch across (under intense light it shrinks to less than half that). If the main lens or mirror of a telescope is two feet across, the telescope will deliver almost 58,000 times as much light as is received by the unaided eye. Even a small telescope with a two-inch lens will give four hundred times as much light to the eye. It is not surprising that so many faint stars become visible with even a small telescope. The 200-inch telescope at Palomar captures four million times as much light as the unaided eye, and in terms of light-gathering ability this would be roughly true whether the telescope were mounted here on Earth or out in space (there is some light lost to scattering in the atmosphere).

It is worth asking just how big a telescope can be made, for use down here on Earth. So far, the world's biggest is the 6-meter (236 inch) instrument at Mount Semirodriki in the Caucasus Mountains.

For a number of reasons this is getting near the limit for earth-bound instruments, and the 6-meter mirror is still not fully in operation.

Notice the term "6-meter mirror"; this telescope, like all the biggest ones, uses a reflecting mirror rather than a lens. The first telescopes, the ones used by Galileo and his contemporaries, were all *refractors*, that is, they used lenses to collect the light. As people began to make bigger lenses they ran into a problem that was first fully explained by Isaac Newton. A lens converges a light beam by using the glass to *refract*, or change the light's direction. But the degree of this refraction differs for different colors of light. Since ordinary white light is a combination of colors, the telescope lens will tend to separate these out, just like a prism. The result is a blurry and colored image, and this type of distortion is called *chromatic aberration.*

To lessen this effect, seventeenth century astronomers made their telescopes longer . . . and longer . . . and longer. Constantyn Huyghens used a telescope with an objective lens (the light-gathering lens) of 8.75 inches diameter, but the instrument was two hundred and twenty-three feet long and impossibly unwieldy. Some other approach had to be found.

Newton's work in optics had convinced him that chromatic aberration was an insoluble problem for refracting telescopes, so with characteristic genius he followed an entirely new approach. In 1671 he built the first *reflecting* telescope, in which a mirror rather than a lens is used to converge the light beam. Since all colors are reflected in the same way, chromatic aberration does not occur. On the other hand it was difficult to produce a uniform, highly reflecting mirror, so refractors remained popular even after Newton's invention.

Eighty-eight years after Newton, John Dollond, building on earlier private work by Chester Moor Hall, solved the problem that his great predecessor had thought impossible. He built an achromatic telescope using lenses. To do so, he used the fact that different glasses refract light to different degrees. By combining layers of crown glass and flint glass in the lens, Dollond produced in 1759 a telescope that was without chromatic aberration. Refractors could then be made bigger, they came back into style with much larger diameters, and by 1895 the 40-inch Yerkes refractor had been built.

That was the end of the line for this type of instrument. Three factors discourage the construction of really large refracting telescopes. First, it is hard to get clear, defect-free glass in big enough pieces; second, lenses so large will sag and change shape under their own weight; and third, and most important, passage of light through the thick glass of such lenses loses so much by absorption that the whole process becomes self-defeating. From 1900 on, all the really big telescopes have been reflectors. Their mirrors can be made as thin as we choose provided they are strong enough to hold their shape, and they lose, large or small, the same fraction of light from absorption. In principle a 10-meter reflector could be made, or even a 40-meter one. But the whole thing still becomes cumbersome. The mirror of the Mount Semirodriki telescope weighs 78 tons, and the assembly containing it almost 1,000 tons.

In spite of the big engineering problems introduced by very large telescopes, it is not those factors that will finally discourage the construction of very large mirrors here on Earth. There is a more fundamental difficulty. In addition to gathering more light, a telescope allows us to see more detail—makes things "look nearer". Unless it fulfills this

function, a big telescope is limited in its uses, and it is in this area that Earth-based telescopes run into difficulties.

This is so important for the remainder of this article that it must be looked at a little more closely.

III. *THE ROLE OF RESOLUTION.* Using a hand-held telescope with a two-inch lens, it is easy to follow in Galileo's footsteps and take a look at the four biggest satellites of Jupiter. They are easily visible on any clear night. Even with the naked eye, people with exceptional eyesight can under ideal conditions see the outer two, Ganymede and Callisto. But no one, no matter how good his or her eyes, can see Io, the innermost of the four, without a telescope.

It is not wholly a question of brightness. Even if Io were as bright as Jupiter, our eyes would have trouble separating it from the planet. The limitation here lies in the *resolving power* of the human eye.

Resolving power can become a complex question, but for most purposes it is nothing more than the ability to see two close objects as distinct rather than as a single merged image. The unaided eye, with a pupil a tenth of an inch across, can separate two bright points about one arc-minute apart (one sixtieth of a degree, or about one thirtieth the apparent diameter of the Moon). As seen from Earth, Io and Jupiter are at most two arc-minutes apart, so that if Io were really bright we might barely see planet and satellite as two separate objects, without a telescope.

This may seem like a peculiar result. One could argue as follows: I know that I can see Sirius quite clearly. But Sirius is a distance of 8.7 light-years away, and it's only a couple of million miles across. This means that the star only subtends one ten-thousandth of an arc-minute at my eye. Therefore, I can

see with a resolution at least this good.

That train of logic confuses the eye's ability to gather light and its ability to resolve detail. We can see Sirius easily, because the eye is adequately sensitive to received light, but the star is only a twinkling point or a diffracted blob. The unaided eye could not separate two sources like Sirius from each other at a distance of eight light-years if they were only two million (or even if they were two billion) miles apart. The eye, with its small pupil, does not have good resolving power.

To measure this resolving power, or resolution, there is a simple and useful formula, due to Lord Rayleigh. It tells the smallest separation that can be observed at a given distance, and it applies to most practical circumstances. If d is the smallest separation of two points that allows them to be seen as separate objects, then:

$$d = \frac{1.22 \times \lambda \times R}{D} \text{ - - - - - - - - -(1)}$$

In this formula, d is in kilometers, λ is the wavelength of the light used for the observation, in centimeters, R is the distance of the observed objects, in kilometers, and D is the diameter of the telescope lens or mirror, in centimeters.

Since this is a theoretical resolution, any real telescope may fall short of the performance implied by Equation (1). If the instrument has a resolution this good, it is said to be *diffraction-limited,* and to achieve the Rayleigh resolution.

Small telescopes, with diameters up to six inches or so, achieve and even surpass the Rayleigh resolution. Well-known examples are the Questar and Celestron instruments. Larger instruments fall far

short of it. For example, according to Equation (1) the Palomar telescope, with its 200-inch mirror, should allow objects 50 meters apart to be distinguished from each other on the Moon's surface. In practice, such a telescope can only resolve objects if they are a kilometer or more apart. The Palomar telescope is a factor of twenty short of the Rayleigh resolution.

The problem is not caused by telescope construction techniques. The villain of the piece is the Earth's atmosphere. It is in constant small-scale turbulence, and it reduces the performance of any Earth-based telescope to the resolution of a ten-inch diffraction-limited instrument. The justification for the construction of large Earth-based telescopes thus lies in their light-gathering power, not their resolving power. Furthermore, the problem seems insoluble. Unless (like Newton) modern astronomers are missing something basic, really good resolution can never be obtained so long as observations are conducted from within the depths of Earth's atmosphere. Telescopes should be up in orbit.

There are other advantages to space-borne telescopes. Distortions caused by the sag of the mirror under gravity are no longer a problem, nor is it necessary to orient the telescope to compensate for image motion effects caused by the Earth's rotation. Diffraction-limited telescopes may be possible at many different observation wavelengths, including ones that do not penetrate the atmosphere. Visible light reaches Earth's surface easily enough, but there are many other wavelengths important for observation, and for many, such as ultra-violet and X-ray radiation, Earth-bound astronomers are effectively blind. We tend to consider visible light as the most important—evolution designed us that way—but for

many astrophysical experiments the real information lies at much shorter or much longer wavelengths.

Most telescopes still concentrate on the visible part of the spectrum. In that range of wavelengths Equation (1) has been used to generate Tables 1 and 2, showing the resolution of several different telescope sizes at a number of different distances of observed objects. In each case, the resolution distance d describes the ability to see two objects separated by this distance as distinct from each other.

An undue emphasis on visible wavelengths and direct viewing can be misleading. Much of modern astronomy is not done by simple look-and-see, but by indirect techniques—by spectroscopy, photoelectric photometry, polarimetry, interferometry, and so on. Nonetheless, use of visible wavelengths is always a good starting point, because it is the region closest to our natural experience and our intuitive feel as to how things should look and behave. The next sections will therefore begin by examining what can be seen at visible wavelengths. This will involve the same issues on telescope performance: *resolution*, and *light-gathering power*.

IV. *INSIDE THE SOLAR SYSTEM*. In a few years the first big space telescope will be launched into orbit by the Space Shuttle. Originally planned as a 3-meter mirror and called the Large Space Telescope (LST), its size has been decreased to 2.4 meters and it is now the Space Telescope (ST).

The ST will make observations using wavelengths down to one-tenth of a micrometer, invisible to the human eye (violet light, the shortest visible wavelength, is a little more than four-tenths of a micrometer). At its shortest wavelengths, the ST will

TABLE 1. Resolution d (in kilometers) as a function of telescope diameter D and distance R (in astronomical units†) of target.

R \ D	2.4 meters	100 meters	10 kilometers	Typical object at distance R
1	41	1	0.01	Sun
5	208	5	0.05	Jupiter
40	1,600	40	0.4	Pluto
100	4,200	100	1.0	Comets, perhaps undiscovered planets.
1,000	42,000	1,000	10.	

TABLE 2. Resolution d (in kilometers) as a function of telescope diameter D and distance R (in light-years) of target.

R \ D	2.4 meters	100 meters	10 kilometers	Typical object at distance R
1	2.6E6**	6 3 E4	634	Outermost comets
4.3	1.1 E7	2.7 E5	2,700	Alpha Centauri
8.7	2.3 E7	5.5 E5	5,500	Sirius
100	2.6 E8	6.3 E6	6.3 E4	Canopus
30,000	7.9 E10	1.9 E9	1.9 E7	Galactic center
2 E6	5.3 E12	1.3 E11	1.3 E9	Andromeda Galaxy
4 E7	1.1 E14	2.6 E12	2.6 E10	Virgo Cluster

**For ease of type-setting, numbers have been written in the exponent form X.XX EXX. The number *following* the letter E is the power of 10 that must be used to multiply the number *preceding* the E. For example, 6.3 E4 = 6.3 × 10,000 = 63,000.

†An astronomical unit (written as 'a.u.') is the mean distance of the Earth from the Sun. It is a useful yardstick, especially within the solar system.

have a resolution five or six times as good as at most visible wavelengths, and objects 100 meters across should be visible on the surface of the Moon.

But men have been to the Moon. Already we have photographs that show objects on the lunar surface much smaller than 100 meters, and there is not much point in using the ST for such a purpose. It is necessary to look farther afield to justify building this instrument.

The ST will resolve features 200 and 400 kilometers across on Jupiter and Saturn respectively. This is impressive, but the Pioneer and Voyager fly-bys did much better than that, albeit for only short periods when they were close to the planets. It is not until we come to Neptune and Pluto, where no fly-bys are planned for the near future, that we can expect the ST to beat all other sources of data collection. For Pluto, the ST should allow Pluto to be seen separately from its satellite Charon, 19,000 kilometers away from it. No earth-based telescope or interplanetary probe has ever been able to do this, and Pluto and Charon have been seen to date as either a single point or as a slightly lop-sided disk.

As we look still farther out, the competition from space probes and fly-bys dwindles. A probe is a terrific idea if you know exactly where you want to go, and you are willing to wait a long time for the pictures. With current technologies, journeys to Uranus and beyond have travel times of five years or more. And beyond Pluto, it is not at all clear where to look. There is a huge region out there, the cometary halo, that may run from 50 astronomical units all the way out to a light-year or more. It forms the border of what may be termed "*intrastellar* space", and there could be all kinds of things there that are now completely unknown; billions of comets; planets; dust clouds; and left-over debris from the

contraction of the Primitive Solar Nebula. The gravitational control of the sun extends at least this far into space, and there is no knowing what may be in stable orbit out at a few tenths of a light-year.

A planet as big as Jupiter, but a hundred times as far from the Sun, might just be visible with the ST, but it would be touch and go. It would largely be a question of luck, to be pointing in the right direction at the right time. The detection of a cometary fragment at such a distance is much more difficult, and the 2.4 meter ST could not do it. Out in the cometary halo, the comets do not possess the long tails that can make them such spectacular objects to naked eye viewing on Earth. The tails are acquired only when volatile materials are boiled off the comet in a close approach to the Sun. Sighting a comet in the halo calls for the detection of an object that may be only 50 to 100 kilometers across, out at a distance of a few hundred astronomical units.

A more appropriate instrument for this search would be the 100-meter space-borne telescope. Deferring for the time being the problems inherent in constructing such an instrument, it will be assumed that a 100-meter diffraction-limited mirror can be built, and this will be termed the *Large Space Telescope* (LST), a title more suited to the 100-meter instrument than to the modest 3-meter mirror that originally claimed this name.

The LST will give us excellent resolution (see Table 1) on Jupiter and its satellites, allowing us to see objects that are only 5 kilometers across. More important, however, for the distant objects of the Solar System, the LST will see bodies a few hundred kilometers across all the way out at several hundred astronomical units—ten times as far away as Pluto. In order to see these bodies they must have a certain

minimum brightness, and this again introduces the question of the light-gathering power of the telescope. To see why this is so, it is necessary to consider how new planets or comets are found in practice. They are not simply looked for by human observers—this would be an incredibly difficult task, looking for slight motion of a very faint object against a background of stars. It is much easier to let a camera do the work. The telescope with camera attachment is pointed at a fixed position in the sky, and a long photographic exposure is made. On the developed picture, the stars are not moving and they appear as points of light, but a planet or comet is moving around the sun and it will show as a streak of light on the photograph. The catch here is that there must be enough light entering the telescope to permit that faint streak to be visible.

The LST, with its 100-meter mirror, captures a billion times as much light as the naked eye, and thus sees objects a billion times as faint. Suppose that it is being used to look for a comet or planetoid that is 100 kilometers across, at a distance of 400 astronomical units (about ten times the distance of Pluto) from the Sun. The illumination of the comet decreases as the inverse square of its distance from the Sun, and its apparent size also decreases as the inverse square of its distance from the Earth. Since the comet is hundreds of times farther from the Sun than the Earth is, to a good approximation its visibility varies as the inverse *fourth power* of its distance from us. Looking for that comet thus turns out to be like looking for a 100-kilometer diameter object with the naked eye, at a distance of 2.2 astronomical units (400 divided by the fourth root of a billion). That is roughly the distance of Mars. But Mars is nearly 7,000 kilometers in diameter; even

though it is one of the brighter objects in the sky, the unaided human eye would not see Mars at all if it were only 100 kilometers across (it would be 5,000 times as faint). Thus the proposed task is beyond (but not much beyond) the powers of the LST. This telescope would comfortably see comets that are 100 kilometers across and orbit at twice the distance of Pluto.

Observations of objects in the cometary halo call for an even larger instrument, and the need for this becomes even more urgent when objects at stellar distances are considered. The VLST (Very Large Space Telescope) will be a 10-kilometer diffraction-limited mirror, and it will be the main tool considered beyond this point. Again, construction questions are deferred until later in this article.

It is worth pointing out that the VLST is by no means the largest structure proposed for space construction. Photovoltaic arrays for use in multi-gigawatt solar power satellites will be a good deal bigger than the VLST.

V. *THE SEARCH FOR EXTRA-SOLAR PLANETS.* Unmanned space probes are a reasonable alternative to telescopic observations for most of the Solar System. This is less true when Neptune or Pluto are considered, and not true at all for examination of even the nearest stars. Travel times for probes, unless some vastly different propulsion system can be invented, will run into centuries. Before the first probe leaves for Alpha Centauri or Procyon, we would like to be reasonably sure that there will be something interesting to see there. And to humans, "interesting" begins with planets—places that our descendants may one day visit, land on, and perhaps colonize.

If current ideas on the origin of the Solar System are correct, the formation of planets should be rather common when stars are born. As many as thirty percent of star systems may have planets, but even so no one wants to send a probe out blind, without some assurance that the target system has a planetary family.

The problem of finding planets outside the Solar System can be broken into three phases, of increasing order of difficulty:

1) the problem of *detecting* the presence of a planet moving around another star, without actually seeing it at all;

2) the problem of *seeing* a planet, as a single point of light; and

3) the problem of *studying* such a planet in detail, down to continents, seas, and even smaller features.

The effort to detect extra-solar planets has been going on for a long time and there are three main techniques in current use.

The first method involves the study of occulting binary stars, star pairs that pass in front of each other as seen from Earth, as they rotate about their common center of mass. For example, the star Algol varies its brightness by about a factor of six over a period of three days. Its variability was probably already known to tenth century Arab astronomers, and certainly the changes are visible to the naked eye.

The modern explanation of the brightness change was given by John Goodricke of York, in 1782. Goodricke, a deaf-mute who died when he was only 21 years old, pointed out that the light changes of Algol are consistent with the pattern that would be seen from two bodies, rotating about each other in such a way that the dimmer one can partially ob-

scure the brighter. The dim companion could be another star, as in Algol's case, or it could be a planet. Pairs of objects of this type are called *eclipsing binaries* and many are known for which we cannot see the separate components at all. It is very difficult to detect a companion planet in this way, since a planet is usually too small to obscure the main star of the system.

Nowadays, frequency shifts of the light received from a star provide the second method for detection of binary systems. Motion of a body towards us or away from us produces such frequency shifts, so that the light from binary pairs will show periodic changes of frequency as the doublet revolves around its center of mass. The method is effective for star pairs, but much less so for a star-planet combination. To detect the Sun-Jupiter system from a distance, it would be necessary to detect velocity changes in the light source (the Sun in this case) of about five meters a second. This is a hundred times too small to be identified with available observing equipment of stellar sources.

The third method used for detecting planets works with the position of a star as measured relative to very distant stars. If a star has a planetary companion, the two bodies will revolve about each other. Although the planet may be quite invisible, a periodic variation in the star's position will be noticed. Tracking this wiggle in position for a few years, or a few hundred years, we can deduce the accompanying planet's orbit and even its mass.

The method is only feasible for nearby stars, and even here the process is not simple.

For example, the British Interplanetary Society in 1978 published a study for an unmanned interstellar probe. The study, titled Project Daedalus, chose

Barnard's Star, 5.9 light-years from the Sun, as the target. Alpha Centauri is a good deal closer, at 4.3 light-years, but when the Daedalus study was planned there seemed to be evidence of a wiggle in the motion of Barnard's Star, enough to suggest a Jupiter-size planetary companion. Unfortunately, more recent calculations seem to suggest that errors in data analysis were the cause of the observed wiggle. The "planet" around Barnard's Star was conceivably created here on Earth. The reality of the putative planet is under dispute.

This illustrates a weakness of the indirect methods. The most convincing evidence of a planet's existence is still by direct observation. Even a single point of light seems more persuasive than statistical analysis unsupported by visual evidence.

Even when a planet is easily bright enough to see with a telescope such as the VLST, the actual observation presents difficulties. We are trying to see a planet near a much brighter object, its parent star. The farther that the planet lies from the star, the less the resolution requirement of the telescope. But then, since the planet shines by reflected light, more distant planets look correspondingly faint, and the light-gathering requirement of the telescope increases.

Viewed from the nearest stars, the Sun looks a hundred million times as bright as Jupiter. Its light will completely drown the planet's light, unless we can somehow mask out the unwanted dazzle of the Sun. There are ways of doing this, called *apodizing* techniques, but their effectiveness is poor unless the distance of the planet from the star is already known. The process seems to be circular. The planet's position must be known *before* we can see it. That means a return to the indirect methods, tedious

years of looking for light changes or small wiggles in position. Fortunately, astronomers tend to be a very patient and tenacious breed.

The VLST will have resolution good enough that separation of star and planet will not be difficult, at least for the nearer stellar neighbors. More than that, a definite planetary disk will be visible.

The nearest candidate for an extra-solar planet is the triple star system of Alpha and Proxima Centauri, 4.3 light-years away. It is not an ideal candidate because the long-term stability of planetary orbits in double and triple star systems remains an open question. The dangers to a planet in such systems range from very close encounters to one star member, to complete gravitational ejection from the whole group of stars.

With this proviso, Table 2 shows that the VLST will resolve points less than 3,000 kilometers apart on a planet orbiting Alpha Centauri. Not only would the disk be visible, but we will see the major oceans and continents on its surface.

The VLST will continue to observe a clear disk out to maybe 14 light-years. In terms of stellar distance scales, that is not very far. There are only a couple of dozen stars this close to the Sun. On the other hand, if a planet is detected farther away, even as a point of light, less direct techniques such as interferometry can be used to pick up surface details. This sort of approach permitted the detection of star-spots on Betelgeuse, a red supergiant star more than 500 light-years away.

For a Jupiter-sized planet, the range goes up considerably. A disk will be visible out to 150 light-years. If Jupiter were in orbit about Alpha Centauri lots of detail would be visible with the VLST. The Red Spot, about 25,000 miles long, would be seen on

Jupiter's surface, and its shape and structure could be studied.

There would also be no shortage of light to observe the planet. The VLST will see objects seventeen million times as faint as can be picked up with the 2.4 meter Space Telescope—fifteen trillion times as faint as the human eye can see. This means that objects a thousand trillion times as faint as Jupiter seen from Earth will certainly be visible. Under favorable circumstances, even that number will be conservative, by perhaps a factor of a thousand.

The consequences of observation with the 10-kilometer instrument can be summarized as follows, for both resolution and light-gathering power:

Jupiter—shows a disk out to 150 light-years.
- —has enough reflected light to be seen 5,000 light-years away (conservative), to 200,000 light-years away (optimal conditions).
- —far enough from sun to be resolved as separate object out to 1.2 million light-years away.*

Since our galaxy is about 100,000 light-years across, the VLST might be able to detect a Jupiter-sized planet around any Sun-like star within it.

Earth—shows a disk out to 14 light-years.
- —has enough reflected light to be seen 660 light-years away (conservative) to 25,000 light-years away (optimal conditions).
- —far enough from Sun to be resolved as separate object out to 250,000 light-years.

The limitations introduced by light-gathering power are variable, as the comments above demonstrate. By use of photographic film, fainter objects

*All these figures assume that no interstellar "smog" lies between the observer and the object viewed. This is a real problem that will be returned to later.

can be seen as the exposure time is increased. Thus if Jupiter at a thousand light-years were too faint to be detected with a one-minute exposure time, it might seem logical to increase this as necessary, to one hour, one day, or longer. Unfortunately, other factors now enter. Apart from the simple practical inconvenience of the long exposures, background sources of light become more important. The background sources are "noise", unwanted signals that limit the ability to observe the true target, and as exposure time increases this noise must increase too. In this article a mean exposure time of a few hours is assumed.

The other assumption made in discussing visible extra-solar planets is that they circle other stars at roughly the same distances as the planets of the Solar System. This may not be true. There may be "rogue" planets, wandering freely through the galaxy and not bound to any star. In this case, the chance of detecting one becomes small indeed. With no reflected radiation, we have only the planet's own radiation to work with. This will derive from the heat generated by radioactive materials in the planet's core, be long-wavelength, and have a negligible signal in the visible spectrum. The VLST is not the instrument for such work, and the detection of rogue planets looks like a problem for a later generation of astronomers. *Magnitudes:* It is cumbersome to talk of brightnesses that differ from each other by factors of trillions, or thousands of trillions. Instead, astronomers prefer to work with *magnitudes*, quantities related to the logarithm of brightness.

If one object is a hundred times as bright as another, their magnitudes differ by five, with the *brighter* object having the *smaller* magnitude. Where brightnesses are multiplied, magnitudes are added;

for example, if one object is a million times as bright as another, its magnitude is 15 less—1,000,000 is 100 x 100 x 100, and each multiplying factor of 100 in brightness *subtracts* 5 from the magnitude.

The convenience of this notation is not obvious when differences in brightness are small. It becomes very useful, however, if large brightness differences are involved. Instead of talking of objects a million trillion times as faint as Jupiter, astronomers instead say those objects have magnitudes 45 times greater than the planet. The two statements are exactly equivalent.

In practice, astronomers use two different forms of magnitude: *apparent* magnitude is the magnitude of an object as it is actually observed; *absolute* magnitude is the magnitude the object would have if viewed from a standard distance of 10 parsecs (about 32.6 light-years). The Sun has an absolute magnitude of +5—it would be just visible with the naked eye from a distance of 10 parsecs. Apparent magnitudes are useful in observational astronomy, absolute magnitudes are useful if the total amount of light actually emitted by an object is required.

VI. *STARS OR PLANETS?* We have talked of finding planets and faint stars as components of binary systems, but we have not said how the two types of object can be distinguished. We can perhaps conceive of a planet as big as the sun, 870,000 miles across, or a star as small as the Moon, 2,000 miles across. Is there any clear dividing line? And if so, how close to that line is Jupiter, with a mass about 1/1000 of the Sun's mass?

Unless these questions can be answered, there is no firm basis for labelling an observed object as "star-like" or "planet-like".

The dividing definition can be drawn from two different theoretical approaches, and fortunately they both give about the same result: an object that is more than 1/100 the mass of the Sun must be a star, not a planet. Jupiter is not far from the planetary limit.

The first theoretical argument is the more obvious. If a body is undergoing nuclear fusion processes at its center, it will be very hot and not in the usual solid or liquid states found here on Earth. It seems reasonable to agree that such objects, whatever they are, differ from the planets found here in the Solar System. Nuclear fusion processes begin at the center of an object condensing under gravitational contraction when its mass exceeds about 1/100 solar masses. Below this, the central pressure in the body will not be enough to start up the nuclear furnace, the temperature remains relatively low, and a planet results.

The second argument requires that a genuine planet should not have a degenerate core.

Degeneracy (astrophysically speaking) comes in two forms. The first and milder form is called *electron degeneracy*. It is found under conditions of high (but not too high) pressure, when atoms are squeezed together so hard that they can no longer maintain their separate and well-defined electron shells. These shells "collapse", and we have a system in which the electrons can no longer be thought of as belonging to particular nuclei, even though the nuclei still preserve their identities and can move about through the electron sea.

A contracting mass, under its own gravity, will produce electron degeneracy at its center if it is bigger than 1/100 the solar mass, and if the contraction is not resisted by the gas and radiation pressure.

If the original mass is large, perhaps several times the mass of the Sun, the contraction does not stop at electron degeneracy. The central pressure goes on increasing until a point is reached of *nuclear degeneracy,* where even the nuclei are compressed together too hard for them to preserve their own integrity. When this happens they first form a rigid, tightly-packed lattice, then as the pressure goes even higher the separate electrons and protons cannot survive. They are squashed together to form neutrons. When nuclear degeneracy of this type occurs, the stars that result are known as *neutron stars.*

Note that degeneracy and fusion processes give a minimum *mass* for a star, but have said nothing about its *size.* Half the question posed earlier has been answered, and we cannot have a planet with the mass of the Sun. However, the possibility of stars as small as the Moon, or smaller, still exists, and if they are made of degenerate matter they may still have masses that far exceed planetary mass.

A hundred years ago, objects with masses bigger than Jupiter but smaller than the Sun were thought to be rare. Now they appear to be rather common. Dwarf stars resemble multiple star systems, in that the more we observe, the more frequently they seem to occur. As one source points out, the estimated frequency of multiple star systems as a percentage of total stars has increased at ten percent per decade for the last forty years—something that obviously can't go on forever!

A VLST will allow us to see anything approaching Jupiter-size orbiting a Sun-like star out to at least a few thousand light-years. From the observed orbit, a good estimate of mass can also be made, and more information obtained on the frequency of large planets and mini-dwarf stars. It would be of great

interest to discover an object very close to 1/100 of a solar mass. The lowest mass determined to date is 1/30 of a solar mass, for an inconspicuous star known only as L 726-8 B. Observation of even smaller stars would provide valuable checks on astrophysical theories.

Unfortunately, there are many stars small in physical size and large in mass. Without more information on the implications of degeneracy on stellar size, the separation between stars and planets from an observational point of view is not clear. Consideration of degeneracy leads to the most exotic classes of observed objects, and will be considered next.

VII. *COLLAPSED STARS: WHITE DWARFS, NEUTRON STARS, AND BLACK HOLES.* White dwarf stars were first detected a long time ago, although their nature was not understood.

In 1834, Friedrich Wilhelm Bessel deduced the presence of a companion star for Sirius by using one of the methods (wiggles in position in space) described earlier. The "dark companion" of Sirius, usually called Sirius-B, was estimated to have a mass about the same as the Sun; but Bessel couldn't see it, nor for a long time could anyone else.

When it was finally observed, in 1862, it proved to be very faint. On the basis of that evidence, a feeble, low-temperature object was posited, a star hardly visible because it radiated so weakly.

That idea was destroyed by spectroscopic studies, performed in detail in 1915. They indicated a bright, high-temperature star that gave off four times as much light per unit area as the Sun. Only one conclusion seemed possible; Sirius-B has to be *tiny,* a "white dwarf" star not much bigger than the Earth. But if that were the case, its Sun-sized mass would

give it a density 65,000 times as great as water. That is the modern view, and when electron and nuclear degeneracy are permitted, such densities, and ones far higher, present no problem. But this was in 1915, and astronomers had a hard time swallowing the idea of such super-dense, compact stars as the white dwarfs represent. The modern picture of the white dwarf stars was first suggested by Eddington.

The process that leads to the formation of a white dwarf star now seems to be fairly well understood. It begins with a mass of gas between one and two solar masses, contracting under its own gravitational force. Increasing central pressure and the heat released by the energy of gravitational contraction start the nuclear fusion process and the body becomes a star, shining with its own light. For most of its life, the star looks rather like our Sun, but after perhaps ten billion years it will evolve to become a diffuse, low-density star, a red giant. Then the nuclear fuel runs out, the star collapses, and the outer shell of the atmosphere is thrown off to leave behind a small high-density core: a white dwarf.

The matter in the residual core is in a state of electron degeneracy. A small spoonful (first find your spoon) weighs a ton. A young white dwarf star has a surface temperature of a few hundred thousand degrees, but it cools gradually as it gets older since it is no longer generating internal heat.

Even though white dwarf stars are small, the VLST will see them as definite disks out to about 15 light-years (they are roughly Earth-sized). Only three white dwarfs lie this close to the Sun: Sirius-B, Procyon-B, and Van Maanen 2. Of these the first discovered and most studied is Sirius-B, at 8.7 light-years from Earth. Table 2 shows a resolution of 5,500 kilometers at this distance. "Hot spots" on the surface of Sirius-B, places where matter from Sirius-

A (the bright companion) may be falling into it, should be visible. The logical place for hot spots of this type is the magnetic poles, where electrons and other charged particles stream in along the lines of the star's powerful magnetic field. Since the magnetic poles do not necessarily lie on the axis of rotation, observation of hot spots may allow us to deduce the star's period of rotation.

White dwarfs will be visible as point sources of light from much farther away. The absolute magnitude of the brightest white dwarfs is about +10 (a hundred times as faint as the Sun), but most are far dimmer. Van Maanen 2, for example, has an absolute magnitude of +14. White dwarfs will be visible from a long way with the VLST, anywhere in our Galaxy and also in the Andromeda Galaxy, two million light-years away.

Oddly enough it may be easier to discover white dwarfs in the Andromeda Galaxy than in our own. If a white dwarf is part of a multiple star system the light from brighter components overwhelms it and makes it very hard to see. On the other hand, if a white dwarf stands alone it is difficult to be sure that we are looking at a dwarf, and not merely a larger star at a greater distance. That problem disappears in the Andromeda Galaxy, where all the stars are, roughly speaking, at the same distance of two million light-years. If stars in the Andromeda Galaxy fainter than absolute magnitude +12 and with surface temperatures hotter than 10,000 degrees are accepted as white dwarfs, this provides a simple rule for discovering white dwarf stars in that galaxy.

Within our own galaxy other faint astronomical objects may be confused with white dwarf stars. One school of astronomers holds that the Galaxy contains large numbers of very faint objects, un-

observable with present instruments. Their presence is called for on theoretical grounds, to solve the "problem of the missing mass." Clusters of galaxies hold together better than they should, given the total amount of observable mass within them. Something —the missing mass—is needed to provide the extra gravitational attraction. One possibility is large numbers of very faint (or even completely dark) objects, lying within and beyond the visible part of the galaxies. Very recently, other possibilities have been suggested, such as gravitating swarms of neutrinos with finite rest masses.

The white dwarf stars are by no means the least luminous of the stellar forms. In creating the white dwarf, an evolving star sheds its outer envelopes of gas. If what is left behind is the mass of the Sun or less, the result is a white dwarf. If, however, the remaining core of matter has a larger mass, equal to several times the mass of the Sun, its central pressure and density is higher than that of a white dwarf. Instead of electron degeneracy, nuclear degeneracy results, and the core collapses down until a couple of solar masses is squeezed into a sphere about twenty kilometers across. A spoonful of this nuclear-degenerate material weighs a billion tons and it bears little resemblance to earthly forms of matter. Atoms have gone, electrons have gone, protons have gone; all that is left is a tightly-packed ball of neutrons.

Neutron stars will not show a visible disk, even with a 10-kilometer mirror looking from a distance of a light-year or two. Even so, there is good evidence for their existence. In 1967, a class of curious objects was discovered, and named "pulsars" because they radiated very regular pulses of electromagnetic signals. These pulsars are believed to be rapidly rotating neutron stars, spinning on their axes

fast enough to make a complete revolution several times a second. The maximum mass of a neutron star is still open for argument, but most theorists believe that it cannot exceed about three solar masses.

Above three solar masses, the collapsed core of an exploding star cannot form a white dwarf, nor can it form a neutron star. Instead, according to the prevailing theories, it must form a black hole.

Black holes were one of the glamor topics of the 1970's, and as a result numerous papers, books, stories, and articles have been written about them. Some of these are serious and scholarly, some are sensationalistic, some are just silly, and some are an unhappy combination of all three. (Both authors must confess to a modest contribution to that outpouring of material—we would hope in the first of the four categories.) Without providing yet another summary of black-hole-ology, we do need a few facts here to tell us how to begin looking for a black hole with our space telescopes.

A black hole is almost the only theoretically predicted end-product in the evolution of a collapsing star whose collapsing core contains more than three solar masses. Unless the star is spinning very rapidly, so fast that centrifugal forces can combat collapse, the contracting star must continue to shrink and become more and more dense. General relativity insists that there is no end-point for that collapse unless some as-yet unknown stable state of matter, beyond nuclear degeneracy, can resist the gravitational pressures. Without that completely hypothetical super-dense state of matter, the collapsing body continues to compress until it forms a singularity—a single mathematical point.

The idea of three solar masses compressed to zero

volume is physically unappealing and perhaps even nonsensical. The mathematical conclusion is almost certainly pointing out to us that the physical models are wrong, that the right way to combine the necessary general relativity and quantum theory has not yet been found. The occurrence of infinite quantities in physics is not so uncommon, and quantum field theory used to be full of them. When a correct synthesis of theories is attained, the undesirable singularities usually go away.

There is also some danger that the whole idea of black holes may go away too. Despite some observational evidence, black holes remain a mainly theoretical construct. If they do survive as real elements of the physical universe, they certainly possess some disconcerting properties.

Nothing can escape from a black hole; not even light, nor any form of radiation. (Note: this may not be true for small black holes, but it is true to a fantastically good approximation for black holes the mass of the Sun or greater.) Since particles and radiation cannot escape, "seeing" a black hole by conventional methods sounds impossible. The problem of detecting an invisible object might well make us ask how real a black hole can be, compared with the other stellar forms encountered in this section.

White dwarf stars are certainly real. They have been observed for a long time, and the mass, temperature, and radius of a number of them are known. Astronomers feel as certain of their existence and structure as they do of that of Mars or Uranus.

Neutron stars are not so well established. No one has actually seen one—they are too small for that. But pulsars are observed, and most workers in the field believe that they are neutron stars. The physics

used to explain the structure and formation of a neutron star is quite consistent with well-established theory and experiment, and neutron stars should be thought of as not only possible but probable. Most practising astronomers would give decent odds that neutron stars do exist.

Black holes sit out there on the ragged edge between fact and fancy. No one has ever seen one, and theory tells us that no one ever will. Indirect evidence for their existence is the only hope. We must look for some predicted quality of the black hole if we are to detect one. Moreover, any test that is used must be sensitive enough to distinguish a black hole from a neutron star. This will not be easy, since both are small and compact objects. Even for the best candidate to date for a detected black hole, an X-ray source called Cygnus X-1, other explanations have been offered as to what has been observed.

Although a black hole cannot be seen, there is a well-defined and useful "radius" for it. This is determined by the *event horizon,* a surface from within which nothing can ever send a signal back to the rest of the universe. For a non-rotating black hole the mass of the Sun, the event horizon is a sphere with about a three-kilometer radius. From an outside observer's point of view, black holes of this size contain matter much more compressed than that of a neutron star. (Since no signal can ever escape, the point of view of an *inside* observer is completely unknowable.)

Black holes are not obliged to be of great mean density. They can exist at all sizes, containing anything from a few atoms to whole galaxies, and at three billion solar masses (the size suggested for a black hole at the center of a galaxy) the average

black hole density is small, only twice that of air at sea level. It would be possible to fall into such a large black hole without knowing it—but once in, escape would be impossible.

Other than its mass, a black hole has only three physical quantities that may be sensed by an outside observer: spin, charge, and magnetic moment. Since the magnetic moment is fixed completely by the charge and the spin, the black hole possesses only three independent observable quantities. The observer must look for evidence of one of these three. But which one?

Most probably, the only practical thing to look for is evidence of *mass*. A black hole creates a gravitational field, like any other object, and there will be a tendency for other matter to be drawn towards it and fall inside the event horizon. In that process the matter will give off considerable quantities of radiation. It will also, despite the wishful thinking of a number of stories, be completely disintegrated by tidal forces if the black hole is the mass of the Sun, or close to it. Black holes may indeed provide humans with the gateway to another world, but other less exotic forms of suicide may be preferred.

Not all the matter that approaches a black hole will fall through the event horizon. Matter that remains outside in orbit about the hole should form what is termed an *accretion disk*. These disks should be readily visible with a VLST, up to perhaps 20,000 light-years away. The distance to Cygnus X-1 is thought to be a few thousand light-years, and the big telescope should be able to see its accretion disk.

Distinguishing that accretion disk from residual rings of matter orbiting a neutron star is another and more difficult matter. The disk could also easily be confused with matter orbiting a white dwarf, or

even with a binary star system in a dynamic phase of mass accretion or transfer. It would be better to look for accretion disks surrounding giant black holes, such as those thought to be at the center of galaxies. These could not be confused with accretion disks of other objects, and the VLST should be able to see them from a distance of many millions of light-years.

VIII. *NOVAS, SUPERNOVAS, SUPERGIANTS, VARIABLE STARS, AND ANOMALIES.* The search for collapsed objects with tiny diameters and little or no emitted radiation is a frustrating business. Fortunately, there are many other interesting things in our own and other galaxies, and a VLST will enable most of them to be seen remarkably well.

Novas are not new stars, as their name implies, but existing stars that undergo sudden and large increase in radiation. They are fairly common, and a good deal is now known about the way that they occur. A nova is less violent than a *supernova,* in which a whole star explodes to throw off its outer gaseous layers. Whereas a supernova is a one-time event in a star's lifetime, it is possible for a star to be a recurring nova.

Both novas and recurring novas are believed to involve binary star systems. They typically consist of a white dwarf component and a partner that is also small in size but much less massive than a white dwarf. The faint partners are called *red dwarfs.* They are the runts of the litter, small stars that have only a tenth or so of a solar mass.

A VLST could answer many tantalizing questions about novas. Although the type of system that goes nova is defined, the process of the explosion is unclear. It may be that the white dwarf itself ex-

plodes to throw off matter; or it could be an event in the dwarf's accretion disk, or a massive transfer of matter between the binary pair, or something else as yet unsuggested. A VLST would separate red dwarfs and white dwarf companions out to a thousand light-years or more (though neither will show a disk at such a distance). Growth of an accretion disk would be visible, and the mechanism as a nova explosion is triggered off can be studied. Novas are numerous enough that there will be plenty of candidates for study within a radius of a thousand light-years.

Supernovas occur far less frequently. It is one of the irritations of modern astronomy that the most recent, really bright supernovas in our galaxy occurred just before the invention of the telescope. Since then astronomers have had to be satisfied with distant supernovas, in distant galaxies. They are easily visible there. At maximum increase in intensity, a supernova will for a few weeks give out as much light as a whole galaxy. It would be nice if one were to occur close to the Sun. (But not too close. A supernova 20 light-years away would completely change Earth's climate and perhaps wipe out all human life.) Observation of a supernova explosion from initial flare in intensity to slow dimming is one of the most desirable experiments of astronomy.

Variable stars constitute another class of "interesting" objects, one that also includes novas and supernovas; as cataclysmic variables; it includes some very strange objects. For example, Mira (Omicron Ceti) is a star that varies its light output by a factor of a hundred and its radius by twenty percent, over a regular schedule. It is about 230 light-years away. A VLST would permit a fascinating movie to be made of Mira. The resolution at that

distance would be about 45,000 kilometers, which sounds poor until we note that Mira is a monster of a star, 570 million kilometers in diameter, 420 times as big as our own Sun. A VLST would permit a time-lapse movie to be made with full TV resolution. Mira would show as a red, fiery blob that pulsates to a regular rhythm. We might also expect a view of spectacular flares and turbulence on the stellar surface. Mira is big enough to have star-spots that could easily engulf the Sun.

A movie of another variable star, Delta Cephei, might be even more interesting. It is a blue supergiant, one of a class called *Cepheid Variables*, after the first one studied, Delta Cephei. These stars are particularly interesting because there is a precise relation between their brightness and their period of pulsation. This means they form a distance scale, a yardstick for this and other galaxies. Whenever a new estimate of the size of the universe is announced, as often as not the period/brightness relation for Cepheid Variables has been refined.

Close observation of Delta Cephei should give more insight into the reason these brilliant stars vary in such a controlled and regular way. At 1,300 light-years, Delta Cephei's 40-million kilometer disk will be easily seen by the VLST, whose resolution at that range is 800,000 kilometers. If the reason for the pulsations of these stars could be related to their absolute magnitudes, the distance scale of the universe would be on a much firmer base.

When one component of a binary system is a supergiant star, some strange systems can result. Beta Lyrae is one example. It is a binary, and one star moves completely surrounded by an outflow of hot gases drawn from its companion. Both astronomy and plasma physics would benefit from a close look

at that swirling, turbulent flow, inaccessible to present telescopes.

Stephenson-Sanduleak 433 (SS-433) is an even odder binary (we think) system. Its spectrum shows that it is both approaching and receding from us at a quarter of the speed of light! The suggested explanations for that spectrum both involve a binary star, one of whose components is either a neutron star or a black hole. In one explanation, the spectrum arises from two spinning jets of hot gas, each a billion kilometers long. Another model suggests that the binary is surrounded by a gaseous ring, and when gas is emitted from the magnetic poles of one of the stars it creates two emitting regions within the ring.

This strange object is about 10,000 light-years away. A VLST would allow us to decide between those two models, or suggest other possibilities. More than that, a VLST would undoubtedly reveal many more exotic objects to fuel the next generation of theoretical astrophysics.

The greatest limitation on what a VLST can see within our galaxy may come not from resolution or light-gathering power, but from the galactic "atmosphere". In addition to stars, the galaxy contains clouds of dust and gas. This "interstellar smog" is the thing that prevents us from seeing the galactic center and makes many parts of the galactic disk inaccessible to study using visible light.

As usual, one man's annoying smog is another's science experiment. Since scattered light from dust and gas has its spectrum changed by that scattering process, study of the light that does reach us can indicate what atoms and molecules are present in "empty" space. Already, the presence of many organic molecules has been detected. A VLST would

take that to a new level of precision, since we will have the light-gathering power and the resolution to make very detailed studies of all parts of the sky. It is quite unlikely, however, that most of these studies will be conducted at visible wavelengths. Radio waves penetrate the obscuring clouds much better, and ultraviolet wavelengths have already proved to be especially revealing since most ionized atoms in the interstellar medium reveal themselves through strong absorption lines superimposed on the spectra of hot stars.

As space telescopes become standard in observational astronomy, the emphasis on visible wavelengths will gradually lessen. It's important to note that of the more than 20 octaves of the electromagnetic spectrum useful to astronomy, the visible wavelengths occupy less than one octave. Present preoccupation with visible light reflects a purely historical influence.

IX. *OBSERVING THE MOST DISTANT PARTS OF THE UNIVERSE.* Many of the hottest questions in astronomy today have little to do with our own galaxy. They concern the nature of other galactic cores, ranging from Seyfert galaxies to quasars and BL Lacertae objects (sometimes called *naked quasars* since they lack a hot gaseous envelope around their core regions).

The nature of quasars is actively debated. Are they matter being thrown out of an exploding galactic core? Or ongoing total annihilation of matter and anti-matter? Or perhaps a massive black hole and its associated accretion disk? Or even a "white hole"? (A white hole is usually defined as "the opposite of a black hole"—which may be like defining something as the opposite of a unicorn, since the ex-

istence of black holes has not been established.)

It is extraordinarily difficult to answer these questions. The observational equipment is simply too limited to permit detailed study, with quasars so distant that the cores are not visible. Estimates of their sizes now come from interferometry measurements at radio wavelengths, where they present an angle of at most a ten-millionth of a degree. The best optical telescope has an angular resolution of about a hundred-thousandth of a degree, but this is degraded by the effects of Earth's atmosphere. However, the VLST has an angular resolution of a few *billionths* of a degree. If the quasar region that emits visible light is about the same size as the region that emits radio waves, the energy-producing parts of a quasar will be studied easily with a VLST.

Based on their observed frequency shifts, quasars are thought to be at least hundreds of millions of light-years away from us. The Seyfert galaxies and the naked quasars inhabit the same regions, so distant that an instrument the size of a VLST is imperative for direct visual observation. Beyond them, out to the edge of the visible universe (this is currently projected to be 18 billion light-years away, the place where the frequency shift becomes infinite) there may be any number of new, as-yet unobserved objects. Unfortunately, those distant regions become progressively harder to observe, and not merely because there is a natural lessening of brightness with distance.

As we look farther out, the expansion of the universe implies that the signals received will be more and more shifted towards the red part of the spectrum—to longer and longer wavelengths. By definition, the edge of the universe will be the place where the expansion of the universe, relative to us, is

proceeding at the speed of light. Incoming radiation from these regions will be moved out to infinite wavelength and thus not measured by any detector.

There still remains the possibility of studying, say, X-ray sources that have been moved in frequency to visible wavelengths by the red shift. This will happen if the region observed is about 17.5 billion light-years away, a mere half billion light-years from the final "edge" of the universe.

It seems almost inevitable that those remote regions will show phenomena that cannot be explained with current cosmology, just as the first telescopes, resolving the Milky Way to separate stars, made astronomers aware of a universe bigger and more complex than anyone had ever dreamed.

X. PLANNING THE FUTURE. Sitting here today, anxiously awaiting the first regular flights of the Space Shuttle, impatient at the delays in the launch of the 2.4 meter Space Telescope, wondering about the general future of the Space Program. . .

It would be easy at this point to dismiss the idea of a 10-kilometer diffraction-limited space telescope as no more than pipe-smoke. There is no plan for anything beyond the first Space Telescope, and there has been no substantial construction work done yet in space. The whole idea of holding a 10-kilometer mirror to focus on a single target might sound too good to be true.

But it isn't. To see this, it is necessary to set the achievements in space to date in their correct context. Twenty-five years ago, the world's best technologies struggled to put into low earth orbit simple transmitters weighing a few hundred pounds. Ten years ago, multi-ton payloads were flown beyond the Moon. In the next few years we are sure to see

the first permanent manned space station, probably a 12-man system placed in orbit by the Russians about 1985. By 1990, facilities of a few hundred tons mass will be in permanent orbit, and probably the first manned maintenance trips to and from geosynchronous orbit will be occurring. Long before 2000 A.D., space structures with kilometric dimensions will have been built.

The idea of a very large telescope in space, it is true, presents unusual construction problems. Whereas an array of cells for a solar power satellite can be a few centimeters out of position without affecting their performance, a diffraction-limited telescope must hold the position of each part to very high accuracy. Unless, that is, completely new approaches are used to telescope design.

This seems entirely possible. Our ideas on the nature of the telescope have changed more in the past twenty years than they did since the time of Galileo. For example, is there any reason why a telescope must consist of a single lens or mirror? A multiple-mirror telescope has been built already in Arizona, and it seems likely to be the first of many. There are also more fundamental changes on the horizon.

A telescope lens or mirror can be thought of as having one main purpose. It ensures that light which began its journey at a particular instant from a distant source will be collected and delivered to the eye (or the camera) *at the same time.* If one part of the mirror is displaced by a hundredth of an inch, light from that part arrives at the focus only one-trillionth of a second late—but that is enough to ruin the telescope's performance. Thus telescopes have always been machined very accurately to eliminate these infinitesimal delays in light travel time that would impair their performance.

Today, there are other options. Thanks to advances in electronics, and to the needs of particle physics experiments, we have techniques that handle time intervals to trillionths and to million-trillionths of a second. This sets the stage for completely new types of telescopes.

In a *distributed telescope*, the light from a distant object is recorded at a large number of small telescopes, together with recordings of accurate arrival times. Later, at our convenience, these separate signals are integrated to a single composite signal, with all the times coordinated. The result is just the same as if the telescopes formed part of a single large, diffraction-limited instrument. Furthermore, the individual telescopes can be as far apart as we choose. We could place a whole series of small telescopes around the Earth's orbit, or scatter them where we wish through the Solar System. Provided only that we can record signals, and later accurately correlate them, resolutions that far exceed any of the telescopes mentioned so far can be achieved. Correlation of telescope signals implies that their relative positions be accurately known, but that can be determined by a completely separate system of observation and control, monitoring the system while the main telescope work is being done. A distributed telescope of this kind shares the properties of conventional telescopes and of interferometers, giving extremely high resolution, but perhaps not providing its results as a simple image. For many purposes, graphs and tables serve as well as the usual and familiar picture.

The Heinlein Distributed Observation System (HDOS), with an effective aperture of two astronomical units, will be an interesting instrument. It will consist of a set of separate, space-

deployed mirrors, phase-controlled and attitude-controlled by a central computer. Each component may be up to a hundred meters in diameter, a size that can be controlled to diffraction-limited performance by conventional control systems proposed already for use in space construction.

The HDOS will provide results with a resolution corresponding to that of a diffraction-limited instrument of 300 million kilometer aperture. It can be used to observe cities on planets that circle suns in the Magellanic Clouds, or to pick out islands the size of Iceland on planets out in the Andromeda Galaxy. The problems of data analysis and correlation will exceed those of instrument construction.

It is debatable whether an instrument like this will ever be built, given the foreseeable problems of instrumentation and control. However, that is not the real issue. Predictions of the *way* that scientific results will be achieved a century or two from now are almost certain to be wrong. However, expectation that the results *will* come are wholly reasonable. There will be advances that our generation finds quite incredible, just as computers and television and nuclear energy would have amazed our grandfathers. The instrument that is employed a century from now to observe the Andromeda Galaxy may look nothing like a VLST; it may use neutrinos, or quarks, or black holes, or something as yet undiscovered. The concepts that lie behind its performance may not have been proposed, but it seems reasonable to assume that the results foreseen in this article will be achieved.

The greater danger lies in the other assumption: that we will *not* develop the tools to explore the universe more deeply than we can imagine now.

In 1835, Auguste Comte assured the world, in his

Cours de Philosophie Positive, that for the heavenly bodies "we can never know anything concerning their chemical or mineralogical structure. . ." He wrote this *after* Fraunhofer's work on the solar spectrum, the work that laid the basis for modern spectroscopy and our still increasing knowledge of planetary and stellar chemical composition. Not only was Comte wrong, he lived long enough for his error to be apparent.

Meanwhile, as bigger and better space telescopes are developed, there will still be people who hate the idea of just sitting around and *looking* at things. They will be developing their own new tools, and they will want to go out and see for themselves. Perhaps Kepler will prove a much better prophet than Auguste Comte. In a letter written three and a half centuries ago to his illustrious colleague Galileo, he said: "Produce ships and sails that can be used in the celestial atmosphere. Then you will also find men to man them, men not afraid of the vast emptiness of space." Afraid or not, they will be guided in their choice of destination by those who merely watch.

And in the end there may be a race we can all look forward to, one between those building new instruments to observe the stars, and those constructing "ships and sails" to explore them directly.

In a race like that, it's difficult to see any losers.

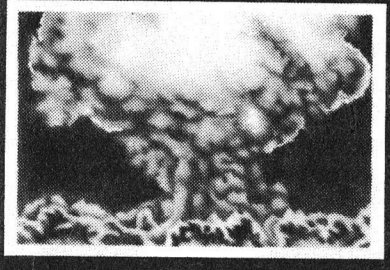
—Charles Sheffield and Yoji Kondo

NUCLEAR SURVIVAL

PART FOUR:

STOCKING YOUR TENACITY CHEST

BY DEAN ING



"Clever folks can extract energy from warm springs and chicken flickins', but your most available energy source will probably be sunlight, wind and water."

In previous issues of *Destinies,* we argued that many Americans could survive an all-out nuclear exchange if we knew what to do, and if we did it. We started this series of articles by describing a firestorm, a more lethal and immediate threat than fallout for city dwellers. You can be asphyxiated and roasted in a blastproof shelter—as three hundred thousand casualties proved in Dresden.

The US Government has agreed about firestorm; has suggested that you relocate from target areas if war seems imminent. We suggested that you relocate *now*—or at least prepare for evacuation with a bike rack on your car for your 'second stage' vehicle.

Our second article showed you how to build air filtration and pump devices from household materials, so you can breathe clean air in a shelter beyond the firestorm area. Oak Ridge National Lab (PO Box X, Oak Ridge, TN 37830) has put a little tax

money to excellent use in developing and testing other homebuilt rigs, including jury-rigged shelters and a high-volume air pump. Their pump will not pull air through a fine filter, but without filter restrictions it pumps much more air than ours.

Our third article illustrated ways to rig toilets and lighting systems in a shelter. Briefly summarized: you build a small potty using thin plastic bags to catch solid waste, and sprinkle hydrated lime or Clorox into the bag before sealing it. Small lights, cannibalized from a car, can be run by auto batteries, or even by tiny 12-volt bike generators that will also power tape recorders and calculators. Wiring is safe and simple.

Finally, we promised to add some tidbits on post-fallout survival; call it cottage industry if you will. If you've read our previous articles, our texts and photographs will testify that we've spent a lot of time developing gadgets and trying advice collected from others. Amerinds, settlers, guerrillas, anthropologists—survivalists all—have taught us how to make fuels, treat illness, and scrounge food; well-informed Americans need not face a hand-to-mouth existence when first emerging from fallout shelters. So we promised, in our last article, to suggest some things to store in your 'tenacity chest' for the post-fallout world. Much of that storage will be in the form of information.

We decided to break our information package down into five groups: shelter, food, health, energy, and utensils. There's a great deal of overlap here; you'll need to build utensils to make your own fuels and lubricants, for example.

Your most intimate shelter is clothing. It was Sylvan Hart, a modern mountain man with an engi-

neering background, who said he was afraid of only one thing: a cold wind. He was talking about hypothermia, the situation when your body heat is drawn away faster than your body can replace it. When you read that someone died of 'exposure', chances are he died of hypothermia.

You can insulate yourself from cold by wearing several layers of clothing, but not if those clothes are wet. The air trapped between clothing layers provides good insulation. Water conducts heat and replaces the air, so your body heat is conducted from your skin through the damp clothes to the cold wind. Conclusion: stay dry in cold weather.

If you can't stay dry, try wearing leather. We find that thick elkhide trousers, though soaking wet in mountain snow, provide much more insulation than heavy jeans. But they dry more slowly, and we swear they weigh fifteen pounds wet!

You can dry your damp socks by putting them inside your shirt just above your belt. It takes awhile, but it's worth it for warm dry feet. Clothes should be vented so body moisture can escape. Rubberized or other entirely moistureproof fabrics tend to trap moisture inside to make you clammy. Outfitters can steer you to a nylon cloth so densely woven that it will shed rain while allowing water vapor to escape. For that matter, a weekend with a veteran backpacker can lead you to the items you need from an outfitter's shelves. Weatherproofing shoes (mink oil), keeping unlined leather gloves on during chores, and rigging a pack are three things that immediately come to mind.

Need oilcloth? The original stuff was, literally, cloth drenched with linseed oil and sun-dried. The sunlight polymerized the linseed oil to a flexible solid. You can start with plain cloth; just remember not

to store it folded. The stuff tends to glue itself together into a useless lump.

We considered clothing as shelter because it's likely that you'll be more mobile—personally mobile; on foot—than you are today. But what if you're afoot and soaking and cold?

If more than an hour from known shelter, stop and get warm. It's nice to have a little hemispherical nylon-and-stiffener tent on your pack, preferably one of drab color. Next best might be a rectangle of ten-mil plastic for a tent, big enough that you can lie on it as well as under it. A down mummybag can be as small as a ten-pound bag of flour. People have also found refuge from that cold wet wind in hollow trees, abandoned cars, haystacks, bridge foundations,—even warm compost heaps.

For more permanent shelter, architects are beginning to rediscover the virtues of dirt, citing the 'soddy' dugouts that insulated settlers from ferocious great-plains weather. Oddly, they don't often cite Wright's berm house of the 1930's, but they should. A berm is an earth ramp. If you build a wooden or stone house, you'll find yourself better protected and insulated with berms shoveled along the outside walls up to the windows or eaves. Since a berm will hold rain and ground water, you should place a water barrier (thin plastic sheet will do, but be careful not to tear it as you shovel dirt against it) between the wall and the dirt berm. A gravel-filled, stone-covered trench at the foot of the wall and under the berm will let ground-water percolate away—if your trench leads away downhill. If you build in a depression you're asking for flooding. We know, we know: there's lots more to it, but we're only touching the high spots.

A semi-permanent shelter requires amenities like

verminproof storage, a firepit with smokehole, and a bough bed or lath-lashed sleeping platform. Study old National Geographics to see how the Ashanti or Blackfoot or Polynesians coped with special environments similar to yours.

We haven't the space here to dwell on ways to fortify shelters; your best protection is probably camouflage—including a grassy berm—and inconspicuous multiple exits also make sense.

Our second category is food, and we'll start with meat. Recently canned food should be okay, of course. Why waste space on the dressing-out of large animals? You probably won't see many. Among common domestic animals, swine and chickens seem to have superior powers to survive high radiation doses. Fish might be plentiful, and the radioactive particles they absorb seem to be concentrated in the organs we normally discard, so fish may be a staple. But remember not to eat shellfish, and if you must, eat only the muscle tissue.

Extrapolating from the known hazards of irradiated fish organs, we suspect you should discard *all* animal organs. And we know the edible meats aren't all represented at Safeway. Frogs and snakes, for example, can be delicacies. Skin the snake and remove the head and organs, cut the flesh into manageable segments, then fry or roast the segments like chicken. Frog legs are skinned, then fried or roasted the same way.

Insects? Many people have survived on such a diet —but not on insects recently subjected to high radiation. Some edible creepies such as grubs, termites, and nightcrawlers might be relatively safe because they don't live in the open—but all have organs which might concentrate irradiated particles, and

the energy you spend collecting them might surpass the energy you get from digesting them. Several months after the last fallout, it might be safe to dine on those crawly critters. They have been praised as soup stock, but not by us!

Vegetables will probably comprise 95% of your diet. We'll admit that corn, wheat, legumes, and other staples will be important, and go on to lesser-known foods. The lowly acorn is plentiful, easily-shelled, and (aren't we all?) bitter as hell when raw. You must leach out the tannin (a substance also boiled from oak bark for tanning hides) by boiling, say, a pint of shelled acorns in a quart of water, changing the water every five minutes, for about forty minutes. Then let the acorns sun-dry. They can be munched as is, or ground into flour for flatcakes or soup stock. When salted, they're so tasty we wonder why they aren't marketed.

We all know about fruit and nuts, but had you thought of crushing nutmeats and pressing them to get oil for cooking or lamps? If you can't rig a powerful hand press, boil and stir the crushed nutmeats and skim off the oil that floats to the top. Save the nut soup, dry it, and use the dried nutmeats for flour or nutcake.

Fruit 'leather' is easy. Boil the fruit whole, drain it, saving the drained liquid to drink, and press the boiled fruit pulp through a sieve—perhaps a metal can with lots of nail-holes. The thickish paste can be sweetened with honey or with the boiled-down juice of fruits. Pour the paste onto a flat surface and dry it, protecting it from insects. When it's leathery, roll it into small tubes and store it as candy.

Cattails have a pulpy inner stem you can mash and eat raw, or better still, boil it first. Where the stem joins the root you'll find a lump that you can

peel and eat like a potato.

Learn to identify the salsify weed, or 'oyster root', which has a purple or yellow blossom and later a puffball like a huge dandelion. In Europe its root is a delicacy. Pull a double-handful of salsify roots, clean and boil them awhile. Big roots can be too fibrous for our taste, but we've seen guests take third helpings of the smaller roots with their faint delicious oysterish taste. The dandelion makes marvelous salad greens, or the leaves can be boiled like spinach. The cleaned, dried, ground-up root makes a tea-colored, coffeeish-flavored brew, and the Vitamin A in dandelions puts a carrot to shame.

Vitamin C is found in tomatoes and citrus, of course; but also in rose hips, the moderately bitter seed pods of the common rose. We are pampering a tiny 'decorative' orange tree two feet high because it winters indoors in Oregon and yields sour fruit the size of ping-pong balls. The little zingers are loaded with Vitamin C and are fresh in January.

Incidentally, the leaves of mint, blackberry, and strawberry can also be brewed as tea. You might grow spices (sage, thyme, mint, oregano) as a barter crop. A pound of dry oregano might be worth a block of sea salt.

Winemaking is an art lauded in many books. Remember that you can make it from berries and fruit, too. It won't be sweet unless you add sugar. Brandy is made by distilling wine to obtain the ethyl alcohol and some of the original wine. If you have the right apparatus, including a sensitive chemical thermometer, you can wind up with almost pure ethyl. If your apparatus includes metals like lead you can wind up poisoned.

If you aren't a gardener, find a plot of bathtub size or larger and start now. A compost pile is a

small art, and the pile can be quite small. The finer the particles of food scraps and decaying leaves you start with, the sooner it becomes good plant food—and if it starts to mildew, it's too damp. Some plants like marigolds and mint seem to repel bugs, and you should learn which veggies you can grow best in your locale. Why only in your locale? Because you're not likely to travel very far from it. Long-distance travel may become hazardous for most of us.

We could go on for volumes, rehashing Euell Gibbons and Brad Angier on the subject of common edible plants—but what for, when others have done it so well? Choose a text or two; stalk the wild whatsit for fun—and longevity.

For health problems: again, you should have advice and texts by experts. We can help a little by parroting them. Aspirin can reduce fever and aching of many kinds from flu to rheumatism. Ethyl or isopropyl ('rubbing') alcohols are among the best general disinfectants without side effects of iodine and merthiolate. Disinfectant should be daubed *around* an open wound, *not* directly into it. Unflavored vodka is about half ethyl alcohol and might serve as an emergency disinfectant. We suspect that germs aren't just wild about acetone, either—and soap and water are among the best cleansers of wounds, especially if you must scrub debris from them.

Bleeding helps to cleanse a puncture wound. A clean bandage, *not* airtight, should cover a break in the skin after disinfecting the surrounding skin.

Burns can be relieved first by cold compresses, followed by a gauze bandage smeared with clean petro-

leum jelly. The jelly helps prevent secondary infection while your body repairs the burn. We've read about mountain men covering a burn with tallow or bear grease—but if trying such a remedy with animal products, you'd better cook the stuff first to kill the bacteria it may harbor.

In the special case of a profusely bleeding surface wound, try to pull edges of the wound together and tape them that way. Don't use a tourniquet unless absolutely necessary; gangrene from tourniquets has caused as many deaths as has blood loss. You can lose a pint of blood without serious loss of mobility. To prevent shock after a burn or other injury, have the victim sip a quart of water containing a level teaspoon of salt and a half-teaspoon of bicarbonate of soda. No booze!

You can often relieve a cough by sucking hard candy, by inhaling over a bowl of steaming water, or by sipping hot drinks. Constipation can be countered by adding fruit, especially prunes, figs, or raisins, to your diet. If the fruit is dry, soak it in water awhile.

For many skin problems—poison oak, rash, fungus infections,—calamine lotion will help. Athlete's foot is a fungus infection, by the way. The fungus thrives on soft, soggy skin, which explains why you must keep your feet and footgear dry—and brings us to an area of special concern: your feet.

When you can no longer buy fuel for your moped and the barter market or paramedic is two klicks away, you will begin to give your feet the respect they always deserved. If you don't think corns or athlete's foot can have you walkin' on your knees, you've led a charmed life. A corn, often from improperly tight shoes, can cause excruciating pain. Commercial preparations can dissolve them, but

you may be reduced to shaving one away with a razor blade. Don't imagine that you can get away with wearing a corn pad indefinitely, unless your shoe was designed for that pad—and it wasn't, was it? So treat the symptom (the corn), and correct its source (usually tight or run-down footgear).

Athlete's foot isn't as painful at first, but it can fill your boot with blood and yuchh, and may lead to serious systemic infection, and the itch can drive you right across the ceiling. Oh, yes; and if you scratch it with fingernails, you can spread the fungus to other parts of your infection-weakened bod. *Now* will you take athlete's foot seriously? Cotton or wool socks help absorb moisture from your foot, while synthetics don't. You could also put tiny lambswool pads between your toes if your feet sweat a lot. Always dry between your toes after a wetting before your socks go on; and a dusting of talc between toes and into shoes will help.

Choose ankle-protecting footgear for ruggedness and reasonably loose fit, and wear two pairs of socks if you need to. Keep shoes pliable and water-resistant. If you try to dry them next to a fire, you're risking serious deterioration of the leather. Don't choose the sexy overlap-closure boots that hint of the downhill racer unless you live in snow. Those closures keep snow out, but water doesn't give a damn for any but the most perfect overlap; step into a creek up to the closure and it may mean instant sog in your boot. Instead, choose the accordion-fold closure, and inspect the lace 'D' rings to be sure they weren't anchored through the leather in such a way as to leave a path for water to trickle through to your sock. Your walking boots should let you step into water nearly up to the lace tie, without letting water in.

If you have a persistent skin sore, whether on your foot or from a hangnail, you might try a last-ditch remedy we've tested: man's best friend. We'd read of people with jungle rot letting a healthy dog treat the wound by licking it, but never tried it until 1978. An infected hangnail had defied our two-week treatment with antiseptic. Then our neighbor's canine medic, Bozo, took a sniff of the offending digit and did everything but write us a prescription. Whatthehell, we thought, and let him treat it twice a day. We can't swear that Bozo licked the swollen hangnail well in a week, but we *can* swear that we used no other medication during 'saliva therapy', and it got well in a week. We were only trying what American guerrillas on Leyte had tried, and got the same excellent results. Hardly a controlled experiment; but it's an idea you might keep on file.

Energy technology, especially alternative sources of heat and fuel, is a fad right now. Pay attention to the simple alternatives. We've seen a cardboard box, with sloping clear glass front and foil-lined insulated inner walls, cook pastries by sunlight. It could just as easily dry fruit leather or cure meat strips into jerky, even in a light overcast.

Many stored fuels, including gasoline and diesel fuel, are perishable within a year. If you use old stored fuels you risk fouling the engine or carburetor by gums and shellacs. There are special stabilizer chemicals you can add to stored fuel, but you might just use alcohol. Rubbing alcohol is about half water and won't work. Methyl ('wood') and ethyl ('booze') alcohols are a bit tough to store because they readily evaporate, but they won't foul an engine. For a diesel, alcohol won't work well. For a gasoline engine, it works well *after you modify the carburetor.*

The optimum gasoline-to-air ratio is different from the optimum alcohol-to-air ratio, and there are two ways to easily modify that ratio in the carburetor. You can ream the carburetor's main jet with a drill bit so that its cross-sectional area is about half again—i.e., 150%—the size of the original hole through the jet. That way, the tiny hole can supply half again as much liquid fuel to provide roughly the same power as always—though your mileage will be poorer with alcohol. Or you can adjust the choke, a much easier process, by mechanically wiring or jamming the carburetor's 'butterfly' air intake valve partly closed. This restricts the carburetor's air intake instead of increasing its alcohol intake—and of course your maximum power will be reduced somewhat. If you don't understand this paragraph, ask any mechanic to show you what we mean.

But where do you get alcohol? You can distill corn mash or wine for ethyl alcohol. You can (because we've done it) distill wood chips or kindling to get methyl alcohol, which is poison if taken internally. Remember that the charcoal left in the container after methyl alcohol distillation is a perfectly good fuel for stoking the next 'charge' of the still. Don't use charcoal in a closed room; its carbon monoxide effluent can kill you.

When you begin to produce alcohol you'll shoot your thirsty Thunderbird in favor of a Honda or moped. Even a five-gallon yield is more than a tabletop operation; you'll need a big metal drum or its equivalent to contain the wood to be heated. An airtight lid on the drum is essential. The condenser of a still may be a coil of tubing, or may be simply a long water-cooled pipe which is much easier to clean out. Water, acids, wood tars and turpentine

are all recoverable from heated wood, along with the alcohol and acetone that will collect in the condenser. Consider a second distillation to separate the alcohol from the acetone by careful control of temperature. Acetone can fuel an engine along with alcohol, but is also a particularly good solvent. You can make quick-drying wood cement by dissolving shavings of many plastics in acetone. When the wood cement is thinned with more acetone it makes lacquer.

On a more modest level, study fire-kindling techniques. Lint and stored dandelion fluff will kindle from a modest flame, be it flint-and-steel or some other device. Wooden matches can be waterproofed by a dip in barely-molten wax, especially beeswax.

A windmill or watermill can power generators taken from old cars, which in turn can power lots of things including pumps, blowers, radios, and lights. Yes, clever folks can extract energy from warm springs and chicken flickin's, but your most available energy sources will probably be sunlight, wind, and wood.

Sad to say, you may have your pick of utensils in a post-fallout world. Sad, because you will be picking from the belongings of people who didn't pull through as you did. Stainless steel utensils will last longer than other metals, which is why they're favored by restaurant kitchens.

You may have to make your own utensils to process, e.g., soap. Start with a gallon container with nail-holes in the bottom, packed nearly full of white wood ash—*not* black, charred ash. Trickle a gallon of water through the ash, catching it in another container, which may take a few days. Sprinkle the sodden ash around the rim of your garden plot to dis-

courage snails and focus on the collected lye water. Filter the lye water if necessary, then boil it or let it evaporate down to a half-pint or so. It's concentrated lye when an egg or a scrap of potato floats in it (specific gravity over 1.2). Meanwhile you've rendered tallow from fat and filtered it clean. A half pint of lye and a pound of grease make a pound and a half of soap. When the tallow is melted, nearly too hot to touch, and lye is body temperature (feel the container), slowly pour the lye into the tallow, stirring for a half-hour. Then pour it into a shallow pan and let it cure a week. Sometimes it won't come out perfectly; unmixed tallow will set on top and lye will be on the bottom. But much or all of it will be firm soap. Don't use an aluminum container; the lye will eat it up.

How about glass containers for chemical work of this sort? Learn to cut and smartly rap gallon jugs with a glass cutter, so the top makes a funnel and the bottom, a wide-mouthed vat. Grind sharp edges with a stone for safety. There's also a grease-soaked, flaming twine-and-water-shock method, too. You'll break several jugs learning these tricks. Hacksaw blades are available today with carbide chips for sawing through glass.

How can you make twine? Soak long pulpy leaves of flax or yucca plants for a week in water, then strip and save the long leaf fibers from the leaf pulp. Fibers can be twisted or braided into twine, thence into rope. The Anasazi braided sandals that way.

Pottery? Find clay that can be squeezed and twisted without crumbling, make it into soup ('slip'), screen it to remove crud, then evaporate it to a plastic solid. Slap a piece repeatedly on a hard surface to remove air bubbles (it's called 'wedging') before you hand-form it. Let hand-formed pieces sun-

dry, then stack them loosely within a specially-built chimney. Build a fire gradually up to roar right through that chimney for an hour or so. Or stack the pieces on a heavy metal grid over an intense and long-lasting fire. You potters will sigh at the things we've left out; you others might watch a potter sometime. We've seen water pumps, tobacco pipes, and toilets built of clay, then fired and glazed for watertightness. You could build distillation heat-exchangers that way, making several parallel tubes instead of a coil, the way metal steam boilers are built.

For strong wood glue, boil and stir shavings of horn or hoof in water until you have a sticky gum. Use it while hot and wet, and give it a day to sun-dry. To save the rest, twirl it on a stick and let it dry, then immerse and boil your glue lollipop the next time you need it, as the Comanche did.

Weaving is too complex an art to detail here; study primitive methods like the simple bow loom as well as modern craft methods. Strips of rabbit fur can be interspersed with fibers when weaving a marvelously warm blanket. You can also knit or tie fiber into fishnet, bird trap, or a blanket grid for those fur strips.

If you have the electricity, the expertise, and the need, you can build a mile-long telegraph line as our guerrillas did. They unwound barbed wire and ran the separated strands from tree to tree, using pop bottles for insulators.

If you can't get lubricating oil for an engine, you might try fractionally distilling old oil to reclaim it. Or perhaps you can locate a few castor bushes. Castor beans, though poisonous, are easily crushed for castor oil. Process them as you would for nut oil, with one exception: don't breathe the vapor while boiling the mush. We found the vapor an all-too-

efficient laxative. Don't worry that good castor oil will damage an engine; many a racing engine has thrived on it. It leaves a varnish on parts eventually, but it's an excellent lubricant.

For hunting small game, consider the sling and slingshot. Both are easy to make, they're quiet, and ammunition is plentiful. A longbow will drop a deer, but takes a good arm and carefully-crafted equipment. If pondering which gun to buy, avoid the calibres for which ammunition may be rare. The most commonly available rounds in the US are the .22, .30-.30, .45 ACP, 12-gauge,—and, at almost every drugstore, the BB. The .22 won't reliably and immediately drop game over thirty pounds, and needs at least an 8" barrel for reasonable accuracy. For birds and rabbits, there are some excellent air pistols with rifled barrels that shoot either lead pellets or BB's interchangeably. An air rifle is more accurate but also pretty big to lug around. We're talking about real, pump-up air guns, not spring-loaded or CO_2-powered guns. A pump pistol is relatively quiet with muzzle velocity up to 500 ft/sec, and will sting the bejeezus out of a mean mutt. Perhaps the best thing about a good air pistol is that you can quietly practice using it for pennies inside your house, using plywood or a dozen thicknesses of corrugated cardboard as backstop.

Jerzy Kosinski once described a simple fire-carrier made from a big juice can, for travelers without matches who need warmth while traveling. Punch ten spaced holes around the side of the can next to its bottom, and cut its top completely out. Add a long wire handle, borrow some fire, and keep a small bed of coals glowing as you hike along. For a fast fire, drop in a few hunks of wood and kindling and swing the can around in a circle; the forced draft

does the rest. Kosinski claimed it was called a 'comet' because of the trail of sparks it makes as it whirls around your head, and we found that the metal can is glowing in less than a minute. If it doesn't discourage an unarmed intruder, he must be desperate. As a small space heater and stove, the 'comet' is a lifesaver. Our kids learned to make them at age six. Since then, we've developed sophisticated versions, testing new wrinkles by stoking a comet in a handy fireplace. It's a low-profile hobby, and it could save the hobbyist's life.

Perhaps you've noticed: we've begun to segue from the software of your tenacity chest, to its hardware. Check on the shelf life of seeds and medicines you keep (even aspirin eventually decays with a vinegary odor), and next time you spot a sale on needles or injector blades, get a handful. A dime may have more purchasing power than a paper bill, so keep a roll of coins. Get a quarter-mile spool of strong monofilament nylon fishing line for lashings, sewing, traps, and so on.

Pick up a hand-cranked meat-grinder at a garage sale. We cut the clamp from one and made a small T-handle so the whole thing, spare grinder heads and all, fits into a bike's handlebar pouch as a mass the size of a grapefruit. It'll grind tough meat or hard corn, and when you have dental trouble it can make life bearable. It's also useful for processing nut and vegetable oils. Why did primitive plant gatherers seldom live past forty? For one thing, grit from their stone grinders wore their teeth down to the gumline by that age, in a chain reaction of events that impaired digestion and health. Get the bloody hand grinder! It's more crucial than you think.

There's one item we won't suggest that you buy,

because you wouldn't; radiation monitors are expensive. But you can make one for next to nothing! Oak Ridge document ORNL-5040 is a little book that gives astonishingly complete instructions on building a calibrated foil electroscope that measures ionizing radiation—i.e., a fallout meter. Its calibration lets you know how much fallout is in your area, so you can judge your tactics better, and the little meter is built entirely of common household materials. We've rarely seen any sophisticated device as well-engineered to be built by rank beginners—and have never seen one as potentially crucial to human survival. Copies of the manual have been sent to libraries in Stanford Research Institute, National Technical Information Services, Illinois Institute of Technology, and defense documentation centers. Your congressbody can probably locate one which could be reproduced for you. Newspaper editors please copy; the document is in the public domain.

We've discovered only some bare necessities to be packed into your tenacity chest, but we must stop somewhere. The one thing you must keep stored, above all, is your own tenacity. If you weren't interested in the history of technology before, you'd be wise to get interested now. Herbert Hoover and wife translated Agricola's mining/smelting treatise, *De Re Metallica,* into English. The conquistadores processed nitrates from horse manure to make gunpowder, and might have used bat guano from caves as well. Platinum jewelry can make catalyst grids for making industrial chemicals including acids. What do you care about thumb-pumped hairspray? Well, the spring-loaded ball check valve is visible inside, and can teach you how larger pumps can be built.

Presuming a post-fallout world, you'll find yourself becoming a generalist, much more self-sufficient

—but you'll be smart to specialize as well, so you can trade special skills and products. Concrete begins with mortar from crushed, kiln-baked seashells. Repeated flooding and evaporation of sea water yields acres of edible salt. Sugar can be extracted from beets or cane. Smokeless powder begins with cotton stepped in a mixture of nitric and sulfuric acids for guncotton which is then washed, dried, dissolved in solvent such as acetone, and extruded to dry as flakes or tiny pellets. It has its dangerous moments, just as producing nitric acid from sulfuric acid and nitrates does. You'd best leave the production of primer explosives to chemists—though guncotton, in its dry fluffy form before solvent processing, can be detonated by a blasing cap or shotgun shell primer and might have brief popularity as a commercial explosive.

Commercial? Positively, yes. Even if governments fail and most citizens die, survivors will clear away the debris and eventually build a new commerce, a new government, a new society. If you've stored enough tenacity with your information and hardware, you may find that life can still be long and sweet and useful. And if you would be fondly remembered, you could hardly do more than demonstrate the pleasures of a life that's long, sweet, and useful.

—Dean Ing

"WASTE NOT, WANT NOT"

by Karl T. Pflock

"There's nothing like a dose of facts to cure a case of nuclear heebie jeebies."

I'm what Jim Baen calls a "fissionary"—a hard-core supporter of all-ahead-full development of nuclear-electric power. But not so long ago, I had my doubts. Serious doubts.

I grew up during the forties and fifties, the age of "Our Friend the Atom," when everyone, including yours truly, *knew* that generation of electricity in nuclear-fission-fired powerplants was the wave of the future. A future of cheap, clean, safe, and well-nigh unlimited energy. A future of abundance. A future that would be our "now" in the seventies and eighties.

When the "antifissionary" tide began to rise, I was a bit surprised but not much concerned. The introduction of a new technology is always resisted by some, even some who should know better. (Edison warned of wholesale slaughter by electrocution when AC power distribution began.) And, after

all, weren't the tremendous economic, environmental, social, and even political advantages of nuclear obvious? We fissionaries were sure the antinuke movement was a flash in the pan. There was no need to mount a countermovement, no need to answer the charges of the antifissionaries. Nuclear was so good it didn't need defending. Boy, were we wrong!

Unchallenged by the fissionaries, the antifissionaries (some of them, anyway) sounded pretty reasonable. Before we knew it, a host of intelligent, concerned people were saying "No more nukes!" in no uncertain terms.

And this fissionary began to have doubts.

I wasn't concerned about the nuclear powerplants themselves. I knew they were far and away safer, cleaner, and more economical than coal-fired plants, their only serious long-term rival in the field of large-scale energy generation. I knew that uranium mining was much safer and far more environmentally desirable than coal mining. I knew the same was true for the rest of the fuel cycle—until it came to wastes.

What about wastes? I wondered. Don't nukes generate dangerously radioactive offal that remains dangerously radioactive for thousands of years? Suppose it's true that there is no known method of safely disposing of nuclear wastes and isolating them from our environment? Suppose that such a method is unlikely to be developed? Would "nuclearization" condemn future generations to a radiological nightmare of cancer, twisted genes, and the potential dictatorship of a "nuclear priesthood" charged with watching over the dumping grounds to protect lesser mortals from the ionizing demons lurking within?

Such a prospect scared the pants off of me. So I decided to dig out the facts. Here is what I found:

(1) It is completely *un*true that no viable method of nuclear waste disposal and management is known.

(2) It is completely *un*true that environmental safety demands that wastes be guarded for thousands of years.

(3) It is *true* that, when it comes to wastes, as in every other department, nuclear offers tremendous safety, public health, and environmental advantages over fossil-fuel power generation.

(4) Nuclear power and other man-created sources of radioactive waste do *not* add radioactivity to our environment. They *reduce* it and redistribute what's left in ways that further cut risk.

There's nothing like a dose of the facts to cure a case of nuclear heebeegeebees. If you are afflicted as I was, I hope what follows will do the trick for you.

All That Trash: Industrial and Powerplant Wastes Today

According to the Environmental Protection Agency, in 1980 the United States produced more than 39 million tons of industrial wastes, and the amount is growing at a rate of about 3 percent a year. Some 10 to 15 percent of this stuff is hazardous. Most of these wastes go into unmonitored landfills, some 100,000 of them. About 10 percent of these are in compliance with new federal regulations which recently began to go into effect.

The rest of the wastes are dealt with in a variety of ways. They are impounded in unlined lagoons, dumped down sewers and into deepwells, burned in uncontrolled incinerators, and even spread on roads. Moonlight dumpers do their bit too, with no regard for ecological niceties.

One year's volume of toxic industrial wastes is

more than 7000 times that of all the nuclear wastes created by nuclear powerplants since the first went into operation 24 years ago. The more stable of these non-nuclear wastes, such as PCBs, remain toxic for centuries. The elemental toxins, such as arsenic, remain toxic forever.

A very significant contributor to our mounting waste problem is the generation of electrical power by fossil-fuel-burning powerplants, in the main, coal-burners. These wastes are massive, persistent, and dangerous.

In 1978, 480 million tons of coal went into American powerplants. That's 913 tons a minute. The wastes that came out weighed more than twice as much. If this surprises you, remember your elementary chemistry. Energy is released from coal in a chemical reaction, in which the mass of the materials coming out must exactly equal the mass of the materials going in. What went in was not only coal but also atmospheric oxygen and some nitrogen too. So in 1978, U.S. coal-fired plants generated more than 960 million tons of waste, and more in 1979, and still more in 1980. . .

All this stuff can go only two places: into a landfill or into the atmosphere. No matter where you live, you'll wind up drinking, breathing and eating some of it. The gases and some particulates pour out of the stacks; the furnace bottom ash and the scrubber sludge go into settlement ponds to be evaporated into dry solids which are then hauled off to landfills. The fly ash, most of it, is precipitated or filtered out of the stack effluents and trucked to landfills to join the gunk from the settlement ponds.

A typical 1000 megawatt (MW) plant generates solid wastes at the rate of 30 pounds per second. They contain carcinogens, 19 toxic metals, and some

mutagens. Because coal contains uranium, radium, pollonium, thorium, and other radioactives, solid wastes and stack emissions are also radioactive, as much as 50 times more so than what is normally emitted by a nuclear plant. As Prof. Petr Beckmann has pointed out, if coal-fired plants fell under the preview of the Nuclear Regulatory Commission, the great majority would be shut down for exceeding radioactivity limits.

But it's not the radioactivity that makes this crud dangerous (even though 50 times greater than the output of nuclear plants, it's minuscule). There are two real problems. One is that the solids are deposited in landfills where nobody pays any attention to them—until they leach out into ground-water supplies, fishing streams, and, maybe, your basement. The really dangerous stuff in these wastes, such as mercury and arsenic, stays dangerous *forever*. (The radioactives, which present no real health hazard, will eventually render themselves unquestionably harmless, one of the virtues of being radioactive.)

The other problem is the incredible volume. Assuming that coal use for power generation remains at the 1979 level—a highly questionable assumption—the scrubber sludge *alone* will add up to 1,440,000 acre-feet (1.44 million acres one foot deep in sludge) by the dawn of the twenty-first century.

But the real danger from a health standpoint is the stuff that spews out of the powerplant stacks. Even though you can barely see it these days, it's there and it's nasty. Our typical 1000 MW coal-burner belches out 30 pounds of sulfur dioxide per second, as much nitrous oxide as 200,000 automobiles running simultaneously, and even if the plant's precipitators are 99 percent efficient, 18 pounds of

particulates per minute, stuff too fine to be filtered out.

Sulfur dioxide has been linked to lung, bronchial, and heart diseases. Cee-oh-two is not toxic, but it may produce significant climatic effects. Nitrous oxides turn into photochemical smog, which not only smells bad and makes your eyes water but also has been linked to cancer in urban areas. Particulates, which are highly abrasive, do all sorts of not-so-nice things to lung and bronchial tissues.

Using the atmosphere as a waste dump for coal-fired powerplants does not come free. A price must be paid, and the price is high. Working from figures developed by the Brookhaven National Laboratory and published in a recent Congressional Office of Technology Assessment report, I have calculated that almost 38,000 Americans paid that price in 1980. They died. By 1990, the annual toll could be more than 43,000. Add to this carnage the number of persons "merely" made sick—greater by orders of magnitude surely than those actually terminated—and the picture becomes bleaker still. We won't even address mere aesthetic considerations of colossal landfills, or of the still speculative but possibly catastrophic dangers of acid rain and run-away greenhouse effect.

But it doesn't have to be. Nuclear power can eliminate *all* of the death-dealing, environment-despoiling wastes produced by fossil-burning powerplants, replacing them with a tiny volume of far-safer waste material. If the entire U.S. electrical-generation capacity were nuclear, the wastes per person per year after reprocessing would occupy a volume the size of an aspirin tablet. It would take a 100 percent nuclear United States 350 years—three and a half centuries—to produce a cube of waste measur-

ing 200 feet on a side. And nearly 40,000 people wouldn't have to die every year.

At the moment, our progress toward this happy goal is stalled, and a principal—if not *the* principal—reason is the *political* problem of nuclear-waste management and disposal. Below, I'll discuss what should and *can* be done with nuclear wastes—using current know-how and technology. Right now, let's consider what actually is being done with them. It can be summed up in one word: nothing.

The propaganda of the antifissionaries has been very effective in political circles. Under a directive issued by former President Carter—a directive that I hope President Reagan will have rescinded by the time this sees print—"spent" nuclear fuel is piling up in the very limited storage facilities at nuclear powerplants around the country, facilities that were meant to be only temporary way-stations in the waste and reprocessing cycle. No permanent repository for high-level wastes is under development. Everything is on hold. And it is all a matter of politics, not science and technology. But let us suppose the politicians suddenly came to their senses, sent the antifissionaries packing, and. . .

How Nuclear Wastes Would Be Handled If . . .

In the beginning, there are fuel rods. The fuel for a light-water reactor (LWR)—with one exception, all U.S. commercial power reactors are LWRs—is a mixture of two isotopes of uranium, the rare, easily fissionable U235 and the common, ordinarily nonfissionable U238. The U235 makes up only 3.3 percent of the mix. In the form of ceramic pellets of uranium dioxide (UO_2), the fuel is sealed into stainless steel or zirconium alloy tubes. These rods are bundled into fuel assemblies and inserted into the

reactor core, where they remain in service for about three years.

During the reactor's operation, neutrons, produced initially by the fission of some of the U235 nuclei, zap other uranium nuclei. Some of these "targets" split, continuing the chain reaction. Others absorb the subatomic bullet, increasing their atomic weight by one. These two types of reactions produce a host of fission products: strontium 90, cesium 17, plutonium 239, and literally hundreds of others. (The plutonium participates in the fission reaction. In fact, near the end of the three-year period, 54 percent of the fission reactions are taking place in Pu239.)

After three years, the build-up of these fission products is so great that an efficient chain reaction can no longer be sustained. The energy in the fuel hasn't been used up. Far from it: of every metric ton (1000 kilograms) of fresh fuel, only 24 kg of U238 and 25 kg of U235 have been consumed. There's a lot of valuable, energy-rich material left, but it must be purged of the "contaminants" that are gumming up the works.

So the "spent" fuel is removed from the reactor and placed in on-site cooling ponds. The rods are hot both radioactively and thermally. Their stay in the cooling ponds, about six months, permits the short-lived, intensely radioactive isotopes (i.e., the most dangerous ones) to die away and the rods to give up some of their heat.

From the cooling ponds, the rods are shipped to a reprocessing plant. (One of these facilities can handle up to five tons of spent fuel a day, the annual output of eighty 1000 MW reactors.) There they are cut up into short pieces and dissolved in a nitric acid bath. The resulting solution is put through a series

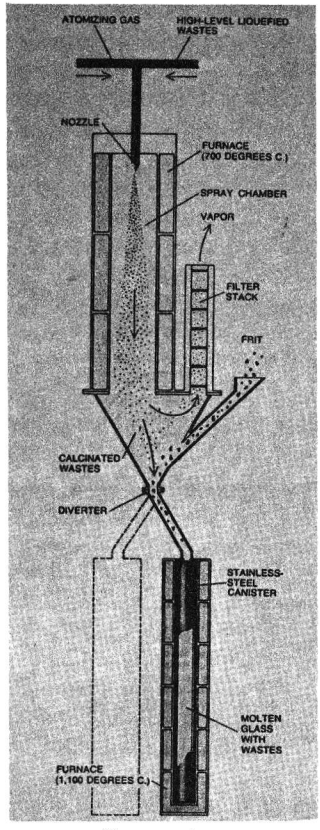


figure A

High-level Waste Processor. Liquid waste is converted into fine powder in calcinating chamber (top), mixed with glassmaking frit (middle), melted into block of glass inside stainless steel storage canister (bottom). When one canister is full, flow is diverted into new canister (broken outline).

of chemical separation processes to recover all but a tiny amount of the fissile (fissionable) uranium and plutonium. What's left is what is known as "high-level" (strongly radioactive) waste.

The extracted uranium is "enriched" (processed so that the proportions of U235 and U238 are 3.3 percent and 96.7 percent respectively) and reprocessed into new fuel elements. The plutonium (plutonium oxide) can be used in "mixed-oxide" fuel rods, in which it is combined with uranium oxide, or it can be stored for use in pure form in advanced reactors not yet in commercial service.

The high-level wastes are in liquid form after reprocessing. They contain all the fission products, the source of most of the radiation given off by the brew, as well as such isotopes as neptunium, americium, and curium, plus very small amounts of uranium and plutonium not caught during the chemical separations.

The next step in the process is the solidification of the liquid wastes. This is done by incorporating them into a leach-resistant medium such as borosilicate glass (a lot like Pyrex) at a ratio of inert material to waste of 2:1. The resulting cylinders each measure about 300 centimeters by 30 centimeters. Their total volume per year for a 1000 MW nuke is about 2 cubic meters. It would fit easily under your dining room table. Not that you'd want it there! (By the way, a coal-fired plant of the same capacity spews out 10 tons of waste—*per minute.)*

Each cylinder is sealed inside a stainless steel canister, which is then shipped to an interim storage site. There the canisters are encased in three-foot-thick concrete storage modules, where they are kept for 10 years, to permit them to lose some of their heat. After 10 years, the heat released by each

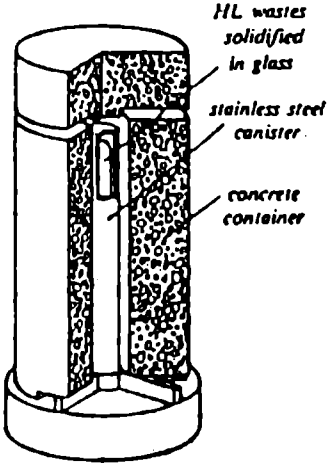


figure B

Interim Storage Module

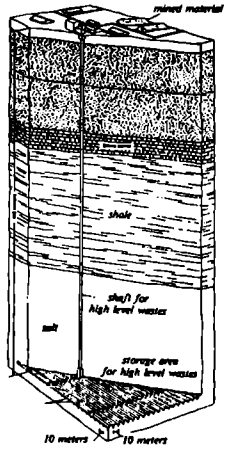


figure C

Permanent High-level
Waste Repository

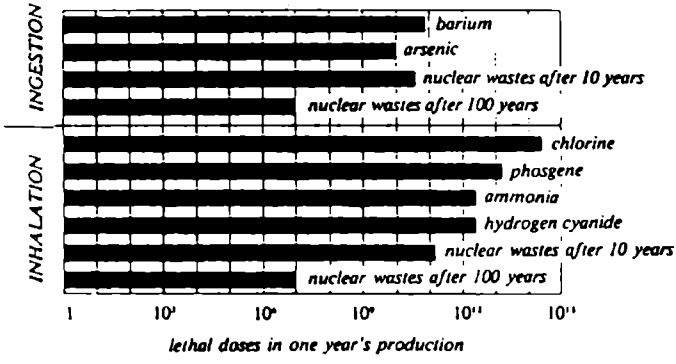


figure D

Nonradioactive Toxins Compared to Nuclear Wastes. Nonradioactives are not buried safely underground. Arsenic, used as pesticide, is spread in agricultural areas, remains poisonous forever.

canister will have dropped to about that put out by your home laundry dryer.

After their stay in the interim depository, the canisters go to their final resting place, 600 meters (about 2000 feet) underground in a geologically stable salt formation. There they are spaced at intervals of about 10 meters, to allow for cooling and possible future retrieval (more about this below).

A year's worth of wastes from a 1000 MW plant goes into 10 canisters. Buried at 10 meter intervals, each canister takes up 100 square meters; all 10 occupy 1000 square meters. If the entire U.S. electric-power network were nuclear, it would require about four hundred 1000 MW plants. Thus the total high-level wastes generated annually by a 100 percent nuclear America would require an area of less than half a square kilometer for permanent storage.

But. . .

Although the reprocessing and waste disposal story was told above in the present tense, only the first step is currently taking place in the United States nuclear power industry. Why? It has nothing to do with scientific or technical problems. Reprocessing technology is solidly proven. It has been used in the defense industry since 1943. Britain, France, and the USSR have commercial reprocessing plants in operation today. Germany and Japan will soon follow suit.

There is some debate over the absolutely best possible substance in which to seal the wastes and about the absolutely ideal location for permanent disposal, but note the qualifying words: "best possible" and "ideal." The disputes are of the "Can't we do it even better?" variety.

No, the problem is not scientific or technical. It is

a matter of politics. Thanks to the activities of the antifissionaries, the future of nuclear-power technology is an uncertain one. As a result, private industry is reluctant to get into the reprocessing business, so we have a shortage of reprocessing and interim storage capacity. As for permanent storage, Congress has recently started action that, if the legislation passes and is enacted, will lead to the development of at least one such site. But this is getting the cart before the horse. We need the reprocessing and interim storage *now;* the permanent site can wait at least 20 years.

Even if we had the necessary reprocessing and interim storage capacity ready to go, we could not use it. Because of the antifissionaries' plutonium-scare campaign, reprocessing has been forbidden by a presidential order issued by Jimmy Carter, "nookeyer engineer." Carter said he was afraid that the plutonium separated from the wastes would pose a health hazard (via sabotage and terrorism) and contribute to nuclear weapons proliferation. Actually, this action was a cynical bid for the votes of the antifissionaries. We all know how much good it did Jimmy Boy (yay!). But I digress.

These issues are dealt with at length and disposed of very effectively elsewhere (notably in Petr Beckmann's *Health Hazards of* Not *Going Nuclear,* available from Ace [Note to organizations: high-discount bulk arrangements available]), so I won't spend much space on them here. Suffice it to say that:

Contrary to the all too frequently repeated line, plutonium is *not* the most deadly substance known to man. Arsenic is 50 times more deadly, botulism toxin, thousands of times more. Only a very inept terrorist would prefer plutonium to, say, botulism as

his weapon. A victim of plutonium poisoning would have 10 to 40 years of good health ahead of him after being dosed (that's the latency period of cancer). Botulism kills in hours.

Weapons proliferation? Plutonium oxide reactor fuel is not the same thing as weapons-grade plutonium. When it comes to making bombs their relationship is something like that of applejack and gasoline as automobile fuels. Those countries who want their own plutonium bombs will be quite capable of turning them out on their own, with no help from the U.S., thank you. Whether or not the American nuclear power industry extracts reactor-fuel-grade plutonium from powerplant waste won't make one whit of difference. As for terrorists, any terrorist gang that decides it needs its own A bomb would almost certainly take the "easy" route, making a grab for a ready-made military job rather than using stolen "applejack" to build one that probably wouldn't work.

Additional barriers to waste management have been thrown up at the state level. In 1976, California banned the construction of new nuclear powerplants until the federal government approved a method of safely disposing of plant wastes (a U.S. District Court judge recently ruled the law unconstitutional). Maine, Wisconsin, Iowa, and New York followed California's lead. Eighteen states have banned or sharply restricted the disposal of nuclear wastes within their borders, and attempts to lay down such restrictions have been proposed in others. One such attempt was introduced and defeated in the Colorado legislature in 1979. It would have prohibited the disposal of any "radioactive waste or material" and defined as *radioactive* "any material, solid, liquid, or gas, which emits ionizing radiation spontaneously." As Beckmann has wryly observed, the spon-

sor of the bill would have been guilty of a class one misdemeanor every time she used the toilet!

So reprocessing and waste disposal is roadblocked by politics based on propaganda and ignorance rather than facts. The spent-fuel rods continue to pile up at an alarming rate at powerplants all over the country, where they might soon become dangerous. This problem, this strictly *political* problem, is today a principal—if not *the* principal—obstacle in the way of a rapidly expanding nuclear power industry. And it's killing on the order of 40,000 Americans a year.

Well, It Sure Sounds Good, But Suppose . . .

The $64,000 question (given inflation, maybe it should be the $264,000 question) is: Will the wastes stay put once they are buried? Stay put *forever?* The answer is: Maybe not—but so what?

Those who have seriously considered the matter, fissionaries and antifissionaries alike, agree that the most likely and most serious problem with buried high-level wastes is the danger that ground water may come into contact with the wastes, leach them into solution, carry them up through the surrounding rock and then into our food and water. This means that human exposure would come through ingestion. The danger from ingested radioactive wastes is very high at first, but after a few hundred years, the hazard drops off considerably, to say the least. B. L. Cohen, director of the University of Pittsburgh's Scaife Nuclear Laboratories, has calculated that after 600 years a waste-eater would have to consume half a pound of the stuff to give himself a 50 percent chance of being done in by cancer. (Chemical, non-radiation-related poisoning would get him far sooner.)

So it is important to be sure that nuclear wastes

are isolated from the biosphere for a few hundred years. At first blush, this may seem impossible. However, we're not dealing with human creations here. We are concerned with natural rock formations 600 meters, more than a third of a mile, below the Earth's surface. This is a slow-motion environment in which the time required for any substantial change is measured in millions of years.

In addition to the general stability of things at this depth, any conceivable release sequence has several built-in time delays. The storage site would be located in a region that is free of circulating ground water and likely to remain so for a geologically long time; a span in which a few hundred years is but an eye-blink, so there's no problem about making such a prediction.

Since earthquakes can change ground-water flow patterns, the storage site would have to be in a tectonically stable (essentially earthquake-free) area. If the site were in a salt formation (the most likely choice at the moment), it would have an added advantage. When salt is subjected to pressure, it flows plastically. Should an earthquake occur afterall, the salt would self-seal any cracks that might develop.

But let's say that water somehow managed to get into the formation in which the waste was buried. There would be a delay while the rock (salt) was being dissolved away. How long a delay? Suppose *all* the ground water now flowing in the area around the proposed New Mexico storage site were somehow diverted to flow through the salt. It would take 50,000 years for the salt surrounding one year's waste deposit to be dissolved away.

It would take the water something like 10,000 more years to finish off the stainless steel canisters. Then it would have to go to work on the glass in

which the wastes were sealed. This would take another 30,000 years.

Now the wastes have to make their way to the surface. Typical ground-water flow rates are less than 30 centimeters a day. The distances involved are tens or hundreds of kilometers (the water doesn't flow straight up, of course). At 30 cm a day, it would take about 1000 years for the water to go 100 km. It would take the wastes even longer to go the distance because they would tend to be filtered out by ion-exchange processes. Cohen uses the example of a strontium ion, which would often exchange with an ion of calcium in the surrounding rock. The strontium would stay behind, while the calcium would move along with the water. Eventually, the strontium would go back into solution, but because of continued ion-exchange stopovers, it would move along about 100 times more slowly than the water, taking something like 100,000 years to make it to the surface. Other isotopes in the waste would take even longer to see the light of day.

Our ancestors of 1,900 *centuries* from now are not likely to be too concerned when the stuff shows up, since the radioactivity will have *long* since decayed to harmless levels. More importantly, it should be obvious that wastes deposited in a properly selected site will pose no danger worth worrying about during the first few hundred years after burial, when they are potent.

So we can see that the danger of properly handled high-level wastes making their way into the biosphere isn't something to loose sleep over. Still, at least some of the stuff will probably worm its way out of its tomb, in 190,000 years or so. What is the likely human cost, in lives lost, of this escape? Professor Cohen asked himself this question and came

up with a very reliable answer. In order to be as conservative as possible, he assumed that one year's wastes from an all-nuclear U.S. power system were buried *completely at random* at a depth of 600 meters, needless to say, an approach to waste disposal we are unlikely to take. Basing his calculations on what is unequivocally known about the release of radioactive particles from natural deposits, Cohen found that we could expect approximately 0.000001 fatality per year after the first few hundred years of storage. Put another way, this comes to 0.4 death during the first million years after burial and an additional four fatalities during the ensuing 100 million. Compare this to the nearly 38,000 Americans who died last year from the effects of coal-fired-powerplants wastes. (Then throw in your niece's last bout of bronchitis.)

So the danger of and from wastes being carried into the environment by natural processes is vanishingly small. But what about sabotage? Suppose the Lime Jello Liberation Front decides to break into the waste repository and make off with a canister or two?

I can't imagine why they would be interested. Of what use to terrorists is a "weapon" that takes 10 to 40 years to kill its targets? They would be much smarter to brew up a botulism culture. But let's say the LJLF is dumb enough to think otherwise. There they are, a third of a mile below the surface, faced with searing radioactivity and more than a little thermal energy (*i.e.*, it's *hot!*) and no way to get the goods to the surface. May they rest in peace.

The simple truth is that securing a permanent repository requires little more than putting the wastes in the hole. Once the facility is filled and sealed, "guarding" it would involve occasional inspections

of the surface area (10 square miles for the wastes produced by 1000 years of an all-nuclear United States) to see that warning signs are still in place and to assure that no one has begun mining or deep-drilling operations. (One of the criteria for a waste site is that it have no mineralization of any importance, so it is unlikely that miners or wildcatters would be interested anyway.) It might also be a good idea to take occasional water samples from nearby streams and wells to check radiation levels.

This means that looking after the site would be a one-man job, and the poor guy would get pretty bored. No "nuclear priests" need apply.

Low-level Wastes, Mill Tailings, and All That

So far, I have dealt only with the "problem" of high-level wastes, which comprise only one percent of the volume (but account for 99 percent of the radiation) of all radioactive wastes. Most of the other stuff, the low- and medium-level wastes, does *not* come from the nuclear power industry. The primary contributors are hospitals, which use "deadly radiation" to heal and to detect and diagnose disease. Most low-level wastes consist of paper, plastics, glass, workers' gloves, etc., that *may* have become contaminated with radioactive substances. For the most part, it is no different from the sort of stuff you chuck out every day, except that it may have been made radioactive (something like 0.01 percent by weight of these throwaways is actually radioactive).

In the United States this material is sealed in steel drums and buried a few feet underground in controlled and monitored disposal sites. Other countries haul their waste drums out to sea and heave them overboard.

This may seem pretty sloppy, but compared to the

total radioactivity of ordinary sewage and other crud pumped into the oceans, there's little to be concerned about. Petr Beckmann has developed an amusing yardstick with which to measure the low-level waste "threat." I call it Beckmann's Whiskey Factor. American whiskey consumption is on the order of 200 million gallons a year. Once it has been ingested by elbow benders from coast to coast, most of its ingredients make their way to the sea. Since whiskey is radioactive (about 1.2 nanocuries per liter), America's boozers contribute virtually the same amount of radiation to the world's oceans as that from one ton of low-level waste. So if someone says to me, "Low-level wastes are not much of a radiation hazard," I'll drink to that.

Mill tailings present a different "problem." When a uranium nucleus breaks down by natural radioactivity, one possibility is that it will become one of the fission products that in turn becomes radium. Radium gives birth to radon, which then leads to a chain of additional unstable elements that finally ends in lead, which is stable. The most dangerous characters in this busy radioactive begatting are radon and its daughters. They are highly radioactive and, as gases, are easily inhaled. As it happens, radon is the most serious natural radioactive health hazard in the biosphere. According to a report of the United Nations Scientific Committee on Effects of Atomic Radiation, it causes 10,000 cancer deaths every year in the U.S. alone. It is also the main source of lung cancer in uranium miners.

Uranium mill tailings (what's left after uranium oxide is extracted from ore) have a fairly high U238 content. So mill tailings are open sources of radon gas. But even assuming that the tailings are just left lying around, they would have to accumulate for

80,000 years before they produce the annual fatalities that result from the use of coal to generate electricity.

As a matter of fact, on this issue of what effect today's mining activities will have on radon emissions, coal turns out to be worse than uranium. Uranium is everywhere, and, everywhere, it gives off radon. On the average, coal contains one part per million of uranium. This tiny amount of uranium is released to the environment as a source of radon. Of course, the hazard from the radon emitted by coal is quite small. But for a coal-fired powerplant, it is 1000 times greater than for a nuclear plant of equal capacity. The nuclear plant uses one heck of a lot more uranium than the coal-fired facility, but in so doing, it burns it up, preventing it from producing radon. The plant's wastes are radioactive, but the total amount of radioactivity that gets into the environment from this waste is less than what the uranium would have given off if left in its natural state. The uranium that is mined to feed nuclear plants is taken from deposits that are close enough to the surface to release radon into the biosphere.

So the net result of mining and burning uranium in nuclear powerplants is to *reduce* the total radiation in our environment—even if the tailings are left lying around unattended. (When we start using breeder reactors to breed U238 into plutonium, it's a sure thing that the tailings won't be left lying around for very long.)

One further point: Uranium and its daughters are found in random natural deposits all over the United States. They occasionally get into food and water, and sometimes they kill people. (Beckmann has pointed out that there are *30 trillion* cancer doses lying around all over this country.) By digging this

stuff out of the ground, using it to produce power and in other applications, and then putting what's left back into the ground in safer places than those in which we found the original ore, we are making our environment a safer place for "children and other living things."

At some point, every nuclear plant will have to be taken out of service. (The same is true for any other energy facility.) Nukes are licensed for 40 years of operation, after which they have to be decommissioned.

In the course of operation, some parts of a plant will have become radioactive. Surface contamination is easily taken care of by chemical cleaning or sandblasting. Some plant materials will have themselves become radioactive (induced radioactivity), and they will have to be handled differently because they will be hazardous for a long time. For example, the steel pressure vessel of a reactor will remain dangerously radioactive for 50 to 100 years.

There are three tested ways to decommission a reactor. The first is mothballing, which involves blocking the entrances with concrete plus some other measures. The second is entombing, which is a simple matter of burying the thing under a mound of earth. The third is dismantling by remote control. All three work. When the time comes to decommission a plant, the choice of which method to use is dictated by economics. Over the past two decades, 65 U.S. reactors, 5 of them power reactors, have been decommissioned using these techniques (only one was immediately dismantled by remote control, in an experiment to test the method). So we have plenty of experience.

The reactor building takes up less than 10 percent

of a typical plant site, so it is quite feasible to mothball or entomb a reactor and install a replacement on the same site. At the moment, the industry seems to favor 100-year mothballing, after which the "spent" reactor can be dismantled and removed with no special precautions. This would cost less than 2 percent of the initial plant-construction outlay.

Clearly, decommissioning presents no major difficulties.

Finally, what about the risks involved in transporting nuclear wastes? Let's first consider those entailed in shipping other hazardous materials, or for that matter, coal.

Nearly 500 tons of coal goes from the mines to U.S. powerplants every year. And every year, 50 to 100 people are killed in the process. (I've done some checking, and so far as I have been able to determine, no one has ever been killed during the shipment of nuclear fuel.)

As for hazardous materials that are routinely produced and shipped all over the country, there are vast quantities and frequent accidents. Pick up today's newspaper or tune in the evening news. It's a good bet that you will come on a story about an evacuation of hundreds of people caused by the derailment of a train loaded with chlorine, sulfuric acid, ammonia, or some other toxic material. The report very likely will include a body count. Annual U.S. production of toxins is tremendous. Every year we turn out 16 million tons of ammonia, 32 million tons of sulfuric acid, and 9 million tons of chlorine. These are only three of hundreds of such dangerous substances produced by the millions of tons annually. We also import large quantities of arsenic,

barium, and other toxins. All of this deadly stuff has to be shipped to users. The hazards presented by the transportation of these substances are a result of the vast quantities involved. It is impossible to prevent major accidents from happening.

I am not suggesting that we should stop manufacturing, importing, and using these things. They are essential to our industrial economy. The point is that major mishaps, involving the deaths of hundreds of people and millions of dollars in property damage every year, are unfortunately a routine consequence of their shipment and use. The vast quantities involved make it inevitable.

However, there are those who shrilly insist that nuclear-waste transportation presents a grave health hazard overshadowing those touched on above. In fact, the quantity of nuclear wastes is so small that it is quite possible to provide safeguards that are out of the question for other hazardous substances. Containers for the shipment of nuclear fuel and wastes have been developed and are in use that can withstand crashing into concrete walls at 60 mph, dropping onto spikes from 30 feet, and prolonged exposure to the flames of an intense fire. That it is possible to provide such protection for nuclear wastes is still another happy consequence of their small volume.

Of course, nothing is impossible. Eventually, there will be a nuclear-waste-transportation accident with some loss of life. Eventually. Meanwhile, the wastes from coal-fired powerplants are killing thousands of people every year.

Still Another "But": Is It All Trash?

Back up the line a bit I mentioned the possibility of storing high-level wastes in such a way that they

could be retrieved. Most nuclear waste is useless, its most important feature is its tiny quantity, its greatest value being as a replacement for vastly greater quantities of far more dangerous junk.

However, some of it is useful now, and some may be useful in the future. Today, certain fission products are extremely valuable as tracers. An isotope's chemical properties remain the same whether or not it is radioactive. Using radioactive isotopes, researchers can, for example, see how a particular chemical is distributed through an organism.

Cancer researchers are using the chemical-equivalence angle in an attempt to develop substances that will seek out cancerous cells and kill them, while leaving normal cells undamaged. Edward Teller reports that in preliminary experiments 70 percent of test animals so treated recovered from breast cancer.

It is possible to use fission products to irradiate sewage sludge, killing the disease-causing bacteria it contains while the sludge itself remains radiation free. The purged sludge would then be useful as fertilizer and animal fodder—a big improvement over dumping it into landfills.

This same process of irradiation can also be used to eliminate bacteria from food, preserving it without the use of chemical additives which may cause serious health problems in humans and leaving the foodstuffs in their natural state. (This process is already in commercial use in South Africa.) Irradiation is also used to sterilize medical instruments and heat-sensitive prosthetics such as heart valves that can't be sterilized in any other way.

Nuclear wastes contain some extremely valuable rare metals that are essential ingredients in certain very important alloys and in other vital applications.

These are formed from a reactor's uranium fuel during the process of fission, a sort of modern alchemy. Three examples are rhodium, palladium, and ruthenium. Today, they are available to us only from Zimbabwe (Rhodesia) and South Africa. Tomorrow it may be possible to economically extract them from nuclear wastes.

"Waste Not, Want Not"

Far from being a problem, nuclear wastes are one of nuclear power's major advantages. They offer us the opportunity to make a big dent in the general waste-disposal problem. For the same amount of energy, nuclear wastes are 3.5 million times smaller in volume than coal wastes. They can be easily and cheaply isolated from the biosphere, and unlike most nonradioactive toxins, their threat to health dissipates over time.

Unlike coal-fired plants, nukes do not spew their wastes into the atmosphere and threaten to inundate the landscape with tons of solid garbage. Nukes could eliminate almost 40,000 unnecessary deaths a year in the U.S. alone, and some of their wastes can be turned into useful products and even be used to make other wastes valuable.

But perhaps the greatest long-term contribution of nuclear power, apart from the energy it can provide, is to the conservation of fossil mineral resources. We are currently burning up hydrocarbons —coal, oil, natural gas—at the rate of millions of tons daily. This is an absurd waste of vital finite materials that future generations must have to make pharmaceuticals, plastics, organic chemicals (including fertilizers), and a host of other extremely useful products. If we cease development of nuclear power and instead keep burning up our fossil resources, we

will almost certainly bequeath our descendants a legacy of deprivation in a dirty and unhealthful world.

Moreover, we may well deny them the stars. Obviously, the colonization and industrialization of space must begin and be supported for a long time from right here on Mother Earth. Such an undertaking requires a strong, secure, and burgeoning industrial base, which in turn requires abundant energy and substantial raw materials, including the fossil resources that are today literally going up in smoke. Our chance to make the unlimited bounty of space our own, our opportunity to make a bid for racial immortality, depends upon this generation—you and me—making wise use of our little planet's limited resources. Going nuclear in a big way would be an important—perhaps the crucial—step in the right direction. In the bargain we would get a clean, healthful, beautiful, and prosperous Earth. That's not a bad deal, if you ask me.

Waste not, want not!

—Karl T. Pflock

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Maybe you can change the past... and maybe not. But some things never change.

The tyrannosaur's bellow made everyone jump except Vickers, the guide. The beast's nostrils flared, sucking in the odor of the light helicopter and the humans aboard it. It stalked forward.

"The largest land predator that ever lived," whispered one of the clients.

"A lot of people think that," said Vickers in what most of the rest thought was agreement.

There was nothing in the graceful advance of the tyrannosaur to suggest its ten ton mass, until its tail side-swiped a flower-trunked cycad. The tree was six inches thick at the point of impact, and it sheared at that point without time to bend.

"Oh dear," the female photographer said. Her brother's grip on the chair arms was giving him leverage to push its cushion against the steel backplate.

The tyrannosaur's strides shifted the weight of its

deep torso, counterbalanced by the swinging of its neck and tail. At each end of the head's arcs, the beast's eyes glared alternately at its prey. Except for the size, the watchers could have been observing a grackle on the lawn; but it was a grackle seen from a june-bug's perspective.

"Goddam, he won't hold still!" snarled Salmes, the old-money client, the know-it-all. Vickers smiled. The tyrannosaur chose that moment to pause and bellow again. It was now a dozen feet from the helicopter, a single claw-tipped stride. If the blasting sound left one able, it was an ideal time to admire the beauty of the beast's four-foot head. Its teeth were irregular in length and placement, providing in sum a pair of yellowish, four-inch deep, saws. They fit together too loosely to shear; but with the power of the tyrannosaur's jaw muscles driving them, they could tear the flesh from any creature on Earth—in any age.

The beast's tongue was like a crocodile's, attached for its full length to the floor of its mouth. Deep blue with purple veins, it had a floral appearance. The tongue was without sensory purpose and existed only to help by rhythmic flexions to ram chunks of meat down the predator's throat. The beast's head-scales were the size of little fingernails, somewhat finer than those of the torso. Their coloration was consistent—a base of green nearing black, blurred by rosettes of a much lighter, yellowish, hue. Against that background, the tyrannosaur's eyes stood out like needlepoints dripping blood.

"They don't always give you that pause," Vickers said aloud. "Sometimes they come—"

The tyrannosaur lunged forward. Its lower jaw, half-opened during its bugling challenge, dropped to full gape. Someone shouted. The action blurred as

the hologram dissolved a foot or two from the arc of clients.

Vickers thumbed up the molding lights. He walked to the front of the conference room, holding the remote control with which the hotel had provided him. The six clients viewed him with varied expressions. The brother and sister photographers, dentists named McPherson, whispered in obvious delight. They were best able to appreciate the quality of the hologram and to judge their own ability to duplicate it. Any fear they had felt during the presentation was buried in their technical enthusiasm afterward.

The two individual gunners were a general contractor named Mears and Brewer, a meat-packing magnate. Brewer was a short man whose full moustache and balding head made him a caricature of a Victorian industrialist. He loosened his collar and massaged his flushed throat with his thumb and index finger. Mears, built like an All-Pro linebacker after twenty years of retirement, was frowning. He still gripped the chair arms in a way that threatened the plastic. Those were normal reactions to one of Vickers' pre-hunt presentations. It meant the clients had learned the necessity of care in a way no words or still photos could have taught them. Conversely, that familiarity made them less likely to freeze when they faced the real thing.

The presentations unfortunately did not have any useful effect on people like the Salmeses. Or at least on Jonathan Salmes, blond and big but with the look of a movie star, not a football player. Money and leisure could not make Salmes younger, but they made him look considerably less than his real age of forty years. His face was now set in its habitual pattern of affected boredom. As not infrequently happens, the affectation created its own reality and robbed

Salmes of whatever pleasure three generations of oil money might otherwise have brought him.

Adrienne Salmes was as blond and as perfectly preserved as her husband, but she had absorbed the presentation with obvious interest. Time safaris were the property of wealth alone, and she had all the trappings of that wealth. Re-emitted light made her dress—and its wearer—the magnet of all eyes in a dim room, and her silver lamé wristlet responded to voice commands with a digital display. That sort of money could buy beauty like Adrienne Salmes'; but it could not buy the inbred assurance with which she wore that beauty. She forestalled any tendency the guide might have had to think that her personality stopped with the skin by asking, "Mr. Vickers, would you have waited to see if the tyrannosaurus would stop, or would you have shot while it was still at some distance from the helicopter?"

"Umm?" said Vickers in surprise. "Oh, wait, I suppose. If he doesn't stop, there's still time for a shot; and your guide, whether that's me or Dieter, will be backing you. That's a good question." He cleared his throat. "And that brings up an important point," he went on. "We don't shoot large carnivores on foot. Mostly, the shooting platform—the helicopter—won't be dropping as low as it was for the pictures, either. For these holos I was sitting beside the photographer, sweating blood the whole time that nothing would go wrong. If the bird had stuttered or the pilot hadn't timed it just right, I'd have had just about enough time to try for a brain shot. Anywhere else and we'd have been in that fellow's gut faster'n you could swallow a sardine." He smiled. It made him look less like a bank clerk, more like a bank robber. "Three sardines," he corrected himself.

"If you used a man-sized rifle, you'd have been a

damned sight better off," offered Jonathan Salmes. He had one ankle crossed on the other knee, and his chair reclined at a 45° angle.

Vickers looked at the client. They were about of an age, though the guide was several inches shorter and not as heavily built. "Yes, well," he said. "That's a thing I need to talk about. Rifles." He ran a hand through his light brown hair.

"Yeah, I couldn't figure that either," said Mears. "I mean, I read the stuff you sent, about big-bores not being important." The contractor frowned. "I don't figure that. I mean, God almighty, as big as one of those mothers is, I wouldn't feel overgunned with a one-oh-five howitzer . . . and I sure don't think my .458 Magnum's any too big."

"Right, right," Vickers said, nodding his head. His discomfort at facing a group of humans was obvious. "A .458's fine if you can handle it—and I'm sure you can. I'm sure any of you can," he added, raising his eyes and sweeping the group again. "What I said, what I meant, was that size isn't important, penetration and bullet placement are what's important. The .458 penetrates fine—with solids—I hope to God all of you know to bring solids, not soft-nosed bullets. If you're not comfortable with that much recoil, though, you're liable to flinch. And that means you'll miss, even at the ranges we shoot dinos at. A wounded dino running around, anywhere up to a hundred tons of him, and that's when things get messy. You and everybody around is better off with you with a gun that doesn't make you flinch."

"That's all balls, you know," Salmes remarked conversationally. He glanced around at the other clients. "If you're man enough, I'll tell you what to carry." He looked at Vickers, apparently expecting

an attempt to silence him. The guide eyed him with a somewhat bemused expression. "A .500 Salmes, that's what," the big client asserted loudly. "It was designed for me specially by Marquart and Wells, gun and bullets both. It uses shortened fifty-caliber machinegun cases, loaded to give twelve thousand foot-pounds of energy. That's enough to knock a tyrannosaurus right flat on his ass. It's the only gun that you'll be safe with on a hunt like this." He nodded toward Vickers to put a period to his statement.

"Yes, well," Vickers repeated. His expression shifted, hardening. He suddenly wore the visage that an animal might have glimpsed over the sights of his rifle. "Does anybody else feel that they need a—a *gun* like that to bring down anything they'll see on this safari?"

No one nodded to the question when it was put that way. Adrienne Salmes smiled. She was a tall woman, as tall as Vickers himself was.

"Okay, then," the guide said. "I guess I can skip the lesson in basic physics. Mr. Salmes, if you can handle your rifle, that's all that matters to me. If you can't handle it, you've still got time to get something useful instead. Now—"

"Now wait a goddamned minute!" Salmes said, his foot thumping to the floor. His face had flushed under its even tan. "Just what do you mean by that crack? You're going to teach *me* physics?"

"I don't think Mr. Vickers—" began Miss McPherson.

"I want an explanation!" Salmes demanded.

"All right, no problem," said Vickers. He rubbed his forehead and winced in concentration. "What you're talking about," he said to the floor, "is kinetic energy. That's a function of the square of the

velocity. Well and good, but it won't knock anything down. What knocks things down is momentum, that's weight times velocity, not velocity squared. Anything that the bullet knocks down, the butt of the rifle would knock down by recoiling—which is why I encourage clients to carry something they can handle." He raised his eyes and pinned Salmes with them. "I've never yet had a client who weighed twelve thousand pounds, Mr. Salmes. And so I'm always tempted to tell people who talk about 'knock-down power' that they're full to the eyes."

Mrs. Salmes giggled. The other clients did not, but all the faces save Salmes' own bore more-than-hinted smiles. Vickers suspected that the handsome blond man had gotten on everyone else's nerves in the bar before the guide had opened the conference suite.

Salmes purpled to the point of an explosion. The guide glanced down again and raised his hand before saying, "Look, all other things being equal, I'd sooner hit a dino—or a man—with a big bullet than a little one. But if you put the bullet in the brain or the heart, it really doesn't matter much how big it is. And especially with a dino, if you put the bullet anywhere else, it's not going to do much good at all."

"Look," said Brewer, hunching forward and spreading his hands palms down, "I don't flinch, and I got a .378 Weatherby that's got penetration up the ass. But—" he turned his hands over and over again as he looked at them—"I'm not Annie Oakley, you know. If I have to hit a brain the size of a walnut with a four-foot skull around it—well, I may as well take a camera myself instead of the gun. I'll have *something* to show people that way."

Salmes snorted—which could have gotten him one of Brewer's big, capable fists in the face, Vickers

thought. "That's another good question," the guide said. "Very good. Well. Brain shots are great if you know where to put them. I attached charts of a lot of the common dinos with the material I sent out, look them over and decide if you want to try.

"Thing is," he continued, "taking the top off a dino's heart'll drop it in a couple hundred yards. They don't charge when they're heart-shot, they just run till they fall. And we shoot from up close, as close as ten yards. They don't take any notice of you, the big ones, you could touch them if you wanted. You just need enough distance to be able to pick your shot. You see—" he gestured toward Brewer with both index fingers—"you won't have any problem hitting a heart the size of a bushel basket from thirty feet away. Brains—well, skin hunters have been killing crocs with brain shots for a century. Crocodile brains are just as small as a tyrannosaur's, and the skulls are just as big. Back where we're going, there were some that were a damn sight bigger than tyrannosaurs'. But don't feel you have to. And anyway, it'd spoil your trophy if you brain-shot some of the small-headed kind."

Brewer cleared his throat. "Hey," he said, "I'd like to go back to something you said before. About using the helicopter."

"Right, the shooting platform," Vickers agreed.

"Look," said the meat-packer, "I mean . . . well, that's sort of like shooting wolves from a plane, isn't it? I mean, not, well, Christ . . . not sporting, is it?"

Vickers shrugged. "I won't argue with you," he said, "and you don't have to use the platform if you don't want to. But it's the only way you can be allowed to shoot the big carnosaurs. I'm sorry, that's just how it is." He leaned forward and spoke more intensely, popping the fingers of his left hand against

his right palm. "It's as sporting as shooing tigers from elephant-back, I guess, or shooting lions over a butchered cow. The head looks just as big over your mantle. And there's no sport at all for me to tell my bosses how one of my clients was eaten. They aren't bad, the big dinos, people aren't in their scale so they'll pretty much ignore you. Wound one and it's kitty bar the door. These aren't plant eaters, primed to run if there's trouble. These are carnivores we're talking about, animals that spend most of their waking lives killing or looking for something to kill. They *will* connect the noise of a shot with the pain, and they *will* go after whoever made the noise."

The guide paused and drew back. More calmly he concluded, "So carnosaurs you'll hunt from the platform. Or not at all."

"Well, what happens if they come to us?" Salmes demanded with recovered belligerance. "Right up to the camp, say? You can't keep us from shooting then."

"I guess this is a good time to discuss arrangements for the camp," Vickers said, approaching the question indirectly. "There's four of us staff with the safari, two guides—that's me and Dieter Jost—and two pilots. One pilot, one guide, and one client—or of you—go up in the platform every day. You'll each have two chances to bag a big carnosaur. They're territorial and not too thick on the ground, but there's almost certain to be at least one tyrannosaur and a pack of gorgosaurs in practical range. The other guide takes out the rest of the clients on foot, well, on motorized wagons you could say, ponies we call them. And the pilot who isn't flying the platform doubles as camp guard. He's got a heavy machinegun—" the guide smiled—"a Russian .51 cal. Courtesy of your hosts for the tour, the Is-

raeli government. It'll stop dinos and light tanks without a bit of bother."

Vickers' face lost its crinkling of humor. "If there's any shooting to be done from the camp," he continued, "that's what does it. Unless Dieter or me specifically tell you otherwise. We're not going to have the intrusion vehicle trampled by a herd of dinos that somebody spooked right into it. If something happens to the intrusion vehicle, we don't go home." Vickers smiled again. "That might be okay with me, but I don't think any of the rest of you want to have to explain to the others how you stuck them in the Cretaceous."

"That would be a paradox, wouldn't it, Mr. Vickers?" Miss McPherson said. "That is, uh, human beings living in the Cretaceous? So it couldn't happen. Not that I'd want any chances taken with the vehicle, of course."

Vickers shrugged with genuine disinterest. "Ma'am, if you want to talk about paradox, you need Dr. Galil and his team. So far as I understand it, though, if there's not a change in the future, then there's no paradox; and if there *is* a change, then there's no paradox either because the change—well, the change is reality then."

Mr. McPherson leaned forward with a frown. "Well, surely two bodies—the same body—can't exist simultaneously," he insisted. If he and his sister had been bored with the discussion of firearms, then they had recovered their interest with mention of the mechanics of time transport.

"Sure they can," the guide said with the asperity of someone who had been asked the same question too often. He waved his hand back and forth as if erasing the thought from a chalk board. "They do. Every person, every gun or can of food, contains at

least some atoms that were around in the Cretacious —or the Pre-Cambrian, for that matter. It doesn't matter to the atoms whether they call themselves Henry Vickers or the third redwood from the big rock. . . ." He paused. "There's just one rule that I've heard for true from people who know," he continued at last. "If you travel into the future, you travel as energy. And you don't come back at all."

Mears paled and looked at the ceiling. People got squeamish about the damnedest things, thought Vickers. Being converted into energy . . . or being eaten . . . or being drowned in dark water lighted only by the dying radiance of your mind—but he broke away from that thought, a little sweat on his forehead with the strain of it. He continued aloud, "There's no danger for us, heading back into the far past. But the intrusion vehicle can't be calibrated closer than 5,000 years plus or minus so far. The, the research side—" he had almost said 'the military side,' knowing the two were synonymous; knowing also that the Israeli government disapproved intensely of statements to that effect—"was trying for the recent past—" 1948, but that was another thing you didn't admit you knew—"and they put a man into the future instead. After Dr. Galil had worked out the math, they moved the lab and cleared a quarter-mile section of Tel Aviv around the old site. They figure the poor bastard will show up sometime in the next few thousand years . . . and nobody better be sharing the area when he does."

Vickers frowned at himself. "Well, that's probably more than the, the government wants me to say about the technical side," he said. "And anyway, I'm not the one to ask. Let's get back to the business itself—which I do know something about."

"You've said that this presentation and the writ-

ten material are all yours," Adrienne Salmes said with a wave of her hand. "I'd like to know why."

Vickers blinked at the unexpected question. He looked from Mrs. Salmes to the other clients, all of them but her husband staring back at him with interest. The guide laughed. "I like my job," he said. "A century ago, I'd have been hiking through Africa with a Mauser, selling ivory every year or so when I came in from the bush." He rubbed his left cheekbone where a disk of shiny skin remained from a boil of twenty years before. "That sort of life was gone before I was born," he went on. "What I have is the closest thing there is to it now."

Adrienne Salmes was nodding. Mr. McPherson put his own puzzled frown into words and said, "I don't see what that has to do with, well, you holding these sessions, though."

"It's like this," Vickers said, watching his fingers tent and flatten against each other. "They pay me, the government does, a very good salary that I personally don't have much use for." Jonathan Salmes snorted, but the guide ignored him. "I use it to make my job easier," he went on, "by sending the clients all the data *I've* found useful in the five years I've been travelling back to the Cretaceous ... and elsewhere, but mostly the Cretaceous. Because if people go back with only what they hear in the advertising or from folks who need to make a buck or a name with their stories, they'll have problems when they see the real thing. Which means problems for me. So a month before each safari, I rent a suite in New York or Frankfurt or wherever the hell seems reasonable, and I offer to give a presentation to the clients. Nobody has to come, but most people do." He scanned the group. "All of you did, for instance. It makes life easier for me."

He cleared his throat. "Well, in another way, we're here to make life easier for you," he went on. "I've brought along holos of the standard game animals you'll be seeing." He dimmed the lights and stepped toward the back of the room. "First the sauropods, the big long-necks. The most impressive things you'll see in the Cretaceous, but a disappointing trophy because of the small heads. . . ."

"All right, ladies and gentlemen," said Dieter Jost. Vickers always left the junior guide responsible for the social chores when both of them were present. "Please line up here along the wall until the Doctor Galil directs us onto the vehicle."

The members of Cretaceous Safari 87 backed against the hanger wall, their weapons or cameras in their hands. The guides and the two pilots, Washman and Brady, watched the clients rather than the crew preparing the intrusion vehicle. You could never tell what sort of mistake a tensed-up laymen would make with a loaded weapon in his or her hands.

In case the clients were not laymen at all, there were four guards seated in a balcony-height alcove in the opposite wall. They wore civilian clothes, but the submachineguns they carried were just as military as their ID cards. The Israelis were, of all people, alert to the chance that a commando raid would be aimed at an intrusion vehicle and its technical staff. For that reason, the installation was in an urban setting from which there could be no quick escape; and its corridors and rooms, including the gaping hanger itself, were better guarded than the Defense Ministry had been during the most recent shooting war.

Dr. Galil and his staff were only occasionally vis-

ible to the group on the floor of the hanger. The intrusion vehicle rested on four braced girders twenty feet high. On its underside, a cylindrical probe was repeatedly blurring and reappearing. The technicians received data from the probe on instruments plugged into various sockets on the vehicle. Eighty million years in the past, the cylinder was sampling its surroundings on a score of wavelengths. When necessary, Dr. Galil himself changed control settings. Despite that care, there was no certainty of the surface over which the travellers would appear—or how far over or under it they would appear. The long legs gave the intrusion vehicle a margin that might otherwise have been achieved by a longer drop than anything aboard would have survived.

"Well, this is it, hey?" said Jonathan Salmes, speaking to Don Washman. To do so, Salmes had to talk through his wife, who ignored him in turn. "A chance to hunt the most dangerous damned creatures ever to walk the Earth!" Salmes' hands, evenly tanned like every other inch of exposed skin on him, tightened still further on the beautiful bolt-action rifle he carried.

Washman's smile went no further than Adrienne Salmes. The pilot was a big man also. The 40 mm grenade launcher he held looked like a sawed-off shotgun with him for scale. "Gee, Mr. Salmes," he said in false surprise. "People our age all had a chance to learn the most dangerous game on Earth popped out of a spider hole with an AK-47 in its hands. All the *men* did, at least."

Vickers scowled. "Don," he said. But Washman was a pilot, not a PR man. Besides, Salmes had coming anything of the sort he got.

Adrienne Salmes turned to Washman and laughed.

A heavy-set man climbed down from the intrusion vehicle and strolled across the concrete floor toward the waiting group. Like the guards, he wore an ordinary business suit. He kept his hands in his pants pockets. "Good evening, ladies and sirs," he said in accented English. "I am Mr. Stern; you might say, the company manager. I trust the preparations for your tour have been satisfactory?" He eyed Dieter, then Vickers, his face wearing only a bland smile.

"All present and accounted for," said Dieter in German. At his side, Mears nodded enthusiastically.

"By God," said Jonathan Salmes with recovered vigor, "I just want this gizmo to pop out right in front of a tyrannosaurus rex. Then I'll pop *him*, and I'll double your fees for a bonus!"

Don Washman smirked, but Vickers' scowl was for better reason than that. "Ah, Mr. Salmes," the guide said, "I believe Mr Brewer drew first shot of the insertion. Fire discipline is something we *do* have to insist on."

"Naw, that's okay," said Brewer unexpectedly. He looked sheepishly at Vickers, then looked away. "We made an agreement on that," he added. "I don't mind paying for something I want; but I don't mind selling something I don't need, either, you see?"

"In any case," said Stern, "even the genius of Dr. Galil cannot guarantee to place you in front of a suitable dinosaur. I must admit to some apprehension, in fact, that some day we will land an intrusion vehicle in mid-ocean." He gestured both elbows outward, like wings flapping. "Ah, this is a magnificent machine; but not, I fear, very precise." He smiled.

"Not precise enough to . . . put a battalion of paratroops in the courtyard of the Temple in 70 AD,

you mean?" suggested Adrienne Salmes with a trace of a smile herself.

Vickers' gut sucked in. Stern's first glance was to check the position of the guards. The slightly seedy good-fellowship he had projected was gone. "Ah, you Americans," Stern said in a voice that was itself a warning. "Always making jokes about the impossible. But you must understand that in a small and threatened country like ours, there are some jokes one does not make." His smile now had no humor. Adrienne Salmes returned it with a wintry one of her own. If anyone had believed her question was chance rather than a deliberate goad, the smile disabused them.

Atop the intrusion vehicle, an indicator began buzzing in a continuous rhythm. It was not a loud sound. The high ceiling of the hangar drank it almost completely. The staff personnel looked up sharply. Stern nodded again to Vickers and began to walk toward a ground-level exit. He was whistling under his breath. After a moment, a pudgy man stepped to the edge of the vehicle and looked down. He had a white moustache and a fringe of hair as crinkled as rock wool. "I believe we are ready, gentlemen," he said.

Dieter nodded. "We're on the way, then, Dr. Galil," he replied to the older man. Turning back to the safari group, he went on, "Stay in line, please. Hold the handrail with one hand as you mount the steps, and do be very careful to keep your weapons vertical. Accidents happen, you know." Dieter gave a brief nod of emphasis and lead the way. The flight of metal steps stretched in a steep diagonal between two of the vehicle's legs. Vickers brought up the rear of the line, unhurried but feeling the tingle at the base of the neck which always preceded time travel

with him. It amused Vickers to find himself trying to look past the two men directly in front of him to watch Adrienne Salmes as she mounted the stairs. The woman wore a baggy suit like the rest of them, rip-stopped Kelprin which would shed water and still breathe with 80% efficiency. On her the mottled coveralls had an interest which time safari clients, male or female, could rarely bring to such garments.

The floor of the intrusion vehicle was perforated steel from which much of the antislip coating had been worn. Where the metal was bare, it had a delicate patina of rust. In the center of the twenty-foot square, the safari's gear was neatly piled. The largest single item was the 500-gallon bladder of kerosene, fuel both for the turbine of the shooting platform and the diesel engines of the ponies. There was some dehydrated food, though the bulk of the group's diet would be the meat they shot. Vickers had warned the clients that anyone who could not stomach the idea of eating dinosaur should bring his own alternative. It was the idea that caused some people problems—the meat itself was fine. Each client was allowed a half-cubic meter chest for personal possessions. Ultimately they would either be abandoned in the Cretaceous or count against the owners' volume for trophies.

The intrusion vehicle was surrounded by a waist-high railing, hinged to flop down out of the way during loading and unloading. The space between the rail and the gear in the center was the passenger area. This open walkway was a comfortable four feet wide at the moment. On return, with the vehicle packed with trophies, there would be only standing room. Ceratopsian skulls, easily the most impressive of the High Cretaceous trophies, could run eight feet long with a height and width in proportion.

On insertion, it was quite conceivable that the vehicle would indeed appear in the midst of a pack of gorgosaurs. That was not something the staff talked about; but the care they took positioning themselves and the other gunners before insertion was not mere form. "Mr. McPherson," Dieter said, "Mr. Mears, if you will kindly come around with me to Side Three—that's across from the stairs here. Do not please touch the red control panel as you pass it."

"Ah, can't Charles and I stay together?" Mary McPherson asked. Both of the dentists carried motion cameras with the lenses set at the 50 mm minimum separation. A wider spread could improve hologram quality; but it might prove impossibly awkward under the conditions obtaining just after insertion.

"For the moment," Vickers said, "I'd like you on Side One with me, Miss McPherson. That puts two guns on each side; and it's just during insertion."

Boots clanking on the metal stairs, the safari group mounted the vehicle. Four members of Dr. Galil's team had climbed down already. They stood in a row beside the steps like a guard of honor in lab smocks. Galil himself waited beside the vertical control panel at the head of the stairs. The red panel was the only portion of the vehicle which looked more in keeping with a laboratory than a mineshaft. Even so, its armored casing was a far cry from the festooned breadboards that typically marked experimental machinery.

Not that anyone suggested to the clients that the machinery was as surely experimental as a 1940 radar set.

Dr. Galil shook hands with each member of the group, staff and clients alike. Vickers shifted his modified Garand rifle into the crook of his left arm

and took the scientist's hand. "Henry, I pray you God-speed and a safe return," Galil said in English. His grip was firm.

"God's for afterwards, Shlomo," the guide said. "You'll bring us back, you and your boys. That's what I have faith in."

Dr. Galil squeezed Vickers' hand again. He walked quickly down the steps. The hangar lights dimmed as the big room emptied of everything but the intrusion vehicle and its cargo. Vickers took a deep breath and unlocked the T-handled switch in the center of the control panel. He glanced to either side. Miss McPherson was to his left, Mrs. Salmes to his right.

Adrienne Salmes smiled back. "Did you put me with you because you think you can't trust a woman's shooting?" she asked.

Vickers cleared his throat. "No," he lied. More loudly, he added, "We are about to make our insertion. Everyone please grip the rail with your free hand. Don't let your rifles or cameras project more than two feet beyond the railing, though." He threw the switch. A blue light on the hangar ceiling began to pulse slowly, one beat per second. Vickers' belly drew in again. At the tenth pulse, the light and the hangar disappeared together. There was an instant of sensory blurring. Some compared the sensation of time travel to falling, others to immersion in vacuum. To Vickers, it was always a blast of heat. Then the heat was real and the sun glared down through a haze thick enough to shift the orb far into the red. The intrusion vehicle lurched in a walloping spray. Ooze and reeds sloshed sideways to replace those scalloped out of the slough and transported to the hangar in Tel Aviv. The vehicle settled almost to the full depth of its legs.

"Christ on a crutch!" snarled Don Washman, hidden from Vickers by the piled gear. "Tell us it's a grassy clearing and drop us in a pissing swamp! Next time it'll be a kelp bed!" In a different voice he added, "Target."

All of Vickers' muscles had frozen when he thought they were about to drown. They were safe after all, though, and he turned to see the first dinosaur of the safari.

It was a duckbill—though the head looked more like that of a sheep than a duck. Jaw muscles and nasal passages filled the hollows of the snout which early restorations had left bare. The dinosaur had been dashing through the low pines fringing the slough when the crash and slap of the insertion caused it to rear up and attempt to stop. Reeds and water sprayed in a miniature echo of the commotion the vehicle itself had made.

The firm soil of the shore was only ten feet from the vehicle, roughly parallel to Side Four. The duckbill halted, almost in front of Washman and Jonathan Salmes. Scrabbling for traction in muck covered by two feet of water, the beast tried to reverse direction. The pilot leveled his grenade launcher but did not fire. Vickers stepped to the corner where he could see the target. It lacked the crests that made many similar species excellent trophies, but it was still two tons at point-blank range and the first dino the clients had seen in the flesh. "Go ahead," he said to Salmes. "It's yours."

The duckbill lunged back toward the shore, swinging the splayed toes of its right foot onto solid ground. Salmes' rifle slammed. It had an integral muzzle brake to help reduce recoil by redirecting muzzle gases sideways. The muzzle blast was redirected as well, a palpable shock in the thick air.

The duckbill lurched, skidding nose-first through a tree. Its long hind legs bunched under it while the stubby forelegs braced to help the beast rise. If it could get to the well-beaten trail by which it had approached the slough, it would disappear.

"Good, good," said Vickers. His voice was tinny in his own ears because of the muzzle blast. "Now finish it with another one at the base of the tail." Fired from such short range, Salmes' bullet could be expected to range through the duckbill's body. It was certain to rip enough blood vessels to let the beast's life out quickly, and it might also break the spine.

The second shot did not come. The duckbill regained its feet. There was a rusty splotch of blood against the brown-patterned hide of its left shoulder. Vickers risked a look away from the shore to see what was the matter with Salmes. The client had a glazed expression on his face. His big rifle was raised, but its butt did not appear to be solidly resting on his shoulder. Don Washman wore a disgusted look. Beyond both gunners, Mr. McPherson knelt and shot holo tape of the beast leaping back toward the trees.

"Shoot, for Chrissake!" Vickers shouted.

Salmes' rifle boomed again. A triple jet of smoke flashed from the bore and muzzle brake. Salmes cried out as the stock hit him. The bullet missed even the fringe of ten-foot pine trees. The duckbill disappeared into them.

Vickers carefully did not look at Salmes—or Adrienne Salmes, standing immediately behind the guide with her rifle ready to shoot if directed. She had snickered after her husband's second shot. "First we'll find a dry campsite and move the gear," Vickers started to say.

The forest edge exploded as the duckbill burst back through it in the midst of a pack of dromaeosaurs.

In the first flaring confusion, there seemed to be a score of the smaller carnivores. In fact, there were only five—but that was quite enough. One had the duckbill by the throat and was wrapping forelegs around the herbivore's torso to keep from being shaken loose. The rest of the pack circled the central pair with the avidity of participants in a gang rape. Though the carnivores were bipedal, they bore a talon on each hind foot that was a sickle in size and lethality. Kicking from one leg, the hooting dromaeosaurs slashed through the duckbill's belly hide. Soft, pink coils of intestine spilled out into the water.

One of the half-ton carnivores cocked its head at the group on the intrusion vehicle. The men on Side Four were already spattered with the duckbill's blood. "Take 'em," Vickers said. He punched a steel-cored bullet through the nearest dromaeosaur's skull, just behind its eyes.

Washman and Adrienne Salmes fired while Vickers' cartridge case was still in the air. The pilot's grenade launcher chugged rather than banging, but the explosion of its projectile against the chest of a carnivore was loud even to ears numbed by the muzzle blasts of Salmes' rifle. The grenade was a caseless shaped charge which could be used point-blank without endangering the firer with fragments. Even so, the concussion from less than twenty feet rocked everyone on the near side of the vehicle. There was a red flash and a mist of pureed dinosaur. A foreleg, torn off at the shoulder, sailed straight into the air. Two of the dromaeosaurs bolted away from the blast, disappearing among the trees in flat

arcs and sprays of dirt and pine straw.

Vickers' target had fallen where it stood. All four limbs jerked like those of a pithed frog. The dromaeosaur Adrienne Salmes had shot dropped momentarily, then sprang to its feet again. The tall woman worked the bolt of her rifle smoothly without taking the butt from her shoulder. The grenade explosion did not appear to have disconcerted her. The guide, poised to finish the beast, hesitated. Adrienne shot again and the dino's limbs splayed. Its dark green hide showed clearly the red and white rosette between the shoulders where the second bullet had broken its spine.

Dieter Jost leaned past Mr. McPherson and put a uranium flechette through the brain of the duckbill, ending its pain. All four of the downed dinosaurs continued to twitch.

"Jesus," said Don Washman quietly as he closed the breech on a grenade cartridge.

Although he had only fired once, Henry Vickers replaced the 20-round magazine of his Garand with a fresh one from his belt pouch. "Mr. McPherson," he said, "I hope you got good pictures, because I swear that's the most excitement I've had in a long time in this business."

Dieter had moved back to watch the slough with Steve Brady. Most of the clients crowded to Side Four to get a better view of the Cretaceous and its denizens. Adrienne Salmes had not moved from where she stood beside Vickers. She thumbed a second cartridge into the magazine of her rifle and closed the breech. "Still doubt I can shoot?" she asked with a smile.

"Heart and spine," the guide said. "No, I guess you can back me up any day of the week. I tell you, dromaeosaurs aren't as impressive as some of the

larger carnivores, but they're just as dangerous." He looked more carefully at her rifle, a Schultz and Larsen with no ornamentation but the superb craftsmanship that had gone into its production. "Say, nice," Vickers said. "In .358 Norma?"

The blonde woman smiled with pleasure. "It's the same rifle I've used for everything from whitetails to elephant," she said. "I'd planned to bring something bigger, but after what you said, I had five hundred bullets cast from bronze and loaded at the factory for me. Johnnie—" she glanced at her husband, now loudly describing how he had shot the duckbill to the other clients. "Well," Adrienne continued quietly, "I'm the hunter in the household, not him. I told him he was crazy to have a cannon like that built, but he listens to me as badly as he listens to everyone else."

"That may be a problem," Vickers muttered. More loudly, he said, "All right, I think it's time to start setting up camp on top of this ridge. Around now, it's asking for trouble to be any closer than a hundred yards to the water, especially with this much meat nearby. After Steve and I get the ponies assembled, we'll need everybody's help to load them. Until then, just try not to get in the way."

Sometimes working with his hands helped Vickers solve problems caused by the human side of his safaris. It did not seem to do so on this occasion. Of course, a client who was both arrogant and gun-shy was a particularly nasty problem.

But Vickers was irritated to realize that it also bothered him that Don Washman and Mrs. Salmes seemed to be getting along very well together.

The campfire that evening provided an aura of human existence more important than the light of its

banked coals. The clients had gone to sleep—or at least to their tents. That the Salmes at least were not asleep was evident from the sound of an argument. The double walls of the tents cut sound penetration considerably, but there were limits. Steve Brady shoved another log on the fire and said, "Damn, but I swear that chainsaw gets heavier every time I use it. Do you suppose the Israelis designed them to be air-dropped without parachutes?"

"You want a high horsepower-to-weight ratio, you don't use a diesel," agreed Dieter Jost with a shrug. "If you want a common fuel supply for everything and need diesel efficiency for the ponies, though—well, you get a heavy chainsaw."

"Can't imagine why she ever married him," Don Washman said. "Beef like that's a dime a dozen. Why, you know he didn't even have the balls enough to chamber a third round? He's scared to death of that gun, scared almost to touch it now."

"Yeah," agreed Vickers, working a patch into the slot of his cleaning rod, "but the question's what to do about it. I don't have any good answers, God knows."

"Do?" Washman repeated. "Well, hell, leave him, of course. She's got money of her own—"

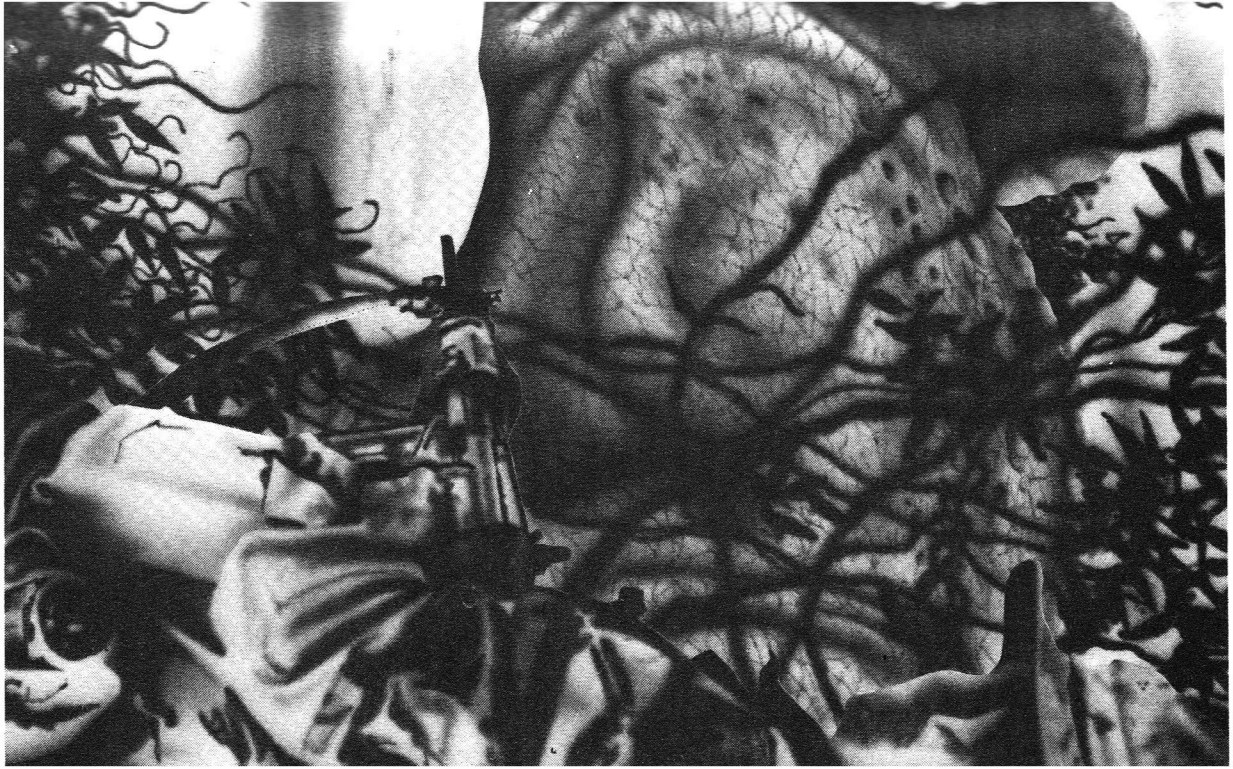
Brady broke into snorting laughter. Dieter grimaced and said, "Don, I do not think it is any business of ours how our clients live. The Salmes are adults and can no doubt solve their own problems." He pursed his lips. The fire threw the shadow of his bushy moustache misshapenly against his cheeks. "As for our problem, Henry, why don't we offer him the use of the camp gun? The .375? I think Mr. Salmes' difficulty is in precisely the same category as the more usual forms of mechanical breakdown or guns falling into the river."

"Fine with me if you can talk him into it," Vickers said dubiously, "but I wouldn't say Salmes is the sort to take a well-meant suggestion." He nodded toward the tent. The couple within seemed to be shouting simultaneously. "Or any other kind of suggestion," he added.

"Things would sure be simpler if they didn't allow booze on safaris," Brady said.

"Things would be simpler for us if our employers paid us to sleep all day and drink schnapps," said Dieter Jost. He tugged a lock of hair absently. "That does not comport well with economic realities, however. And so long as each of our clients has paid fifty thousand American dollars for the privilege of spending two weeks in the Cretaceous, it is unrealistic to assume that the staff will be treated as anything but the hired help. If drunken clients make the job more difficult, then that is simply one of the discomforts of the job. Like loading gear in the heat, or tracking down an animal that a client has wounded. It is easier for our employers, Mr. Stern and those above him, to hire new staff members than it would be to impose their underlings' views on persons of the sort who take time safaris."

"Moshe Cohn was head guide when I made my first insertion," said Vickers aloud. His cleaning rod rested on his lap beside the Garand, but he had not run it through the bore yet. "He told a client—a Texan, it was a US safari that time too—that he'd be better off to slack up a little on his drinking while he was in the field. The client was generally too stiff to see a dino, much less shoot one." The guide's forefinger tapped the breech of his rifle as he recalled the scene. "He said to Moshe, 'Jew-boy, you sound just like my third wife. One more word and I'll whip you with my belt, just like I did her.' Moshe broke his



hand on the Texan's jaw. When we got back, the government—the Israeli but very pragmatic government—fired Moshe and denied him compensation for his hand. Ten days in the field with broken bones, remember." Vickers paused, then went on, "That taught me the rules. So far, I've been willing to live by them."

Don Washman laughed. "Right, when you hit a client, use your gunstock," he said and opened another beer.

Technically Steve Brady had the first watch, even though all four staff members were up. The alarm panel was facing Steve when it beeped, therefore. "Jesus!" the stubby, long-haired pilot blurted when he saw the magnitude of the signal fluorescing on the display. "Down the trail—must be a herd of something!"

Don Washman upset his fresh beer as he ran to the spade grips of the heavy machine-gun. It was in the center of the camp, on ground slightly higher than its immediate surroundings but by no means high enough to give the weapon an unbroken field of fire. The staff had sawed clear a campsite along the game trail leading down to the intrusion vehicle two hundred yards away. Assuming that animals were most likely to enter the area by the trail, Dieter had sited the tents on the other side of the gun. The next day they could lash together a six-foot high tower for the gun, but time had been too short to finish that the first night.

While the other staff members crouched over weapons, Vickers darted to the three occupied tents. The sensor loop that encircled the camp 100 yards out could pick up very delicate impacts and relay them to the display screen. This signal, however, was already shaking the ground. Miss McPherson poked

her head out of the tent she shared with her brother. "What—" the dentist began.

The file of huge ceratopsians rumbled into sight on their way to the water to drink. They were torosaurs or a species equally large. In the dim glow of the fire, they looked more like machines than anything alive. Their beaks and the tips of their triple horns had a black glint like raku ware, and they averaged twice the size of elephants.

The tent that Mears and Brewer shared shuddered as both clients tried to force their way through the opening simultaneously. Vickers lifted the muzzles of their rifles skyward as he had been waiting to do. "No shooting now," he cried over the thunder of the dinosaurs. "In the morning we'll follow them up."

Adrienne Salmes slipped out of her tent before Vickers could reach over and take her rifle. It was pointed safely upward anyway. Despite the hour-long argument she had been engaged in, the blonde woman looked calm and alert. She looked breathtakingly beautiful as well—and wore only her rifle. "If you can wait a moment for my firepower," she said to Vickers without embarrassment, "I'll throw some clothes on." The guide nodded.

The bony frills at the back of the ceratopsians' skulls extended their heads to well over the height of a man. Less for protection than for muscle attachment, the frills locked the beasts' heads firmly to their shoulders. The bulging jaw muscles that they anchored enabled the ceratopsians to literally shear hardwood the thickness of a man's thigh. The last thing a safari needed was a herd of such monsters being stampeded through the camp. A beast wounded by a shot ill-aimed in the darkness could lead to just that result.

Mears and Brewer were staring at the rapid pro-

cession in wonder. The left eye of each torosaur glinted in the firelight. "Mother o' God, what a trophy!" Brewer said.

"Best in the world," Vickers agreed. "You'll go back with one, never fear." He looked at the McPhersons to his other side. The dentists were clutching their holo cameras, which were almost useless under the light conditions. "And you'll get your fill too," Vickers said. "The trip isn't cheap, but I've never yet guided a client who didn't think he'd gotten more than he bargained for." Though a drunken SOB like Jonathan Salmes might spoil that record, he added silently.

Adrienne Salmes re-emerged from her tent, wearing her coveralls and boots. Mears and brewer had been so focused on the herd of torosaurs that the guide doubted the men had noticed her previous display. She was carrying a sleeping bag in addition to her rifle. Vickers raised an eyebrow. Adrienne nodded back at the tent. "Screaming beauty seems to have passed out," she said, "but I'm damned if I'll stay in the tent with him. Going on about his shoulder, for God's sake, and expecting sympathy from *me*. Is it all right if I doss down in the open?"

The ceratopsians were sporting in the water, making as much noise as the Waikiki surf. Vickers smiled. "They could eat tree trunks and drink mud," he said, as if he had not heard the client's question. "And I still meet people who think mammals are better adapted for survival than dinos were." He turned to Adrienne Salmes. "It's all right, so long as you stay out of the gun's way," he said, "but you'll wash away if it rains. And we're bound to get at least one real gully-washer while we're here."

"Hell, there's an easy answer to that," said Don Washman. He had strolled over to the tents when it

became clear no predators had followed the torosaurs. "One of us is on watch all night, right? So there's always a slot open in the staff tents. Let noble hunter there sleep by himself, Hank. And she shoots well enough to be a pro, so let her stay dry with us too." He gave his engaging smile.

The other clients were listening with interest. "Maybe if Mr. McPherson wants to trade—" Vickers began in a neutral voice.

Adrienne Salmes hushed him with a grimace. "I'm a big girl now, Mr. Vickers," she snapped, "and I think I'm paying enough to make my own decisions. Don, if you'll show me the tent, I'll resume getting the sleep I've been assured I'll need in the morning."

Washman beamed. "Let's see," he said, "Steve's got watch at the moment, so I suppose you're my tentmate till I go on at four in the morning. . . ."

They walked toward the tent. Dieter, standing near the fire with his rifle cradled, looked from them to Vickers. Vickers shrugged. He was thinking about Moshe Cohn again.

"Platform to Mobile One," crackled the speaker of the unit clipped to Vickers' epaulet. Vickers threw the last of the clamps that locked the two ponies into a single, articulated vehicle. "Go ahead, Dieter," he said.

"Henry, the torosaurs must have run all night after they left the water," the other guide announced through the heavy static. "They're a good fifteen klicks west of camp. But there's a sauropod burn just three klicks south and close to the river. Do you want me to drop a marker?"

Vickers frowned. "Yeah, go ahead," he decided. He glanced at but did not really see the four clients,

festooned with gear, who awaited his order to board the ponies. "Any sign of carnosaurs?"

"Negative," Dieter replied, "but we're still looking. I spotted what looked like a fresh kill when we were tracking the torosaurs. If we don't get any action here, I'll carry Miss McPherson back to that and see what we can stir up."

"Good hunting, Dieter," Vickers said. "We'll go take a look at your sauropods. Mobile One out." Again his eyes touched the clients. He appeared startled to see them intent on him. "All right," he said, "if you'll all board the lead pony. The other's along for trophies—sauropods this time, we'll get you the ceratopsians another day. Just pull down the jump seats."

The guide seated himself behind the tiller bar and clipped his rifle into its brackets. His clients stepped over the pony's low sides. The vehicle was the shape of an aluminum casket, scaled up by a half. A small diesel engine rode over the rear axle. Though the engine was heavily muffled, the valves sang trills which blended with the natural sounds of the landscape.

Don Washman waved. He had strung a tarp from four trees at the edge of the clearing. In that shade he was pinning together the log framework of the gun tower. The alarm and his grenade launcher sat beside him.

"Take care," Vickers called.

"You take care," the pilot responded with a broad grin. "Maybe I can lose the yo-yo and then we're all better off." He jerked his head toward the tent which still held Jonathan Salmes. Dieter had tried to arouse Salmes for breakfast. Because Vickers was sawing at the time, no one but Dieter himself heard what the client shouted. Dieter, who had served in at least three armies and was used to

being cursed, had backed out of the tent with a white face. Vickers had shut down the saw, but the other guide had shaken his head. "Best to let him sleep, I think," he said.

Remembering the night before, Vickers wished that it was Brady and not Washman who had the guard that day. Oh, well. "Hold on," he said aloud. He put the pony into gear.

Just west of the crest on which they had set up camp, the height and separation of the trees increased markedly. Small pines and cycads were replaced by conifers that shot over one hundred feet in the air. Everything east of the ridgeline was in the floodplain, where the river drowned tree roots with a regularity that limited survival to the smaller, faster-growing varieties. The thick–barked monsters through which Vickers now guided the ponies were centuries old already. Barring lightning or tornado, they would not change appreciably over further centuries. They were the food of the great sauropods.

The forest was open enough to permit the pony to run at over 15 mph, close to its top speed with the load. The saplings and pale, broad-leafed ferns which competed for the dim light were easily brushed aside. Animal life was sparse, but as the pony skirted a fallen log, a turkey-sized coelurosaur sprang up with a large beetle in its jaws. Mears' .458 boomed. There was an echo-chamber effect from the log which boosted the muzzle blast to a near equal for that of the .500 Salmes. Everyone on the pony jumped—Vickers more than the rest because he had not seen the client level his rifle. The dinosaur darted away, giving a flick of its gray-feathered tail as it disappeared around a trunk.

"Ah, don't shoot without warning," the guide said, loudly but without looking around. "It's too

easy to wound something that you should have had backup for. Besides, we should be pretty close to the sauropods—and they make much better targets."

Even as Vickers spoke, the forest ahead of them brightened. The upper branches still remained, but all the limbs had been stripped below the level of sixty feet. One tree had been pushed over. It had fallen to a 45° angle before being caught and supported by the branches of neighboring giants. The matted needles were strewn with fresh blankets of sauropod droppings. They had a green, faintly Christmasy scent. Vickers stopped the vehicle and turned to his clients. "We're getting very close," he said, "and there'll be plenty of shooting for everybody in just a moment. But there's also a chance of a pack of carnosaurs nearby for the same reason that we are. Keep your eyes open as we approach—and for *God's* sake don't shoot until I've said to." His eyes scanned the forest again and returned to Adrienne Salmes. A momentary remembrance of her the night before, a nude Artemis with rifle instead of bow, made him smile. "Mrs. Salmes," he said, "would you watch behind us, please? Carnivores are likely to strike up a burn as we did . . . and I can't watch behind us myself."

Adrienne grinned. "Why Mr. Vickers, I think you've just apologized for doubting I could shoot," she said. She turned and faced back over the towed pony, left arm through the sling of her rifle in order to brace the weapon firmly when she shot.

Vickers eased forward the hand throttle. They were past the marker beacon Dieter had dropped from the shooting platform. The responder tab on the guide's wrist had pulsed from green to red and was now lapsing back into fire orange; he cut it off absently. The sounds of the dinosaurs were audible

to him now: the rumble of their huge intestines; the slow crackle of branches being stripped of their needles, cones, and bark by the sauropods' teeth; and occasional cooing calls which the clients, if they heard them over the ringing of the diesel, probably mistook for those of unseen forest birds.

The others did not see the sauropods even when Vickers cut the motor off. They were titanosaurs or a similar species, only middling huge for their order. Vickers pointed. Mears, Brewer, and McPherson followed the line of the guide's arm, frowning. "It's all right now, Mrs. Salmes," Vickers said softly. "The dinos will warn us if predators get near." Adrienne Salmes faced around as well.

"Oh, Jesus Christ," someone whispered as he realized what Vickers was pointing out. It was incredible, even to the guide, how completely a score or more of thirty-ton animals could blend into an open forest. In part, it may have been that human minds were not used to interpreting as animals objects which weighed as much as loaded semis. Once recognized, the vast expanses of russet and black hide were as obvious as inkblot pictures which someone else has described.

Silently and without direction, McPherson stepped from the pony and spread the lenses of his camera. Vickers nodded to the others. "They won't pay attention to a normal voice," he said—in a quieter than normal voice. "Try to avoid sudden movements, though. They may think it's a warning signal of some kind." He cleared his throat. "I want each of you to mark a target—"

"That one!" whispered Mears urgently, a boy in the toystore, afraid his aunt will renege on her promise of a gift unless he acts at once. The big contractor was pointing at the nearest of the sauropods, a

moderate-sized female only thirty feet away.

"Fine, but wait," the guide said firmly. "I'll position each of you. When I call 'fire', go ahead—but only then. They won't attack anything our size, but they might step on one of us if they were startled at the wrong time. That big, they don't have to be hostile to be dangerous."

The nearby female, which had been browsing on limbs twenty feet high, suddenly stepped closer to a tree and reared up on her hind legs. She anchored herself to the trunk with her forefeet, each armed with a single long claw. It shredded bark as it gripped. With the grace and power of a derrick, the titanosaur's head swung to a high branch, closed, and dragged along it for several yards. It left only bare wood behind.

With his left hand, Vickers aimed a pen-sized laser pointer. A red dot sprang out on the chest of the oblivious titanosaur. "There's your aiming point," the guide said. "If she settles back down before I give the signal, just hit her at the top of the shoulder."

Mears nodded, his eyes intent on the dinosaur.

Vickers moved Brewer five yards away, with a broadside shot at a large male. McPherson stood beside him using a pan-head still camera on the six sauropods visible within a stone's throw. The dentist's hands were trembling with excitement.

Vickers took Adrienne Salmes slightly to the side, to within twenty yards of another male. He chose the location with an eye on the rest of the herd. Sauropods had a tendency to bolt straight ahead if aroused.

"Why does this one have bright red markings behind its eyes?" Adrienne asked.

"First time I ever saw it," the guide said with a

shrug. "Maybe some professor can tell you when you get back with the head." He did not bother to gesture with the laser. "Ready?" he asked.

She nodded and aimed.

"Fire!"

The three gunners volleyed raggedly. The thick tree trunks acted as baffles, blurring the sharpness of the reports. The gunfire had the same feeling of muffled desecration as farts echoing in a cathedral. The red-flashed titanosaur began striding forward. Adrienne Salmes worked her bolt and fired again. A wounded animal gave a warning call, so loud and low-pitched that the humans' bowels trembled. Mrs. Salmes fired again. The titanosaur was a flickering picture in a magic lantern formed by open patches between six-foot tree boles. The huntress began to run after her disappearing prey.

Vickers grabbed her shoulder, halting her with an ease that belied his slender build. She turned on him in fury. "I won't let a wounded animal go!" she screamed.

"It won't go far," Vickers said. He released her. "We'll follow as soon as it's safe." He gestured, taking in the bellowing, mountainous forms padding in all directions among the even larger trees. "They'll circle in a moment. Then it'll be safe for things our size to move," he said.

Russet motion ceased, though the tidal bellowing of over a dozen sauropods continued. Mears was still firing in the near distance. Brewer had lowered his rifle and was rubbing his shoulder with his left hand. "Let's get everybody together," the guide suggested, "and go finish off some trophies."

Brewer's expression was awed as they approached. "It really did fall," he said. "It was so big, I couldn't believe. . . . But I shot it where you said

and it just ran into the tree." He waved. "And I kept shooting and it fell."

The haunches of the titanosaur were twice the height of a man, even with the beast belly-down in the loam. McPherson pointed at the great scars in the earth beneath the sauropod's tail. "It kept trying to move," he said in amazement. "Even though there was a tree in the way. It was kicking away, trying to get a purchase, and I thought the *tree* was going to go over. But it did. The, the dinosaur. And I have a tape of all of it!"

Mears, closest to the bellowing giants, was just as enthusiastic. "Like a shooting gallery!" he said, "but the tin ducks're the size of houses. God Almighty! I only brought one box of ammo with me. I shot off every last slug! God Almighty!"

The titanosaurs had quieted somewhat, but they were still making an odd series of sounds. The noises ranged from bird calls as before, to something like the venting of high-pressure steam. Vickers nodded and began walking toward the sounds. He had caught Adrienne Salmes' scowl of distaste at the contractor's recital. If the guide agreed, it was still not his business to say so.

The herd was larger than Vickers had estimated. Fully forty of the sauropods were circled, facing outward around a forest giant enough bigger than its neighbors to have cleared a considerable area. Several of the beasts were rearing up. They flailed the air with clawed forefeet and emitted the penetrating steam-jet hiss that seemed to incongruous from a living being. Mears raised his rifle with a confulsed look on his face before he remembered that he had no ammunition left.

McPherson was already rolling tape. "Have you reloaded?" the guide asked, looking from Salmes to Brewer. The blonde woman nodded curtly while the

meat packer fumbled in the side pocket of his coveralls.

"I don't see the one I hit," Adrienne Salmes said. Her face was tight.

"Don't worry," the guide said quietly. "It's down, it couldn't have made it this far the way you hit it. It's the ones that weren't heart-shot that we're dealing with now."

"That's not my responsibility," she snapped.

"It's no duty you owe to me," Vickers agreed, "or to anything human."

Brewer snicked his bolt home. Vickers' laser touched the center of the chest of a roaring titanosaur. Orange pulmonary blood blashed its tiny head like a shroud. "On the word, Mr. Brewer," he said, "If you would."

Adrienne said, "All right." She did not look at Vickers.

Across the circle, eighty yards away, a large male was trying to lick its belly. Its long neck strained, but it was not flexible enough to reach the wound. The laser pointer touched below the left eye. "There?" the guide asked.

Adrienne nodded and braced herself, legs splayed. Her arms, sling, and upper body made a web of interlocking triangles.

The guide swung his own weapon onto the third of the wounded animals. "All right," he said.

Adrienne's Schultz-and-Larsen cracked. The light went out of the gut-shot sauropod's eye. Undirected, the rest of the great living machine began slowly to collapse where it stood. Brewer was firing, oblivious of his bruised shoulder in the excitement. Vickers put three rounds into the base of his own target's throat. Its head and neck were weaving too randomly to trust a shot at them.

Either the muzzle blasts or the sight of three more

of their number sagging to the ground routed the herd. Their necks swung around like compass needles to iron. With near simultaneity, all the surviving titanosaurs drifted away from the guns. Their tails were held high off the ground.

Adrienne Salmes lowered her rifle. "God Almighty, let me use that?" Mears begged, reaching out for the weapon. "I'll pay you—"

"Touch me and I'll shove this up your bum, you bloody butcher!" the blonde woman snarled.

The contractor's fist balled. He caught himself, however, even before he realized that the muzzle of the .358 had tilted in line with his throat.

"The river isn't that far away," said Vickers, pointing in the direction the sauropods had run. "We'll follow in the pony—it's a sight worth seeing. And taping," he added.

The undergrowth slowed the hunters after they recrossed the ridgeline, but the titanosaurs were still clearly evident. Their heads and even hips rocked above the lower vegetation that sloped toward the river. The herd, despite its size and numbers, had done surprisingly little damage in its rush to the water. The pony repeatedly had to swing aside from three-inch saplings which had sprung back when the last of the titanosaurs had passed.

But the beasts themselves were slowed by the very mechanics of their size. Their twelve-foot strides were ponderously slow even under the goad of panic. The tensile strength of the sauropods' thigh bones simply was not equal to the acceleration of the beasts' mass to more than what would be a fast walk in a man. The hunters reached a rocky spur over the mudflats fringing the water just as the leading titanosaurs splashed into the stream 150 yards away. The far bank of the river was lost in haze. The

sauropods continued to advance without reference to the change in medium. Where a moment before they had been belly-deep in reeds, now they were belly-deep in brown water that was calm except for the wakes of their passage. When the water grew deeper, the procession sank slowly. The beasts farthest away, in mid-stream over a quarter mile out, were floating necks and tails while the forefeet propelled them by kicking down into the bottom muck.

"Don't they hide underwater and snorkel through their necks?" Brewer asked. Then he yipped in surprise as his hand touched the barrel of his Weatherby. The metal was hot enough to burn from strings of rapid fire and the Cretaceous sunlight.

Vickers nodded. He had heard the question often before. "Submarines breathe through tubes because the tubes are steel and the water pressure doesn't crush them," he explained. "Sauropods don't have armored gullets, and their lungs aren't diesel engines inside a steel pressure hull. Physics again. Besides, they float—the only way they could sink would be to grab a rock."

As Vickers spoke, the last titanosaur in the line sank.

"Well, I'll be damned!" the guide blurted.

The sauropod surfaced again a moment later. It blew water from its lungs as it gave the distress cry that had followed the shooting earlier.

The mild current of the river had bent the line of titanosaurs into a slight curve. The leaders were already disappearing into the haze. None of the other beasts even bothered to look back to see the cause of the bellowing. No doubt they already knew.

The stricken titanosaur sank again. It rolled partly onto its left side as it went under the surface this

time. It was still bellowing, wreathing its head in a golden spray as it disappeared.

"I think," said Adrienne Salmes dryly, "that this time the rock grabbed the dinosaur."

Vickers grunted in reply. He was focusing his binoculars on the struggle.

Instead of rising vertically, the sauropod rolled completely over sideways. Clinging to the herbivore's left foreleg as it broke surface was something black and huge and as foul as a tumor. The linked beasts submerged again in an explosion of spray. Vickers lowered the binoculars, shivering. They were not common, even less commonly seen. Great and terrible as they were, they were also widely hated. For them to sun themselves on mudbanks as their descendants did would have been to court death by the horns and claws of land animals equally large. But in their own element, in the still, murky waters, they were lords without peer.

"Christ Almighty," Mears said, "was that a whale?"

"A crocodile," the guide replied, staring at the roiling water. "Enough like what you'd find in the Nile or the Congo that you couldn't tell the difference by a picture. Except for the size." He paused, then continued, "The science staff will be glad to hear about this. They always wondered if they preyed on the big sauropods too. It seems that they preyed on *any* goddam thing in the water."

"I'd swear it was bigger than the tyrannosaurus you showed us," Adrienne Salmes observed, lowering her own binoculars.

Vickers shrugged. "As long, at least. Probably heavier. I looked at a skull, a fossil in London . . . I don't know how I'd get one back as a trophy. . . . It was six feet long, which was impressive; and six feet

wide, which was incredible, a carnivore with jaws six feet wide. Tyrannosaurs don't compare, no. Maybe whales do, Mr. Mears. But nothing else I know of."

There were no longer any titanosaurs visible. The herd had curved off down-stream, past the intrusion vehicle and the hunting camp. They were lost against the haze and the distant shoreline by now. The water still stirred where the last of them had gone down, but by now the struggles must have been the thrashings of the sauropod's automatic nervous system. The teeth of the crocodile were six inches long; but they were meant only to hold, not to kill. The water killed, drowning a thirty-ton sauropod as implacably as it would any lesser creature anchored to the bottom by the crocodile's weight.

"We'd best take our trophies," Vickers said at last. No one in the world knew his fear of drowning, no one but himself. "The smell'll bring a pack of gorgosaurs soon, maybe even a tyrannosaur. I don't want that now, not with us on the ground."

The guide rubbed his forehead with the back of his left hand, setting his bush hat back in place carefully. "The ponies convert to boats," he said, patting the aluminum side. "The tread blocks can be rotated so they work like little paddle wheels." He paused as he swung the tiller bar into a tight circle. "I guess you see why we don't use them for boats in the Cretaceous," he added at last. "And why we didn't keep our camp down on the intrusion vehicle."

Vickers was even quieter than his wont for the rest of the morning.

The shooting platform had returned before the ponies did, the second of them dripping with blood from the titanosaur heads. Two heads had Mears' tags on them, though the contractor had finished

none of the beasts he had wounded. The best head among those he had sprayed would have been the one the guide had directed Adrienne Salmes to kill—with a bullet through the skull that destroyed all trophy value.

There were no game laws in the Cretaceous, but the line between hunters and butchers was the same as in every other age.

The McPhersons greeted each other with mutual enthusiasm. Their conversation was technical and as unintelligible to non-photographers as the conversation of any other specialists. Jonathan Salmes was sitting on a camp stool, surly but alert. He did not greet the returning party, but he watched the unloading of the trophies with undisguised interest. The right side of his face was puffy.

"We've found a tyrannosaur," Dieter called as he and the pilots joined Vickers. That was good news, but there was obvious tension among the other members of the staff. Brady carried a spray gun loaded with antiseptic sealer. A thorough coating would prevent decay for almost a month, ample time to get the heads to proper taxidermists.

When Dieter was sure that all the clients were out of earshot, he said in a low voice, "Don has something to tell you, Henry."

"Eh?" prompted Vickers. He set one of the sauropod heads on the spraying frame instead of looking at the pilot.

"I had to clobber Salmes," Washman said, lifting out the red-flashed trophy. "He was off his head—I'm not sure he even remembers. There was a mixed herd of duckbills came down the trail. He came haring out of his tent with that gun of his. He didn't shoot, though, he started chasing them down the trail." The pilot straightened and shrugged. Steve

Brady began pumping the spray gun. The pungent mist drifted down wind beyond the gaping heads. "I grabbed him. I mean, who knows what might be following a duckbill? When he swung that rifle at me, I had to knock him out for his own good. Like a drowning man." Washman shrugged again. "His gun wasn't even loaded, you know?"

"Don, run the ponies down to the water and mop them out, will you?" Vickers said. The pilot jumped onto the leading vehicle and spun them off down the trail. The two guides walked a little to the side, their rifles slung, while Brady finished sealing the trophies. "It's going to have to be reported, you know," Vickers said. "Whether Salmes does or not."

"You or I might have done the same thing," Dieter replied.

"I'm not denying that," the senior guide snapped. "But it has to be reported."

The two men stood in silence, looking out at a forest filled with sounds that were subtly wrong. At last Dieter said, "Salmes goes up in the platform with you and Don tomorrow, doesn't he?"

Vickers agreed noncommittally.

"Maybe you ought to go with Steve instead," Dieter suggested. He looked at Vickers. "Just for the day, you know."

"Washman just flies us," Vickers said with a shake of his head. "I'm the one that's in contact with the client. And Don's as good as pilots come."

"That he is," the other guide agreed, "that he is. But he is not a piece of furniture. You are treating him as a piece of furniture."

Vickers clapped his companion on the shoulder. "Come on," he said, "Salmes'll be fine when he gets his tyrannosaur. What we ought to be worrying

about is three more for the others. If Salmes goes home with a big boy and the rest have to settle for less—well, it says no guarantees in the contracts, but you know the kind of complaints the company gets. That's the kind of problem we're paid to deal with. If they wanted shrinks instead of guides, they'd have hired somebody else."

Dieter laughed half-heartedly. "Let us see what we can arrange for lunch," he said. "At the moment, I am more interested in sauropod steak than I am in the carnivores that we compete with."

"Damn, the beacon cut out again!" Washman snarled. There was no need of an intercom system; the shooting platform operated with only an intake whine which was no impediment to normal speech. The silence was both a boon to coordination and a help in not alarming the prey. It did, however, mean that the client was necessarily aware of any technical glitches. When the client was Jonathan Salmes—

"God damn, you're not going to put *me* on that way!" the big man blazed. He had his color back and with it all his previous temper. Not that the bruise over his right cheekbone would have helped. "One of the others paid you to save the big one for them, didn't they?" he demanded. "By God, I'll bet it was my wife! And I'll bet it wasn't money either, the—"

"Take us up to a thousand feet," Vickers said sharply. "We'll locate the kill visually if the marker isn't working. Eighty tons of sauropod shouldn't be hard to spot."

"Hang on, there, it's on again," said the pilot. The shooting platform veered slightly as he corrected their course. Vickers and Salmes stood clutching the rail of the suspended lower deck which served as

landing gear as well. Don Washman was seated above them at the controls, with the fuel tank balancing his mass behind. The air intake and exhaust extended far beyond the turbine itself to permit the baffling required for silent running. The shooting platform was as fragile as a dragonfly; and it was, in its way, just as efficient a predator.

By good luck, the tyrannosaur had made its kill on the edge of a large area of brush rather than high forest. The platform's concentric-shaft rotors kept blade length short. Still, though it was possible to maneuver beneath the forest canopy, it was a dangerous and nerve-wracking business to do so. Washman circled the kill at 200 feet, high enough that he did not need to allow for trees beneath him. Though the primary airflow from the rotors was downward, the odor of tens of tons of meat dead in the sun still reached the men above. The guide tried to ignore it with his usual partial success. Salmes only wrinkled his nose and said, "Whew, what a pong." Then, "Where is it? The tyrannosaurus?"

That the big killer was still nearby was obvious from the types of scavengers on the sauropod. Several varieties of the smaller coelurosaurs scrambled over the corpse like harbor rats on a drowned man. None of the species weighed more than a few hundred pounds. A considerable flock of pterosaurs joined and squabbled with the coelurosaurs, wings tented and toothless beaks stabbing out like shears. There were none of the large carnivores around the kill—and that implied that something was keeping them away.

"Want me to go down close to wake him up?" Washman asked.

The guide licked his lips. "I guess you'll have to," he said. There was always a chance that a pterodac-

tyl would be sucked into the turbine when you hovered over a kill. The thought of dropping into a big carnosaur's lap that way kept some guides awake at night. Vickers looked at his client and added, "Mr. Salmes, we're just going to bring the tyrannosaur out of wherever it's lying up in the forest. After we get it into the open, we'll maneuver to give you the best shot. All right?"

Salmes grunted. His hands were tight on his beautifully-finished rifle. He had refused Dieter's offer of the less-bruising camp gun with a scorn that was no less grating for being what all the staff had expected.

Washman dropped them vertically instead of falling in a less wrenching spiral. He flared the blades with a gentle hand, however, feathering the platform's descent into a hover without jarring the gunners. They were less than thirty feet in the air. Pterosaurs, more sensitive to moving air than the earth-bound scavengers, squealed and hunched their wings. The ones on the ground could not take off because the down-draft anchored them. The pilot watched carefully the few still circling above them.

"He's—" Vickers began, and with his word the tyrannosaur strode into the sunlight. Its bellow was intended to chase away the shooting platform. The machine trembled as the sound induced sympathetic vibrations in its rotor blades. Coelurosaurs scattered. The cries of the pterosaurs turned to blind panic as the downdraft continued to frustrate their attempts to rise. The huge predator took another step forward. Salmes raised his rifle. The guide cursed under his breath but did not attempt to stop him.

At that, it should have been an easy shot. The tyrannosaur was within thirty feet of the platform

and less than ten feet below them. All it required was that Salmes aim past the large head as it swung to counterweight a stride and rake down through the thorax. Perhaps the angle caused him to shoot high, perhaps he flinched. Vickers, watching the carnosaur over his own sights, heard the big rifle crash. The tyrannosaur strode forward untouched, halving the distance between it and the platform.

"Take us up!" the guide shouted. If it had not been a rare trophy, he might have fired himself and announced that he had 'put in a bullet to finish the beast'. There were three other gunners who wanted a tyrannosaur, though; if Salmes took this one back, it would be after he had shot it or everyone else had an equal prize.

Salmes was livid. He gripped the bolt handle, but he had not extracted the empty case. "God damn you!" he screamed. "You made it wobble to throw me off! You son of a bitch, you robbed me!"

"Mr. Salmes—" Vickers said. The tyrannosaur was now astride the body of its prey, cocking its head to see the shooting platform fifty feet above it.

"By God, you want another chance?" Washman demanded in a loud voice. The platform plunged down at a steep angle. The floor grating blurred the sight of the carnosaur's mottled hide. Its upturned eye gleamed like a strobe-lit ruby.

"Jesus *Christ!*" Vickers shouted. "Take us the hell up, Washman!"

The platform steadied, pillow soft, with its floor fifteen feet from the ground and less than twenty from the tyrannosaur. Standing on the sauropod's corpse, the great predator was eye to eye with Vickers and his client. The beast bellowed again as it lunged. The impulse of its clawed left leg rolled the sauropod's torso.

Salmes screamed and threw his rifle to the grating. The guide leveled his Garand. He was no longer cursing Washman. All of his being was focused on what would be his last shot if he missed it. Before he could fire, however, the shooting platform slewed sideways. Then they were out of the path of the charging dinosaur and beginning to circle with a safe thirty feet of altitude. Below them, the tyrannosaur clawed dirt as it tried to follow.

Salmes was crying uncontrollably.

"Ah, want me to hold it here for a shot?" Washman asked nervously.

"We'll go on back to the camp, Don," the guide said. "We'll talk there, all right?"

"Whatever you say."

Halfway back, Vickers remembered he had not dropped another marker to replace the one that was malfunctioning. God knew, that was the least of his problems.

"You know," Brewer said as he forked torosaur steaks onto the platter, "it tastes more like buffalo than beef; but if we could get some breeding stock back, I'd by God find a market for it!"

Everyone seemed to be concentrating on their meat—good, if pale and lean in comparison with feed-lot steer. "Ah," Vickers said, keeping his voice nonchalant. He looked down at the table instead of the people sitting around it. "Ah, Dieter and I were talking. . . . We'll bunk outside tonight. The, ah, the rest of that pack of dromaeosaurs chased some duckbills through the camp this morning, Steve thinks. So just for safety's sake, we'll both be out of the tent. . . . So, ah, Mrs. Salmes—"

Everyone froze. Jonathan Salmes was turning red. His wife had a forkful of steak poised halfway to her

mouth and her eyebrows were rising. The guide swallowed, his eyes still fixed on his plate, and plowed on. "That is, you can have your own tent. Ah, to sleep in."

"Thank you," Adrienne Salmes said coolly, "but I'm quite satisfied with the present arrangements."

Dieter had refused to become involved in this, saying that interfering in the domestic affairs of the Salmeses was useless at best. Vickers was sweating now, wishing that there was something to shoot instead of nine pairs of human eyes fixed on him. "Ah," he repeated, "Mrs. Salmes—"

"Mr. Vickers," she overrode him, "who I choose to sleep with—in any sense of the term—is none of your business. Anyone's business," she added with a sharp glance across the table at her husband.

Jonathan Salmes stood up, spilling his coffee cup. His hand closed on his fork. Each of the four staff members made unobtrusive preparations. Cursing, Salmes flung the fork down and stalked back to his tent.

The others eased. Vickers muttered, "Christ." Then, "Sorry, Dieter, I. . . ." The thing that bothered him most about the whole incident was that he was unsure whether he would have said anything at all had it been Miss McPherson in Don's bed instead of someone he himself found attractive. Christ. . . .

"Mr. Vickers?" Adrienne Salmes said in a mild voice.

"Umm?" His steak had gotten cold. With Brewer cutting and broiling the meat, the insertion group was eating better than Vickers could ever remember.

"I believe Mr. Brady is scheduled to take me up in the platform tomorrow?"

"Yeah, that's right," Vickers agreed, chewing very slowly.

"I doubt my—husband—will be going out again tomorrow," the blonde woman continued with a nod toward his tent. "Under the circumstances, I think it might be better if Mr. Brady were left behind here at the camp. Instead of Don."

"Steve?" Dieter asked.

Brady shrugged. "Sure, I don't need the flying time. But say—I'm not going to finish ditching around the tents by myself. I've got blisters from today."

"All right," said Dieter. "Henry, you and Don—" no one was looking directly at Washman, who was blushing in embarrassment he had damned well brought on himself—"will take Mrs. Salmes up after the tyrannosaur tomorrow." Vickers and Brady both nodded. "The rest of us will wait here to see if the duckbills come through again as they have become accustomed. Steve, I will help you dig. And if the duckbills have become coy, we will ride down the river margin a little later in the morning and find them. Perhaps Mr. Salmes will feel like going with us by then."

Thank God for Dieter, Vickers thought as he munched another bite of his steak. He could always be counted on to turn an impossible social situation into a smoothly functioning one. There would be no trouble tomorrow after all.

The bulging heads of three torosaurs lay between the gun tower and the fire. There the flames and the guard's presence would keep away the small mammals that foraged in the night. As Miss McPherson followed her brother to their tent, she paused and fingered one of the brow horns of the largest trophy. The tip of the horn was on a level with the dentist's eyes, even though the skull lay on the ground.

"They're so huge, so . . . powerful," she said. "And for them to fall when you shoot at them, so many of them falling and running. . . . I could never understand men who, well, who shot animals. But with so many of them everywhere—it's as if you were throwing rocks at the windows of an abandoned house, isn't it? It doesn't seem to hurt anything, and it's . . . an attractive feeling."

"Mary!" objected her brother, shadowed by the great heads.

"Oh, I don't mean I'm sorry that I didn't bring a gun," continued Mary McPherson calmly, her fingers continuing to stroke the smooth black horn. "No, I'm glad I didn't. Because if I had had a gun available this morning, I'm quite sure I would have used it. And after we return, I suppose I would regret that. I suppose." She walked off toward the tent. The rhythms of her low-voiced argument with her brother could be heard until the flaps were zipped.

"Dieter tells me they bagged sixteen torosaurs today," Vickers said. "Even though the intrusion vehicle hasn't room for more than one per client." Only Washman, who had the watch, and Adrienne Salmes were still at the campfire with him.

"*I* bagged one," the woman said with an emphatic flick of her cigar. "Jack Brewer shot six; and I sincerely hope that idiot Mears hit no more than ten, because that's all Dieter and I managed to finish off for him." She had unpinned her hair as soon as she came in from the field. In the firelight it rolled across her shoulders like molten amber.

"Dieter said that too," Vickers agreed. He stood, feeling older than usual. "That's why I said 'they'." He turned and began to walk back to the tent where Dieter was already asleep. There had been no point

in going through with the charade of sleeping under the stars—overcast, actually—since the dromaeosaurs were daylight predators. They were as unlikely to appear in the camp after dark as the Pope was to speak at a KKK rally.

To the guide's surprise—and to Don Washman's—Adrienne rustled to her feet and followed. "Mr. Vickers," she said, "might I speak to you for a moment, please?"

Vickers looked at her. As the staff members did, and unlike the other clients, the blonde woman carried her weapon with her at all times. "All right," he said. They walked by instinct to the shooting platform, standing thirty feet away at the end of the arc of tents. The torosaur heads were monstrous silhouettes against the fire's orange glow. "Would it bother you as much if I were a man?" she asked bluntly.

"Anything that makes my job harder bothers me," Vickers said in half-truth. "You and Don are making my job harder. That's all."

Adrienne stubbed out her small cigar on the platform's rail. She scattered the remnants of the tobacco on the rocky soil. "Balls," she said distinctly. "Mr. Vickers—Henry, for Christ's sake—my husband was going to be impossible no matter what. He's here because I was going on a time safari and he was afraid to look less of a man than his wife was. Which he is. But he was going to be terrified of his rifle, he was going to pack his trunk with Scotch, and he was going to be a complete prick because that's the way he is."

"Mrs. Salmes—"

"Adrienne, and let me finish. I didn't marry Jonathan for his money—my family has just as much as his does. I won't claim it was a love match,

but we ... we seemed to make a good pair. A matched set, if you will. He won't divorce me—" her dimly-glimpsed index finger forestalled another attempt by the guide to break in—"because he correctly believes I'd tell the judge and the world that he couldn't get it up on our wedding night. Among other things. I haven't divorced him because I've never felt a need to. There are times that it's been marvelously useful to point out that 'I *do* after all have a husband, dearest....' "

"This is none of my business, Mrs. Salmes—"

"Adrienne!"

"Adrienne, dammit!" Vickers burst out. "It's none of my business, but I'm going to say it anyway. You don't have anything to prove. That's fine, we all should be that way. But most of my clients have a lot to prove, to themselves and to the world. Or they wouldn't be down here in the Cretaceous. It makes them dangerous, because they're out of normal society and they may not be the men they hoped they were after all. And your husband is very goddamned dangerous, Adrienne. Take my word for it."

"Well, it's not *my* fault," the woman said.

"Fault?" the guide snapped. "Fault? Is it a pusher's fault that kids OD on skag? You're goddamn right it's your fault! It's the fault of everybody involved who doesn't make it better, and you're sure not making it better. Look, you wouldn't treat a gun that way—and your husband is a human being!"

Adrienne frowned in surprise. There was none of the anger Vickers had expected in her voice when she said, "So are you, Henry. You shouldn't try so hard to hide the fact."

Abruptly, the guide strode toward his tent. Adrienne Salmes watched him go. She took out another

cigar, paused, and walked carefully back to the fire where Washman waited with the alarm panel. The pilot looked up with concern. Adrienne sat beside him and shook her hair loose. "Here you go, Don sweetest," she said, extending her cigar. "Why don't you light it for me? It's one of the things you do so well."

Washman kissed her. She returned it, tonguing his lips; but when his hand moved to the zipper of her coveralls, she forced it away. "That's enough until you go off guard duty, dearest," she said. She giggled. "Well—almost enough."

Jonathan Salmes hunched in the shadow of the nearest torosaur head. He listened, pressing his fists to his temples. After several more minutes, he moved in a half-crouch to the shooting platform. In his side pockets were a dozen pebbles, walnut-sized bits of quartz that he had worried from the ground with his fingers. Stepping carefully so that his boots did not scrunch on the metal rungs, Salmes mounted the ladder to the pilot's seat. He paused there, his khaki coveralls and strained, white face reflecting the flames. The couple near the fire did not look up. The pilot was murmuring something, but his voice was pitched too low to hear . . . and the words might have been unintelligible anyway, given the circumstances.

Jonathan Salmes shuddered also. He moved with a slick grace that belied the terror and disgust frozen on his face. One at a time he removed the quartz pebbles from his pocket. Stretching his right arm out full length while he gripped the rotor shaft left-handed, Salmes set each pebble just inside the air intake of the turbine. When he was finished, he scrambled back down the ladder. He did not look at his wife and the pilot again, but his ears could not

escape Adrienne's contented giggle.

"Hank, she just isn't handling right this morning," Don Washman said. "I'm going to have to blow the fuel lines out when we get back. Must've gotten some trash in the fuel transferring from the bladder to the cans to the tank. Wish to hell we could fuel the bird directly, but I'm damned if I'm going to set down on the intrusion vehicle where it's sitting now."

Vickers glanced down at the treetops and scowled. "Do you think we ought to abort?" he asked. He had not noticed any difference in the flight to that point. Now he imagined they were moving slower and nearer the ground than was usual, and both the rush of air and the muted turbine whine took on sinister notes.

"Oh. . . ," the pilot said. "Well, she's a lot more likely to clear herself than get worse—the crud sinks to the bottom of the tank and gets sucked up first. It'll be okay. I mean, she's just a little sluggish, is all."

The guide nodded. "M—" he began. After his outburst of the night before, he was as embarrassed around Adrienne Salmes as a boy at his first dance. "Ah, Adrienne, what do you think?"

The blonde woman smiled brightly, both for the question and the way it was framed. "Oh, if Don's willing to go on, there's no question," she said. "You know I'd gladly walk if it were the only way to get a tyrannosaurus, Henry—if you'd let me, I mean. We both know that when we go back in today, I've had my last chance at a big carnosaur until you've rotated through all your clients again. Including my husband."

"We'll get you a tyrannosaur," Vickers said.

Adrienne edged slightly closer to the guide. She said softly, "Henry, I want you to know that when we get back I'm going to give Johnnie a divorce."

Vickers turned away as if slapped. "That's none of my business," he said. "I—I'm sorry for what I said last night."

"Sorry?" the woman repeated in a voice that barely carried over the wind noise. "For making me see that I shouldn't make a doormat of . . . someone who used to be important to me? Don't be sorry." After a pause, she continued, "When I ran for Congress . . . God I was young! I offended it must have been everybody in the world, much less the district. But Johnnie was fantastic. I owe what votes I got to hands he shook for me."

"I had no right to talk," Vickers said. By forcing himself, he managed to look the blonde woman in the eyes.

Adrienne smiled and touched his hand where it lay on the forestock of his rifle. "Henry," she said, "I'm not perfect, and the world's not going to be perfect either. But I can stop trying to make it actively worse."

Vickers looked at the woman's hand. After a moment, he rotated his own to hold it. "You've spent your life being the best man around," he said, as calm as he would be in the instant of shooting. "I think you've got it in you to be the best person around instead. I'm not the one to talk . . . but I think I'd be more comfortable around people if more of them were the way you could be."

With a final squeeze, Vickers released Adrienne's hand. During the remainder of the fifteen-minute flight, he concentrated on the ground below. He almost forgot Washman's concern about the engine.

* * *

Dieter Jost flicked a last spadeful of gritty soil from the drainage ditch and paused. Steve Brady gave him a thumbs-up signal from the gun tower where he sat. "Another six inches, peon," he called to the guide. "You need to sweat some."

"Fah," said Dieter, laughing. "If it needs to be deeper, the rain will wash it deeper—not so?" He dug the spade into the ground and began walking over to the table. They had found a cache of sauropod eggs the day before. With the aid of torosaur loin and freeze-dried spices from his kit, Brewer had turned one of them into a delicious omelet. Brewer, Mears, and the McPhersons were just finishing. Dieter, who had risen early to finish ditching the tents, had worked up quite an appetite.

"Hey!" Brady called. Then, louder, "Hey! Mr. Salmes, that's not safe! Come back here, please!"

The guide's automatic rifle leaned against the gun tower. He picked it up. Jonathan Salmes was carrying his own rifle and walking at a deliberate pace down the trail to the water. He did not look around when the guard shouted. The other clients were staring in various stages of concern. Cradling his weapon, Dieter trotted after Salmes. Brady, standing on the six-foot tower, began to rotate the heavy machinegun. He stopped when he realized what he was doing.

The guide reached Salmes only fifty yards from the center of the camp, still in sight of the others. He put a hand on the blond man's shoulder and said, "Now, Mr. Salmes—"

Salmes spun like a mousetrap snapping. His face was white. He rang his heavy rifle off Dieter's skull with enough force to tear the stock out of his hands. The guide dropped as if brainshot. Salmes backed away from the fallen man. Then he turned and

shambled out of sight among the trees.

"God damn!" Steve Brady said, blinking in surprise. Then he thought of something even more frightening. He unslung his grenade launcher and jumped to the ground without bothering to use the ladder. "If that bastard gets to the intrusion vehicle —" he said aloud, and there was no need for him to finish the statement.

Brady vaulted the guide's body without bothering to look at the injury. The best thing he could do for Dieter now was to keep him from being stranded in the Cretaceous. Brady's hobnails skidded where pine needles overlay rock, but he kept his footing. As the trail twisted around an exceptionally large tree, Brady caught sight of the client again. Salmes was not really running; or rather, he was moving like a man who had run almost to the point of death.

"Salmes, God damn you!" Brady called. He raised the grenade launcher. Two dromaeosaurs burst from opposite sides of the trail where they lay ambushed. Their attention had been on Salmes; but when the guard shouted, they converged on him.

The leftward dromaeosaur launched itself toward its prey in a flat, twenty-foot leap. Only the fact that Brady had his weapon aimed permitted him to disintegrate the beast's head with a point-blank shot. Death did nothing to prevent the beast from disemboweling Brady reflexively. The two mutilated bodies were thrashing in a tangle of blood and intestines as the remaining clients hurtled around the tree. They skidded to a halt. Mr. McPherson, who held Salmes' rifle—his sister had snatched up Dieter's FN a step ahead of him—began to vomit. Neither Salmes nor the other dromaeosaur were visible.

Jonathan Salmes had in fact squelched across the mud and up the ramp of the intrusion vehicle. He had unscrewed the safety cage from the return

switch and had his hand poised on the lever. Something clanged on the ramp behind him.

Salmes turned. The dromaeosaur, panicked by the grenade blast that pulped its companion's head, was already in the air. Salmes screamed and threw the switch. The dromaeosaur flung him back against the fuel bladder. As everything around it blurred, the predator picked Salmes up with its forelegs and began methodically to kick him to pieces with its right hind foot. The dinosaur was still in the process of doing so when the submachineguns of the startled guards raked it to death with equal thoroughness.

The broad ribs of the sauropod thrust up from a body cavity that had been cleared of most of its flesh. There was probably another meal on the haunches, even for a beast of the tyrannosaur's voracity. If Adrienne missed the trophy this morning, however, Vickers would have to shoot another herbivore in the vicinity in order to anchor the prize for the next client.

Not that there was much chance that the blonde woman was going to miss.

Adrienne held her rifle with both hands, slanted across her chest. Her hip was braced against the guardrail as she scanned the forest edge. If she had any concern for her balance, it was not evident.

"Okay, down to sixty," Don Washman said, barely enough height to clear the scrub oaks that humped over lower brush in the clearing. The lack of grasses gave the unforested areas of the Cretaceous an open aspect from high altitude. Lower down, the spikes and wooden fingers reached out like a hedge of spears.

The tyrannosaur strode from the pines with a hacking challenge.

"Christ, he's looking for us," the pilot said. The

carnosaur slammed aside the ribs of its kill like bowling pins. Its nostrils were flared, and the sound it made was strikingly different from the familiar bellow of earlier occasions.

"Yeah, that's its territorial call," Vickers agreed. "It seems to have decided that we're another tyrannosaur. It's not just talking, it wants our blood."

"S'pose Salmes really hit it yesterday?" Washman asked.

Vickers shook his head absently. "No," he said, "but the way you put the platform in its face after it'd warned us off.... Only a tyrannosaur would challenge another tyrannosaur that way. They don't have much brain, but they've got lots of instinctive responses; and the response we've triggered is, well ... a good one to give us a shot. You ready, Adrienne?"

"Tell me when," the blonde woman said curtly. Washman was swinging the platform in loose figure-8s about 150 yards distant from the carnosaur. They could not circle at their present altitude because they were too low to clear the conifer backdrop. Adrienne aimed the Schultz and Larsen when the beast was on her side of the platform, raising the muzzle again each time the pilot swung onto the rear loop of the figure.

"Don, see if you can draw him out from the woods a little farther," the guide said, squinting past the barrel of his Garand. "I'd like us to have plenty of time to nail him before he can go to ground in the trees."

"Ah, Hank...," the pilot began. Then he went on, "Oh, hell, just don't blow your shots. That's all I ask." He put the controls over and wicked up. There was a noticeable lag before the turbine responded to the demand for increased power. The

platform was vibrating badly.

"If you'll stand over here, Mis—Adrienne," Vickers said, stepping to the back rail of the platform. The client followed with brittle quickness. "When I say shoot," Vickers continued, "aim at the middle of the chest."

Washman had put the platform in an arc toward the tyrannosaur. The big carnivore lunged forward with a series of choppy grunts like an automatic cannon. The pilot rotated the platform on its axis, a maneuver he had carried out a thousand times before. This time the vehicle dipped. It was a sickening, falling-elevator feeling to the two gunners and a heart-stopping terror to the man at the controls who realized it was not caused by clumsiness. The platform began to stagger away from the dinosaur, following the planned hyperbola but lower and slower than intended.

"Nail him," Vickers said calmly, sighting his rifle on the green-mottled sternum for the backup shot.

Partial disintegration of the turbine preceded the shot by so little that the two seemed a single event. Both gunners were thrown back from the rail. Something whizzed through the side of the turbine and left a jagged rent in the housing. Adrienne Salmes' bullet struck the tyrannosaur in the lower belly.

"Hang on!" Don Washman shouted needlessly. "I'm going to try—"

He pulled the platform into another arc, clawing for altitude. To get back to camp they had to climb over the pine forest that lay between. No one knew better than the pilot how hopeless that chance was. Several of the turbine blades had separated from the hub. Most of the rest were brushes of boron fiber now, their casing matrices destroyed by rock and harmonics induced by the imbalance. But Washman

had to try, and in any case they were curving around the wounded tyrannosaur while it was still—

The whole drive unit tore itself free of the rest of the shooting platform. Part of it spun for a moment with the rotor shafts before sailing off in a direction of its own. Had it not been for the oak tree in their path, the vehicle might have smashed into the ground from fifty feet and killed everyone aboard. On the other hand, Don Washman just might have been able to get enough lift from the auto-rotating blades to set them down on an even keel. Branches snagged the mesh floor of the platform and the vehicle nosed over into the treetop.

They were all shouting, but the din of bursting metal and branches overwhelmed mere human noise. Vickers held the railing with one hand and the collar of his client's garment with the other. Both of the rifles were gone. The platform continued to tilt until the floor would have been vertical had it not been so crumpled. Adrienne Salmes was supported entirely by the guide. "For God's sake!" she screamed. "Let go or we'll go over *with* it!"

Vickers' face was red with the impossible strain. He forced his eyes down, feeling as if even that minuscule added effort would cause his body to tear. Adrienne was right. They were better off dropping onto a lower branch—or even to the ground forty feet below—than they would be somersaulting down in the midst of jagged metal. The platform was continuing to settle as branches popped. Vickers let go of the blonde woman. Screaming at the sudden release of half the load, he loosed his other hand from the rail.

The guide's eyes were shut in a pain reflex. His chest hit a branch at an angle that saved his ribs at the cost of cloth and a plate-sized swatch of skin. He

snatched convulsively at the limb. Adrienne, further out on the same branch, seized him by the collar and armpit. Both her feet were locked around the branch. She took the strain until the guide's overstressed muscles allowed him to get a leg up. The branch swayed, but the tough oak held.

Don Washman was strapped into his seat. Now he was staring straight down and struggling with the jammed release catch. Vickers reached for the folding knife he carried in a belt pouch. He could not reach the pilot, though. "Don, cut the strap!" he shouted.

A large branch split. The platform tumbled outward and down, striking on the top of the rotor shafts. The impact smashed the lightly-built aircraft into a tangle reeking of kerosene. Don Washman was still caught in the middle of it.

The limb on which Vickers and Adrienne Salmes balanced was swaying in harmony with the whole tree. When the thrashing stopped, the guide sat up and eyed the trunk. He held his arms crossed tightly over his chest, each hand squeezing the opposite shoulder as if to reknit muscles which felt as if they had been pulled apart. Nothing was moving in the wreckage below. Vickers crawled to the crotch. He held on firmly while he stepped to a branch three feet lower down.

"Henry," Adrienne Salmes said.

"Just wait, I've got to get him out," Vickers said. He swung down to a limb directly beneath him, trying not to wince when his shoulders fell below the level of his supporting hands.

"Henry!" the blonde woman repeated more urgently. "The tyrannosaur!"

Vickers jerked his head around. He could see nothing but patterns of light and the leaves that sur-

rounded him. He realized that the woman had been speaking from fear, not because she actually saw anything. There was no likelihood that the carnosaur would wander away from its kill, even to pursue a rival. Adrienne, who did not understand the beast's instincts, in her fear imagined it charging toward them. The guide let himself down from the branch on which he sat, falling the last five feet to the ground.

Adrienne thought Vickers must have struck his head during the crash. From her vantage point, thirty feet in the air and well outboard on the limb that supported her, she had an excellent view of the tyrannosaur. Only low brush separated it from the tree in which they had crashed. The beast had stood for a moment at the point Washman lifted the platform in his effort to escape. Now it was ramping like a creature from heraldry, balanced on one leg with its torso high and the other hind leg kicking out at nothing. At first she did not understand; then she saw that each time the foot drew back, it caressed the wounded belly.

Suddenly the big carnivore stopped rubbing itself. It had been facing away from the tree at a 30° angle. Now it turned toward the woman, awesome even at three hundred yards. It began to stalk forward. Its head swung low as usual, but after each few strides the beast paused. The back raised, the neck stretched upward, and now Adrienne could see that the nostrils were spreading. A leaf, dislodged when Vickers scrambled to the ground, was drifting down. The light breeze angled it toward the oncoming dinosaur.

Vickers cut through one of the lower cross-straps holding Washman five feet in the air with his seat above him. The pilot was alive but unconscious. The guide reached up for the remaining strap, his free

hand and forearm braced against the pilot's chest to keep him from dropping on his face.

"Henry, for God's sake!" the woman above him shouted. "It's only a hundred yards away!"

Vickers stared at the wall of brush, his lips drawn back in a snarl. "Where are the guns? Can you see the guns?"

"I can't see them! Get back, for God's sake!"

The guide cursed and slashed through the strap. To take Washman's weight, he dropped his knife and bent. Grunting, Vickers manhandled the pilot into position for a fireman's carry.

The tyrannosaur had lowered its head again. Adrienne Salmes stared at the predator, then down at Vickers staggering under the pilot's weight. She fumbled out one of her small cigars, lit it, and dropped the gold-chased lighter back into her pocket. Then she scrambled to the bole and began to descend. The bark tore the knees and elbows out of her coveralls and the skin off the palms of both hands.

From the lowest branch, head-height for the stooping Vickers, Adrienne cried, "Here!" and tried to snatch Washman from the guide's back. The pilot was too heavy. Vickers thrust his shoulders upward. Between them, they slung Washman onto the branch. His arms and legs hung down to either side and his face was pressed cruelly into the bark.

The tyrannosaur crashed through the woody undergrowth twenty feet away. It stank of death, even against the mild breeze. The dead sauropod, of course, rotting between the four-inch teeth and smeared greasily over the killer's head and breast . . . but beyond the carrion odor was a tangible sharpness filling the mouths of guide and client as the brush parted.

Vickers had no chance of getting higher into the

oak than the jaws could pick him off. Instead he turned, wishing that he had been able to keep at least his knife for this moment. Adrienne Salmes dragged on her cigar, stood, and flung the glowing cylinder into the wreckage of the platform. "Henry!" she cried, and she bent back down with her hand out to Vickers.

One stride put the tyrannosaur into the midst of the up-ended platform. As flimsy as the metal was, its edges were sharp and they clung instead of springing back the way splintered branches would. The beast's powerful legs had pistoned it through dense brush without slowing. It could still have dragged the wreckage forward through the one remaining step that would have ended the three humans. Instead, it drew back with a startled snort and tried to nuzzle its feet clear.

The kerosene bloomed into a sluggish red blaze. The tyrannosaur's distended nostrils *whuffed* in a double lungful of the soot-laden smoke that rolled from the peaks of the flames. The beast squealed and kicked in berserk fury, scattering fire-wrapped metal. Its rigid tail slashed the brush, fanning the flames toward the oak. Deeply-indented leaves shrivelled like hands closing. Vickers forgot about trying to climb. He rolled Don Washman off the branch again, holding him by the armpits. The pilot's feet fell as they would. "While we've got a chance!" the guide cried, knowing that the brush fire would suffocate them in the treetop even if the flames themselves did not climb so high.

Adrienne Salmes jumped down. Each of them wrapped one of the pilot's arms around their shoulders. They began to stumble through the brush, the backs of their necks prickling with the heat of the fire.

The tyrannosaur was snarling in unexampled rage. Fire was familiar to a creature which had lived a century among forests and lightning. Being caught in the midst of a blaze was something else again. The beast would not run while the platform still tangled its feet, and the powerful kicks that shredded the binding metal also scattered the flames. When at last the great killer broke free, it did so from the heart of an amoeba a hundred yards in diameter crackling in the brush. Adrienne and the guide were struggling into the forest when they heard the tyrannosaur give its challenge again. It sounded far away.

"I don't suppose there's any way we could retrieve the rifles," Adrienne said as Vickers put another stick on their fire. It was a human touch in the Cretaceous night. Besides, the guide was chilly. They had used his coveralls to improvise a stretcher for Washman, thrusting a pruned sapling up each leg and out the corresponding sleeve. They had not used the pilot's own garment for fear that being stripped would accelerate the effects of shock. Washman was breathing stertorously and had not regained consciousness since the crash.

"Well, I couldn't tell about yours," Vickers said with a wry smile, "but even with the brush popping I'm pretty sure I heard the magazine of mine go off. I'd feel happier if we had it along, that's for sure."

"I'm going to miss that Schultz and Larsen," the woman said. She took out a cigar, looked at it, and slipped it back into her pocket. "Slickest action they ever put on a rifle. Well, I suppose I can find another when we get back."

They had found the saplings growing in a sauropod burn. Fortunately, Adrienne had retained her sheath knife, a monster with a saw-backed,

eight-inch blade that Vickers had thought a joke—until it became their only tool. The knife and the cigaret lighter, he reminded himself. Resiny wood cracked, pitching sparks beyond the circle they had cleared in the fallen needles. The woman immediately stood and kicked the spreading flames back in toward the center.

"You saved my life," Vickers said, looking into the fire. "With that cigar. You were thinking a lot better than I was, and that's the only reason I'm not in a carnosaur's belly."

Adrienne sat down beside the guide. After a moment, he met her eyes. She said, "You could have left Don and gotten back safely yourself."

"I could have been a goddam politician!" Vickers snapped, "but that wasn't a way I wanted to live my life." He relaxed and shook his head. "Sorry," he said. She laughed and squeezed his bare knee above the abrasion. "Besides," Vickers went on, "I'm not sure it would have worked. The damned tyrannosaur was obviously tracking us by scent. Most of what we know about the big carnivores started a minute or two before they were killed. They . . . I don't mean dinos're smart. But their instincts are a lot more efficient than you'd think if you hadn't watched them."

Adrienne Salmes nodded. "A computer isn't smart either, but that doesn't keep it from solving problems."

"Exactly," Vickers said, "exactly. And if the problem that tyrannosaur was trying to solve was us—well, I'm just as glad the fire wiped out our scent. We've got a long hike tomorrow lugging Don."

"What bothers me," the blonde woman said carefully, "is the fact it could find us easily enough if it tried. Look, we can't be very far from the camp, not

at the platform's speed. Why don't we push on now instead of waiting for daylight?"

Vickers glanced down at the responder on his wrist, tuned to the beacon in the center of the camp. "Five or six miles," he said. "Not too bad, even with Don. But I think we're better off here than stumbling into camp in the dark. The smell of the trophies is going to keep packs of the smaller predators around it. They're active in the dark, and they've got damned sharp teeth."

Adrienne chuckled, startling away some of the red eyes ringing their fire. Vickers had whittled a branch into a whippy cudgel with an eye toward bagging a mammal or two for dinner, but both he and his client were too thirsty to feel much hunger as yet. "Well," she said, "we have to find something else to do 'til daybreak, then—and I'm too keyed up to sleep." She touched Vickers' thigh again.

All the surrounding eyes vanished when a dinosaur grunted.

It could have been a smaller creature, even an herbivore; but that would not have made it harmless. In the event, it was precisely what they feared it was when the savage noise filled the forest: the tyrannosaur hunting them and very close.

The fire was of branches and four-foot lengths of sapling they had broken after notching with the knife. Vickers' face lost all expression. He grabbed the unburned end of a billet and turned toward the sound. "No!" Adrienne cried. "Spread the fire in a line—it won't follow us through a fire again!"

It was the difference between no good chance and no chance at all. Vickers scuffed a bootload of coals out into the heaped pine needles and ran into the night with his brand. The lowest branches of the pines were dead and dry, light-starved by the foliage

nearer the sky. The resin-sizzling torch caught them and they flared up behind the guide. Half-burned twigs that fell to the forest floor flickered among the matted needles. Vickers already was twenty yards from their original campfire when he remembered that Don Washman still lay helpless beside it.

The dozen little fires Vickers had set, and the similar line Adrienne Salmes had ignited on the other side of the campfire, were already beginning to grow and merge. The guide turned and saw the flames nearing Washman's feet, though not—thank God—his head. That was when the tyrannosaur stepped into view. In the firelight it was hard to tell the mottled camouflage natural to its hide from the cracked and blistered areas left by the earlier blaze. Vickers cursed and hurled his torch. It spun end over end, falling short of its intended target.

The tyrannosaur had been advancing with its head hung low. It was still fifteen feet high at the hips. In the flickering light, it bulked even larger than the ten tons it objectively weighed. Adrienne looked absurd and tiny as she leaped forward to meet the creature with a pine torch. Behind her the flames were spreading, but they were unlikely to form a barrier to the beast until they formed a continuous line. That was seconds or a minute away, despite the fact that the fuel was either dry or soaking with pitch.

Adrienne slashed her brand in a figure-8 like a child with a sparkler. Confused by the glare and stench of the resinous flames, the carnosaur reared back and took only a half step forward—onto the torch Vickers had thrown.

The guide grabbed up the poles at Washman's head. He dragged the pilot away from the fire like a pony hauling a travois. When the tyrannosaur

screeched, Vickers dropped the stretcher again and turned, certain he would see the beast striding easily through the curtain of fire. Instead it was backing away, its great head slashing out to either side as if expecting to find a tangible opponent there. The blonde woman threw her torch at the dinosaur. Then, with her arms shielding her face, she leaped across the fire. She would have run into the bole of a tree had Vickers not caught her as she blundered past. "It's all right!" he shouted. "It's turned! Get the other end of the stretcher."

Spattering pitch had pocked but not fully ignited Adrienne's garments. The tears furrowing the soot on her cheeks were partly the result of irritants in the flames. "It'll be back," she said. "You know it will."

"I'll have a rifle in my hands the next time I see it," the guide said. "This is one dino that won't be a matter of business to shoot."

The alarm awakened the camp. Then muzzle flashes lit the white faces of the clients when the first dinosaur trotted down the trail. Even the grenade launcher could not divert the monsters. After a long time, the gunfire slackened. Then Miss McPherson returned with additional ammunition.

Somewhat later, the shooting stopped for good.

If he had not been moving in a stupor, the noise of the scavengers would have warned Vickers. As it was, he pushed out of the trees and into a slaughter-yard teeming with vermin on a scale with the carvases they gorged on. Only when Mears cried out did the guide realize they were back in the camp. The four clients were squeezed together on top of the machinegun tower.

Vickers was too shocked to curse. He set down his

end of the stretcher abruptly. The other end was already on the ground. "Henry, do you want the knife?" Adrienne asked. He shook his head without turning around.

There were at least a dozen torosaurs sprawled on the northern quadrant of the camp, along the trail. They were more like hills than anything that had been alive, but explosive bullets from the 12.7 mm machinegun had opened them up like chainsaws. The clients were shouting and waving rifles in the air from the low tower. Vickers, only fifty feet away, could not hear them because of the clatter of the scavengers. There were well over one hundred tons of carrion in the clearing. Litterally thousands of lesser creatures had swarmed out of the skies and the forest to take advantage.

'Lesser' did not mean 'little' in the Cretaceous.

Vickers swallowed. "Can you carry Don alone if I lead the way?" he asked. "We've got to get to the others to find out what happened."

"I'll manage," the woman said. Then, "You know, they must have fired off all their ammunition. That's why they're huddled there beside—"

"I know what they goddam did!" the guide snarled. "I also know that if there's one goddam round left, we've got a chance to sort things out!" Neither of them voiced the corollary. They had heard the tyrannosaur challenge the dawn an hour earlier. Just before they burst into the clearing, they had heard a second call; and it was much closer.

Adrienne knelt, locking one of the pilot's arms over her shoulders. She straightened at the knees, lifting her burden with her. Washman's muscles were slack. "That's something I owe my husband for," Adrienne gasped. "Practice moving drunks. When I was young and a fool."

Vickers held one of the stretcher poles like a quarterstaff. He knew how he must look in his underwear. That bothered him obscurely almost as much as the coming gauntlet of carrion-eaters did.

A white-furred pterosaur with folded, twenty-foot wings struck at the humans as they maneuvered between two looming carcases. Vickers slapped away the red, chisel-like beak with his staff. Then he prodded the great carrion-eater again for good measure as Adrienne staggered around it. The guide began to laugh.

"What the hell's so funny?" she demanded.

"If there's an intrusion vehicle back there," Vickers said, "which there probably isn't or these sheep wouldn't be here now, maybe I'll send everybody home without me. That way I don't have to explain to Stern what went wrong."

"That's a hell of a joke!" Adrienne snapped.

"Who's joking?"

Because of the huge quantity of food, the scavengers were feeding without much squabbling. The three humans slipped through the mass, challenged only by the long-necked pterosaur. Fragile despite its size, the great gliding creature defended its personal space with an intensity that was its only road to survival. Met with equal force, it backed away of necessity.

Dieter Jost lay under the gun tower, slightly protected by the legs and cross-braces. He was mumbling in German and his eyes did not focus. Vickers took the pilot's weight to set him by the ladder. Mears hopped down and began shrieking at Adrienne Salmes, "God damn you, your crazy husband took the time machine back without us, you bitch!"

Vickers straightened and slapped the contractor with a blow that released all the frustrations that

had been building. Mears stumbled against the tower, turned back with his fists bunched, and stopped. The blonde woman's knife was almost touching his ribs.

"Where's Steve?" the guide asked loudly. He was massaging his right palm with his left as if working a piece of clay between them.

Miss McPherson jumped to the ground. In the darkness the tower had drawn them. Since both boxes of 12.7 mm ammunition had been sluiced out into the night, it was obviously irrational to stay on a platform that would not reach a tyrannosaur's knee . . . but human reason is in short supply in a darkened forest. "One of the dinosaurs killed him," the older woman blurted. "We, we tried to keep Mr. Jost safe with us, but we ran out of bullets and, and, the last hour has been—"

Brewer had a cut above his right eyebrow. He looked shell-shocked but not on the edge of hysteria as his three companions were. "When it was light enough to search," he said, "I got your ammo out. I thought it might work in his—" he gestured toward Dieter beneath him—"rifle. Close but no cigar." The meat packer's fingers traced the line which a piece of bursting cartridge case had drawn across his scalp.

"Well, we put the fear of God into'em," Mears asserted sullenly. "They've been afraid to come close even though we're out of ammo now. But how d'we get *out* of here, I want to know!"

"We don't," Vickers said flatly. "If the intrusion vehicle's gone, we are well and truly screwed. Because there's never yet been an insertion within a hundred years of another insertion. But we've got a closer problem than that, because—"

The tyrannosaur drowned all other sounds with its roar.

Vickers stepped into the nearer of the ponies without changing expression. The engine caught when he pushed the starter. "Adrienne," he said, "get the rest of them down to the slough—Don and Dieter in the pony. Fast. If I don't come back, you're on your own."

Adrienne jumped in front of the vehicle. "We'll both go."

"God damn it, *move!*" the guide shouted. "We don't have time!"

"We don't know which of us it's tracking!" the woman shouted back. "I've got to come along!"

Vickers nodded curtly. "Brewer," he called over his shoulder, "get everybody else out of here before a pack of carnosaurs arrives and you're in the middle of it." He engaged the pony's torque converter while the blonde woman was barely over the side. As they spun out southward from the camp, the guide shouted, "Don't leave Don and Dieter behind, or so help me—"

"How fast can it charge?" Adrienne asked as they bounced over a root to avoid a tangle of berry bushes.

"Fast," Vickers said bluntly. "I figure if we can reach the sauropods we killed the other day, we've got a chance, though."

They were jouncing too badly for Adrienne to stay in a seat. She squatted behind Vickers and hung onto the sides. "If you think the meat's going to draw it off, won't it stop in the camp?" she asked.

"Not that," said the guide, slamming over the tiller to skirt a ravine jeweled with flecks of quartz. "I'm betting there'll be gorgosaurs there by now, feeding. That's how we'd have gotten carnosaur heads for the other gunners, you see. The best chance I can see is half a dozen gorgosaurs'll take care of even *our* problem."

"They'll take care of us too, won't they?" the woman objected.

"Got a better idea?"

The smell of the rotting corpses would have guided them the last quarter mile even without the marker. The tyrannosaur's own kill had been several days riper, but the sheer mass of the five titanosaurs together more than equalled the effect. The nearest of the bodies lay with its spine toward the approaching pony in a shaft of sunlight through the browsed-away top cover. Vickers throttled back with a curse. "If there's nothing here," he said, "then we may as well bend over and kiss our asses goo—"

A carnosaur raised its gory head over the carrion. It had been buried to its withers in the sauropod's chest, bolting bucket-loads of lung tissue. Its original color would have been in doubt had not a second killer stalked into sight. The gorgosaurs wore black stripes over fields of dirty sand color, and their tongues were as red as their bloody teeth. Each of the pair was as heavy as a large automobile, and they were as viciously lethal as leopards, pound for pound.

"All right," Vickers said quietly. He steered to the side of the waiting pair, giving the diesel a little more fuel. Three more gorgosaurs strode watchfully out of the forest. They were in an arc facing the pony. The nearest of them was only thirty feet away. Their breath rasped like leather pistons. The guide slowed again, almost to a stop. He swung the tiller away.

One of the gorgosaurs snarled and charged. Both humans shouted, but the killer's target was the tyrannosaur that burst out of the forest behind the pony. Vickers rolled the throttle wide open, sending the vehicle between two of the lesser carnivores. In-

stead of snapping or bluffing, the tyrannosaur strode through the gorgosaur that had tried to meet it. The striped carnosaur spun to the ground with its legs flailing. Pine straw sprayed as it hit.

"It's still coming!" Adrienne warned. Vickers hunched as if that could coax more speed out of the little engine. The four gorgosaurs still able to run had scattered to either side. The fifth thrashed on the ground, its back broken by an impact the tyrannosaur had scarcely noted. At another time the pack might have faced down their single opponent. Now the wounded tyrannosaur was infuriated beyond questions of challenge and territory.

"Henry, the river," the woman said. Vickers did not change direction, running parallel to the unseen bank. "Henry," she said again, trying to steady herself close to his ear because she did not want to shout, not for this, "we've done everything else we could. We have to try this."

A branch lashed Vickers across the face. His tears streamed across the red brand it left on his cheek. He turned as abruptly as the pony's narrow axles allowed. They plunged to the right, over the ridgeline and into the thick-set younger trees that bordered the water. Then they were through that belt, both of them bleeding from the whipping branches. Reeds and mud were roostering up from all four wheels. The pony's aluminum belly began to lift. Their speed dropped as the treads started to act as paddles automatically.

"Oh dear God, he's stopping, he's stopping," Adrienne whimpered. Vickers looked over his shoulder. There was nothing to dodge now that they were afloat, only the mile of haze and water that they would never manage to cross. The tyrannosaur had paused where the pines gave way to reeds, laterite

soil to mud. It stood splay-legged, turning first one eye, then the other, to the escaping humans. The bloody sun jeweled its pupils.

"If he doesn't follow—" Vickers said.

The tyrannosaur stepped forward inexorably. The muddy water slapped as the feet slashed through it. Then the narrow keel of the breastbone cut the water as well. The tyrannosaur's back sank to a line of knobs on the surface, kinking horizontally as the hind legs thrust the beast toward its prey. The carnosaur moved much more quickly in the water than did the vehicle it pursued. The beast was fifty yards away, now, and there was no way to evade it.

They were far enough out into the stream that Vickers could see the other pony winking on the bank a half mile distant. Brewer had managed to get them out of the charnel house they had made of the camp, at least. "Give me your knife," Vickers said. Twenty feet away, the ruby eye of the carnosaur glazed and cleared as its nicitating membrane wiped away the spray.

"Get your own damned knife!" Adrienne said. She half-rose, estimating that if she jumped straight over the stern she would not overset the pony.

Vickers saw the water beneath them darken, blacken. The pony quivered. There was no wake, but the tons of death slanting up from beneath raised a slick on the surface. They were still above the crocodile's vast haunches when its teeth closed on the tyrannosaur.

The suction of the tyrannosaur going under halted the pony as if it had struck a wall. Then the water rose and slapped them forward. Vickers' hand kept Adrienne from pitching out an instant after she had lost the need to do so. They drew away from the battle in the silt-golden water, fifty yards, one hun-

dred. Vickers cut off the engine. "The current'll take us to the others," he explained. "And without the paddles we won't attract as much attention."

Adrienne was trying to resheathe her knife. Finally she held the leather with one hand and slipped the knife in with her fingers on the blade as if threading a needle. She looked at Vickers. "I didn't think that would work," she said. "Or it would work a minute after we were . . . gone."

The guide managed to laugh. "Might still happen," he said, nodding at the disturbed water. "Offhand, though, I'd say the 'largest land predator of all time' just met something bigger." He sobered. "God, I hope we don't meet its mate. I don't want to drown. I really don't."

Water spewed skyward near the other pony. At first Vickers thought one of the clients had managed to detonate a grenade and blow them all to hell. "My God," Adrienne whispered. "You said they couldn't. . . ."

At the distance they were from it, only the gross lines of the intrusion vehicle could be identified. A pair of machineguns had been welded onto the frame, and there appeared to be a considerable party of uniformed men aboard. "I don't understand it either," Vickers said, "but I know where to ask." He reached for the starter.

Adrienne caught his arm. He looked back in surprise. "If it was safer to drift with the current before, it's still safer," she said. She pointed at the subsiding froth from which the tyrannosaur had never reemerged. "We're halfway already. And besides, it gives us some time—" she put her hand on Vickers' shoulder—"for what I had in mind last night at the campfire."

"They're watching us with binoculars!" the guide

sputtered, trying to break away from the kiss.

"They can all sit in a circle and play with themselves," the blonde woman said. "We've earned this."

After a moment, Vickers began to respond.

The secretary wore a uniform and a pistol. When he nodded, Vickers opened the door. Stern sat at the metal desk. Dr. Galil was to his right and the only other occupant of the room. Vickers sat gingerly on one of the two empty chairs.

"I'm not going to debrief you," Stern said. "Others have done that. Rather, I am going to tell you certain things. They are confidential. Utterly confidential. You understand that."

"Yes," Vickers said. Stern's office was not in the Ministry of Cultur and Tourism; but then, Vickers had never expected that it would be.

"Dr. Galil," Stern continued, and the cherubic scientist beamed like a Christmas ornament, "located the insertion party by homing on the alpha waves of one of the members of it. You, to be precise. Frankly, we were all amazed at this breakthrough; it is not a technique we would have tested if there had been any alternative available."

Vickers licked his lips. "I thought you were going to fire me," he said flatly.

"Would it bother you if we did?" Stern riposted.

"Yes." The guide paused. The fear was greater now that he had voiced it. He had slept very little during the week since the curtailed safari had returned. "It—the job . . . suits me. Even dealing with the clients, I can do it. For having the rest."

Stern nodded. Galil whispered to him, then looked back at Vickers. "We wish to experiment with this effect," Stern continued aloud. "Future

rescues—or resupplies—may depend on it. There are other reasons as well." He cleared his throat.

"There is the danger that we will not be able to consistently repeat the operation," Dr. Galil broke in. "That the person will be marooned, you see. For there must of course be a brain so that we will have a brain wave to locate. Thus we need a volunteer."

"You want a base line," Vickers said in response to what he had not been told. "You want to refine your calibration so that you can drop a man—or men—or tanks—at a precise time. And if your base line is in the Cretaceous instead of the present, you don't have the problem of closing off another block each time somebody is inserted into the future before you get the technique down pat."

Stern grew very still. "Do you volunteer?" he asked.

Vickers nodded. "Sure. Even if I thought you'd let me leave here alive if I didn't, I'd volunteer. For that. I should have thought of the—the research potential—myself. I'd have blackmailed you into sending me."

The entryway door opened unexpectedly. "I already did that, Henry," said Adrienne Salmes. "Though I wouldn't say their arms had to be twisted very hard." She stepped past Vickers and laid the small receiver on Stern's desk beside the sending unit. "I decided it was time to come in."

"You arranged this for me?" Vickers asked in amazement.

"I arranged it for us," Adrienne replied, seating herself on the empty chair. "I'm not entirely sure that I want to retire to the Cretaceous. "But—" she looked sharply at Stern—"I'm quite sure that I don't want to live in the world our friends here will shape if they do gain complete ability to manipulate

the past. At least in the Cretaceous, we know what the rules are."

Vickers stood. "Shlomo," he said shaking Dr. Galil's hand, "you haven't failed before, and I don't see you failing now. We won't be marooned. Though it might be better if we were." He turned to the man behind the desk. "Mr. Stern," he said, "you've got your volunteers. I—we—we'll get you a list of the supplies we'll need."

Adrienne touched his arm. "This will work, you know," she said. She took no notice of the others in the room. "Like the crocodile."

"Tell me in a year's time that it *has* worked," Vickers said.

And she did.

—David Drake

ON PREDICTING THE FUTURE: PROGRAMMING TOMORROW

by Frederik Pohl

"The moral is amazing... You will lose less by betting public favorites than by betting the selections of a professional."

In this, the second half of our look at ways of dealing with the future, we will turn to the past. We will speak of such great names as Theaenetus the son of Tolmides, Eupompidas the son of Dalmachus and John W. Campbell, the father of us all.

If you don't happen to remember offhand who the two Greek gentlemen were, don't feel badly. Hardly anyone does, although, as we shall see, they were close to inventing one of the best modes of forecasting, two and a half millennia ago. If you don't know who John Campbell is, though, shame on you. He was the editor of *Astounding/Analog* for more than thirty years. He brought into the field Robert A. Heinlein, A.E. Van Vogt, Lester del Rey, L. Sprague de Camp and about a million other great writers, and he was a man whom I greatly admired. And still do.

He was also a man with some surprising traits of credulity. If it were not for John Campbell the world probably would never have heard of Dianetics or Scientology, or the Hieronymus Machine or the Dean Drive. He was even so perverse as to believe, or more or less believe, in astrology. We discussed this now and then. We disagreed. As nearly as I can remember the conversations—that is to say, the monologues—they went something like this: "The trouble with you, Fred, is that you just don't believe some of the greatest scientists in history are as smart as you are. *They* believed in astrology. I'm not talking about columns in the newspapers. I'm talking about the purpose for which the science of astrology was invented: to predict events in the sky, such as the movement of planets, the occurrence of eclipses . . . and the weather. And for all of those things *it still works!*"

One of the things I admired about Campbell was that he was always willing to put his money where his mouth was. What he did on this occasion was to commission a series of astrological weather forecasts prepared by a man named Joseph Goodavage, and publish them, each month, in his magazine. I had known Goodavage slightly a few years earlier, and I watched the experiment with interest.

Was it a success? I thought not at the time. When each month's forecast came in, it was for the period when the magazine was on sale. Comparing what I saw when I looked out my window with what Goodavage said I was supposed to see did not convince me. I don't think Campbell was very delighted with its success, because he stopped running them before very long. (But I must admit that I made no systematic evaluation of the series and do not know anyone else who did.)

So a few months ago I was given a second chance to check this out. I seized it with pleasure. Joe Goodavage is still alive and well, and not long ago published a book on "astrometeorology" called *Our Threatened Planet.* According to Goodavage the winter of 1980-1981 was to have been something special: "bitterly cold . . . particularly in the Northeastern and Northwestern and border states of the USA, throughout the Canadian northwest, and especially in Europe and the Soviet Union. The Deep Freeze of 1981 will last from the time of the winter solstice of December 21, 1980, through January, February and March of 1981, more intensely so during Saturn's stationary position centering on January 25, 1981. This promises to be the most bitterly cold week of the most bitterly cold winter within living memory."*

So I followed the last few months (this is being written at the end of February) with considerable interest.

The winter season started out not badly for Goodavage. Christmas Day in the New York-New Jersey area was the coldest December 25th on record, and it stayed cold for the first week or so of January. The Pacific Northwest, however, showed no strong correlation, neither did Europe (while, for instance, Los Angeles had its *warmest* Christmas ever and was still enjoying sun-bathing weather when I got there around January 1st.) Probably the best measure of "bitter cold" is the accumulation of degree-days. As of this writing (February 25th, 1981) the New York area had accumulated 3760 degree-days for this heating season, which is about

Quoted in *The Strangest Star,* by John Gribbin, Athlone Press (London), 1980.

eight and a half per cent colder than the normal 3465 for this period. (But fluctuations of a few hundred degree days happen every year, and last week, for instance, New York City set an all-time high for date of 68°.) The whole month of February averaged 6° above normal. Unless March comes up with something very special, it will certainly not be "the most bitterly cold winter within living memory".

How about the specific "more intense" period around January 25th? There the record is unequivocal.

I have before me the New York *Sunday Times* for that date, which contains the synoptics supplied by the U.S. Weather Service.* In Europe, of the seventeen cities reporting, the lowest was from Moscow, at 21°. In Moscow when it gets up to 21° in January they start trying on bathing suits. Only four of the seventeen European cities were below freezing, while London came in at 48° and even Stockholm made it to 39°.

In the United States 58 cities reported. Only two were below freezing: Burlington, Vermont, at 28° and Syracuse, New York, at 31°. My son, who spent four years at Syracuse University, says that practically constitutes a heat wave, and actually, there are not many January days that do not show high

* All temperatures are in Fahrenheit, because that's how the *Times* reports them. Temperatures for European cities are approximately mid-day, which means they are probably the highs for the day, or within a degree or two. For U.S. cities the *Times* reports both highs and lows. Temperatures given in the text are all highs for the day. The *Times* also gives the lows for the day for U.S. cities; lowest low reported was Portland, Maine, with 11°. As the report was issued on the 25th, the temperatures are actually for the day before, i.e., January 24th, 1981.

temperatures somewhere in the lower 48 which are not only below freezing but often below zero. At about that time a few years ago, for my sins, I happened to have to go to Minneapolis and Eau Claire and for the first time in my life experienced a temperature of -40°. It is not an experience I hope to repeat.

When I was a weatherman for the Air Force we had a way of describing this sort of forecast. We said, "Aw, hell, we blew it again."

John Campbell's contention about astrometeorology represents a widely held belief, which can be generalized like this: "If everybody that mattered in the whole world believed something to be true, there had to be *something* to it." That's a plausible statement. But it isn't a true one: everybody that mattered once believed the world to be flat, and it isn't.

Moreover, let's think for a moment about the *usefulness* of forecasts in general, and weather forecasting in particular. My own belief system does not extend to astrology in any form, but I do confess to a certain amount of faith in the Bjerknes air-mass hypothesis and satellite photography. To some extent, by some means, the weather *can* be predicted. (I believe.)

Sometimes that can be quite useful. If you are going to try to bomb Berlin from a base in England without instruments, you want to know if you're going to be able to see the city when you get over it; so a forecast of cloud cover is very fine to have. But there are times when a prediction looks as though it should be useful, but isn't. A fine example of that came along five years ago in New Jersey. An August hurricane was coming up the coast. Hurricane

tracks are notoriously unreliable, but by about twelve hours before ETA the weather trackers could see there was some worrisome chance of its coming close enough inshore to produce massive and damaging tides along the New Jersey coast (most of which is sandspits that used to come and go with the ocean's whim until human beings began building on them).

In the 1976 (and present) state of the art, the best the forecasters could do was to say there was "a chance". Let's say they could do better. Let's say they could have said twelve hours, ahead, absolutely and without question, that the hurricane would strike the sand bars, tides would be six feet above normal, and all persons and property thereon would be a grave risk. They could have saved many lives and much damage, right?

Wrong. They probably could not have saved a single life, and might easily have cost a great many. At that time of year the New Jersey beaches are full of vacationers. They get there from the mainland on a rather small number of bridges. They get back the same way, but not without severe traffic james and much delay in high-traffic periods. If there had been an emergency evacuation attempt it is impossible that most of them could have got away. A great many would have been trapped in the most vulnerable places of all, namely the bridges and approaches. There would certainly have been uncontrollable panic and consequently much loss of life and property.

I will concede that that is a special case. But all of weather forecasting is a special case. It is canonically unlike most crystal-ball gazing. The reason for this is that it rests more on "discovery" (remember, we discussed this in the last column) than on prediction.

Let me give you an analogy about the difference between "discovery" and "prediction" in case you missed the last installment. Suppose you're hiking along a railroad track and, becoming fatigued, decide to take a nap on the ties. Prudently you put your ear to the rail. You hear a thrumming, so you decide to nap elsewhere.

Have you discovered that a train will be coming? No. You've discovered that a train *is* coming. The only uncertainty is when it will get there, or whether it will switch off to some other track.

Most of weather forecasting is quite like that, and quite unlike the purer kinds of prediction we're dealing with here. In the area of long-range prediction we call "futurology"—or "futuristics" or "future studies" or, best of all in Bertrand de Jouvenel's coinage, "futuribles"—specific, accurate and complete information about future events has severely limited value. In some cases it has none at all. The only value information about the future has is as an input in decision-making about actions in the present. (I argued this at greater length last time, in case that seems paradoxical.)

So what is really wanted is a workable way of getting advance indications that is useful. We can describe what that way might be. The methodology involved should be heuristic (i.e., a learning process); it should lead to decision-making that is normative (i.e., encourages future events we want); and it would be nice if it could make some use of the "consensual wisdom" that John Campbell shared, without locking us into universal errors.

Such workable ways exist. The name of the key to them is DELPHI.

DELPHI is a future-forecasting methodology de-

veloped largely by Norman Dalkey and Olaf Helmer for the RAND Corporation, and elaborated by them, by Thedore J. Gordon and by a good many others. It has been around for nearly twenty years, and the chances are at least fair that you've already heard of it. (If you made it to the World Science Fiction Convention in Los Angeles in 1972, for instance, Norman Dalkey performed a DELPHI there.)

DELPHI is simply a way of integrating a number of individual predictions about the future to produce a consensus. It is named after the Delphic oracle, and as a matter of fact that methodology goes back to the Greeks. The earliest precursor I have been able to find comes from the siege of Plataea in the Peloponnesian War. The Peloponnesians had surrounded Plataea with a brick wall; the Plataeans wanted to break out. The best way to do it was a surprise attack with scaling ladders, but how long should the ladders be?

The Plataeans found a methodology for deciding that:

> The idea was suggested by Theaenetus the son of Tolmides, a diviner, and Eupompidas the son of Dalmachus, one of their generals.... They first made ladders equal in length to the height of the enemy's wall, which they calculated by the help of the layers of brick on the side facing the town, at a place where the wall had accidentally not been plastered. A great many counted at once and, although some might make mistakes, the calculation would be oftener right than wrong; for they repeated the process again and again.*

* Thucydides, *The Peloponnesian War*, translated by Benjamin Jowett, Bantam Books, p. 166.

What the Plataeans did was to get a panel of the best available experts and systematically pool their guesses; and that's what the RAND Corporation did with Delphi in 1964. RAND circulated a questionnaire to 82 respondents—12 economists, 20 engineers, 14 mathematicians and logicians, one military officer, 4 operations analysts, 17 physical scientists, 9 social scientists and 5 writers. They asked each of the respondents "to list below major inventions and scientific breakthroughs in areas of special concern to you which you regard as both urgently needed and feasible within the next 50 years."* The resulting list was tabulated and recirculated to the respondents, who were then asked to estimate the time when the breakthrough was likely to occur. These results were again recirculated, to the same panel, and the tabulated results formed the report.

Obviously the idea of getting a consensus of experts is not new. Two questions arise immediately: 1, is the RAND methodology any better than any of a million others? 2, is there any reason to believe that a consensus is any better than a smart person's individual guess?

The RAND people asked themselves those same questions. What is wrong with most attempts at getting a consensus is that there is a herd effect in problem-solving groups: the smartest, or most powerful, person in the group says what he thinks may be so and few subordinates dare disagree. DELPHI deals with that by keeping the respondents anonymous and physically separated; the best way to conduct a DELPHI is by mail or computer

Report on a Long-Range Forecasting Study, T. J. Gordon and Olaf Helmer, Document P-2982, the RAND Corporation, 1964.

linkage. Another source of error is in trying to "average" opinions. DELPHI deals with that by asking for quantitative answers—"What probability would you assign to this event?" or "In what year do you expect it to happen?"—so that simple arithmetic is all that is needed. DELPHI is not wholly free from sources of error. For one thing, much rests on the judgment of the people who compile the questionnaires and formulate the questions. But it clearly reduces some of the principal distortions of group decision-making.

So then the second question: Is a group opinion any more valuable than yours or mine?

Obviously most of us are inclined to think so, or at least to hope so, because that is how democratic governments are run. But the DELPHI people ran an experiment to check it out. Using the same procedures as for forecasting, they asked a panel about certain facts which are verifiable, though not likely to be known to most people. The questions were like "How many board feet of lumber did Oregon produce in 1954?" or "If the name 'Martin' appears on the middle page of the Los Angeles phone book, how many pages before or after the middle will it appear in the Philadelphia book?" The results were pleasing. The median answers of the group were more accurate, over the whole list of questions, than the answers of any individual within the group.

But there's more. While I was first getting involved in formal future studies I came across a curious confirmation of the validity of group prediction, from a source wholly removed from DELPHI or think-tanks in general. It comes from horse-racing.

As any horse bettor knows, most horse-players lose. If you listen to the talk around the finish line at

any track you will come to believe they really deserve to, because many bettors bet hunches, or their oldest child's age, or dreams, or tips. (When I worked, briefly, at a track twenty years ago the employer who won most consistently revealed his secret to me: Every day in the daily double he bet his badge number.)

Yet a study by Burton P. Fabricand, Ph.D., a nuclear physicist interested in horse-racing only as a hobby, shows that the stupid money is astonishingly smart. He studied the parimutuel odds of more than 20,000 individual races around the United States and contrasted the "public favorites" (i.e., the horse in each race that went off at lowest odds, showing the most bets placed on it) against the selections of the professional handicappers. The public was more often right than any handicapper!*

The moral is amazing. Not only is a group consensus more reliable than the individual estimates of any full-time professional, but it is so even when a great many members of the group, if not a majority of them, are obviously poorly informed. You can't be sure of winning by betting "public favorites"—the bite the track and tax authorities take out of parimutuel wagerings is hard to overcome. But you will lose less by betting "public favorites" than by betting the selections of a professional.

Taken all in all, then, DELPHI has a lot going for it. Its methodology is simple enough to be practical. It has eliminated some known sources of error. And many of its procedures are supported by independent checks.

Horse Sense, by Burton P. Fabricand, Ph.D., David McKay Co., Inc.

The only criticism one might really make of it is that, considered as a mechanism for making accurate statements about future events, it is not very successful. Seventeen years have passed since the first major report was issued. There have been some hits and some misses; without attempting a statistical analysis it is difficult to give it a batting average. But one thing seems clear. Its greatest accuracy of prediction was in areas like the space program—which is to say, in areas where the projects that would produce the predicted events were often already under way when the DELPHI was run.

But be of good cheer! Remember that accurate and complete forecasts of the future are worth very little (for reasons discussed in the last column), and that what we really want is the sort of information about the future that can guide us in action in the present. And there DELPHI has great treasures for us.

For one thing, you can't get the right answers unless you ask the right questions. At formulating the right questions DELPHI is superb. In each stage of the cascade of questionnaires the respondents are invited to comment on or object to the questions, and the responses lead to reformulation of the questions.

In the 1964 series one question had to do with the ultimate outlook for computers. In the first round the request was to predict the date for "Computing machines becoming the most significant intelligence on Earth." On the basis of respondent remarks, this was changed to "Availability of a machine which comprehends standard IQ tests and scores above 150", and finally amended by adding a parenthesis: " . . . where 'comprehend' is to be interpreted behavioristically as the ability to respond to questions

printed in English and possibly accompanied by diagrams." Note the sharpening that has occurred. An iffy and essentially meaningless question has been clarified and quantified. A question that really cannot be answered has been replaced by one that can, at least in principle.

All by itself, that feature would very nearly justify using DELPHI. But there's more. In a few DELPHIs a special feature is added. After predicting what *will* occur, the panel is asked to evaluate proposed measures to encourage the good events and prevent the bad ones. For example, in the 1964 project the respondents were offered a list of 42 proposed measures for averting catastrophic war. Each measure was to be evaluated in three ways, as to desirability, effectiveness and probability of implementation; and in each case the rating was on a three-valued scale: high, medium and low.

Perhaps it is not surprising that it turned out that a number of methods that were strongly agreed to be effective were not likely to happen, and that some measures that were considered both effective and probable were considered, for other reasons, not very desirable.

That's as far as the RAND's DELPHI went. But it's possible to go farther.

Let's sketch out an extension of DELPHI, which we will call PHI-DELPH. Our study has indicated a high probability of something very undesirable—an all-out nuclear war. We have identified a large number of measures to avert it, and evaluated them. Unfortunately, it turns out that the measures that seem probably effective also seem either unlikely, or undesirable.

The next step is to look into the factors which make them undesirable. Are there ways of averting

the undesirable aspects, or at least ameliorating them? Can we make a quantitative assessment, and perhaps show that the undesirable "bad" is overbalanced by the "good" of the results expected? As, for example, the "bad" of being forced to stop for a traffic light is balanced by the "good" of reducing accidents.

And as to the unlikeliness of a given measure, is it possible to find out what causes it to be unlikely, and to find ways around the roadblocks? This is fairly standard practice in some sorts of industry, where flowpath or relevance-tree analysis is used to locate bottlenecks and find ways to avoid them.

It is not likely that PHI-DELPH or any other formal methodology will solve all real-world problems. Some social problems are perhaps insoluble, as long as there is no unanimity on certain goals, or even what is "good" or "bad" in certain contexts. And those are probably among the most troubling problems of all.

Even if the methodology is valid, there are difficulties in converting theoretical practices to the real world. I once ran a simplified PHI-DELPH for a large industrial association. It turned out to be hard to get even the early inputs in some cases. One response on a question was "If I answer that I'll get fired"; on another question, a respondent said, "That information has cost my company $6,000,000 so far to get." An early DELPHI run by a think-tank involved the defense industry; when higher-ups heard of it they forbade their officers to participate because their answers would reveal too much of military capabilities. And, as the solutions to most major social problems are at least in part political, there is the obstacle of the political process to contend with before any substantial measures can be implemented.

But at least it is a start. . . .

It is even possible that formal methodologies can be invented to resolve some of the disagreements. Let me mention a suggestion of my own. Some years ago I was asked to keynote the American Astronautical Society's annual Goddard Lecture series in Washington. I was flattered to be invited, and besides John Campbell was one of the other speakers, so I decided to spread myself. The theme of that year's series was "Technology and Social Progress: Conflict or Synergy?" and I decided to tackle the question of just what "progress" was, anyway. How do you identify what is "progressive" when you have it?

So I developed a diagnosis of "progress" for the occasion:

Progress is a measure of increasing options, for individuals or collectives.

A development which increases the choices open to a government, a corporation, a trade union, a family or a person constitutes progress. Any development which decreases available choices is negative progress. And the amount of progress can be quantified, albeit crudely, by measuring the number and magnitude of the options.

Under this measure, some recent "progressive" technological developments would include the space program, microchips and the Pill. "Negative progressive" developments would include the arms race, first and foremost, as well as such less obvious developments as major-organ transplant surgery.

Of course, there is room for argument over these points. In the unobvious case of major-organ transplant surgery, my thesis is that it represents such a vast allocation of scarce resources that it actually reduces the resources, and thus the options, available

to persons needing more ordinary medical care. (I am not alone in this position, of course; a number of major institutions have decided to terminate their transplant programs on exactly those grounds.) But value judgments do come into it, because the arguments I make against the major transplants might well be adapted for use against the space program for someone with a different set of values. I don't believe that quantifying what is "good" or "bad" in this way would end arguments.

But I do think it would help us to know what we are arguing about.

The basic law of future studies (so I think, anyway) is the statement of Dennis Gabor, inventor of holography and one of the founding fathers of future studies:

"The future cannot be predicted. It can only be invented."

All I would add to that is that even if the future could be predicted, the results would hardly be worth while.

But inventing the future is about an important an activity as the human race can undertake. To invent a future worth having, we need to know the options, prospects and problems the future may hold—that is, the "futuribles"—and we need to know them with more precision and detail than we can reliably expect from intuition alone. We need to learn about consequences, side-effects and fallout before making a decision to a course of action that seems attractive in itself, but carries concealed flaws.

That's what DELPHI and its modifications and accessories can give us—and, my, how useful that is going to be!

—Frederik Pohl

SACRIFICE

by David Langford

It was a perfect vengeance; a playwright had written it for him.

This was a thing which had happened before—

Barbaric in red and blue, black and gold, the procession moved solemnly along the ancient street. A sheen of sweat coated the walkers' faces and those of the watchers on either side; ritual pomp and regalia did not allow for the vagaries of summer. In a little while the ceremony would begin: Encaenia, the presentation of honorary degrees at the University of Oxford.

The heat was intolerable and the crowd more so. Deverell looked up in alarm as his mother's hand shook and slackened its grip on his. He felt the hot darkness filling her eyes, and whimpered. In the alien world of this big city she was his one hold on normality; and she was swaying; and he was only eleven. The mixed crowd of tourists, students and

casual passers-by in Broad Street watched the last members of Congregation filing into the Sheldonian Theatre. Ripples of dissolution began to spread up and down the street. And Deverell's mother staggered, and fell forward in a faint. A reflexive twisting landed her on one side, no more than bruised; she lay there in the pervasive heat, red dress bright like blood. Huge people bent around her, a grey man with a camera, a young Oriental with dark eyes —

—and a light went out in Deverell's mind. It had never been like this before! When his mother drifted into sleep, it was a calm motion, usually drawing him gently along: but this! A vortex, a whirlpool, dizzy blindness and oblivion. He screamed in fear. The confused mutter of strangers' thoughts whispered and babbled on every side, belying this city's architecture of calm.

As though a film were playing in reverse, the dissipation of a crowd became a concentration. Something like this had happened before, at school, once. Fear! Panic! The broadcast struck below the level of human reason, stirring the dust of ancient logic: *This fears; this is weak; this may be killed.* And even if they pressed in from sympathy, they still pressed in. With the uncontrolled feedback of fear from Deverell's strange mind, the crowd was making the transition from crowd to mob. A self-controlled child (appalling little wet was how one uncle had put it), Deverell had never provoked such a thing before —in public. There had been a time at school; the heat as dreadful as now; a mob of children converging; he defended himself.

* * *

Under a shaky control, he brandished the weapon he had used against bullies at that school, while there were still bullies at that school. Projection, now: not his fear, he felt fiercely, but theirs. *Go away!* Above the confused crowd-sounds his mind screamed in overriding power, and the film reversed once more, a widening circle of panic spreading through Broad Street from the still centre of Deverell and his fallen mother. Phobos and Deimos circled tightly from mind to mind, fear and panicpanicpanic—until Deverell himself was sucked into the whirling dark, as though fear should fear itself. . .

When all had settled, three people lay dead. Blood oozed and clotted upon the hot, dusty pavement. No one knew why they had behaved so: save for a very few.

This was a thing which had happened before, in other forms and places; and in accordance with precedent, Deverell Marron was taken to a place of classified location. His parents were consoled bleakly, with the thought of their son's power and importance (they were also questioned keenly about the concealment of such a potent Talent). Almost, the matter died away there, for two of the dead were of no account.

The third was the son of Iwura John.

Thus the placement of dominoes, falling click click click click to a sharpened sword and a green jade block—

There are never enough photographs of the dead, thought Iwura John. The picture of Sui, so carefully placed amid appropriate symbols in the tiny shrine, was badly posed despite being the best to hand. He

looked more closely into the smiling face: *Did my son really look like that?* Iwura had had plans for young Sui, in accordance with the aged nepotic traditions of the West, but now there was an emptiness. What remained? He would set assassins to destroy this Marron. He would gather a band of friends and make the execution himself. . . . He could do nothing. His wealth had made no impression on a government which did not stamp out murderous Talents, but instead whisked them off to be trained in a place of classified location (of which he only knew that it was not on Earth. Or, of course, Mars).

Have patience, Sui. I will preserve your honour and that of the ancestors—Fitting words, to be sure, but even in this private place Iwura found them too embarrassing to speak aloud. Sometimes he felt that he had grown away from his father's culture, he who was only half of the blood.

And the killer a mere boy! A child! Iwura tried hard to visualize Sui at eleven, and failed: the only image he could call up, and that badly posed, was the one on the shrine, his son in academic dress just after entering Oxford.

Can I kill a boy? Another image took shape: Sui at the age of nineteen, face contorted in alien terror, screaming and running until he fell and the feet of the Talent-lashed mob crushed his skull, lying there in blood on the ground, never to be a director of Iwura Electronics, never to—

Iwura John stood motionless in the great office, and told whatever remained of Sui to rest assured: there would be no forgiveness. It seemed the thing to do.

As though in reply, something moved in the picture; it was the reflection of his own dark eyes.

* * *

"You will not," they said to young Deverell. "You will not, because we have more power than you." Invisible fingers poked reprovingly at him; the adepts of the Place moved in torchlit processions down the corridors of his brain, tut-tutting at what they found. They had more power than he; he submitted to conditioning, training, conditioning.

"You will not," they said later to an older Marron. "You will not, because your conditioning compels you to act as ordered save in the last extremity. Also because of your own conscience, upon which, despite the mitigations, there should still be a weight." The first point he accepted; the second he silently doubted. Training continued.

"You will not," they said to Graduate Talent Marron, "for the reasons you know and for one more: the survival of yourself and this Place. You have the power and must wield it lightly; you will be resented and must not resent." The clear voice rang in his skull for many hours. "You will not—" except in extremity, of course, he thought, clinging to the last wistful hopes of power and superiority—

"You will not harm any man."

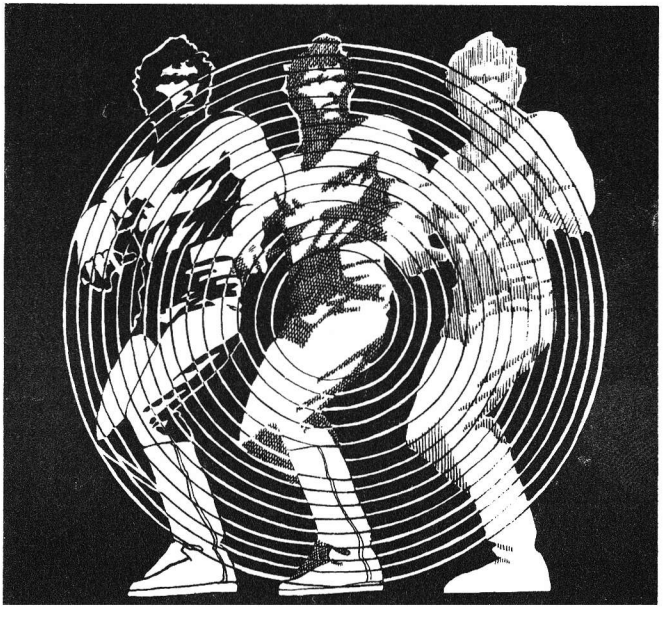
Marron shook his head: jetlag! From a classified location to the North Sahara spaceport; thence via plane and train, along a route which only his mail had followed for the past seven years. He was going to Banbury in England. Pushing back dark hair, he yawned and shivered. He was going home.

Seven years: training, discipline, the development of talents to the limit, coupled with ruthless conditioning which was intended to make misuse most disagreeable. And always there had been the hazy memory of a hot and fearful day in Oxford. He would see his parents again; he could relearn the

ways of the world before being called to duty. It was, he thought, a calculated irony that he should be assigned to Riot Control.

In London he soaked up the almost forgotten sensation of crowds. Their wash and murmur could now be screened off by an act of will; or he could filter out a single stream of thoughts. Not far away, a thief wrenched a woman's handbag from her and slid off. Outraged (such things did not happen at the Place), Marron yanked the bag away with a tiny effort of mind, and restored it to the bewildered woman. Then he frowned. His mental censors accepted this altruism as in the line of duty, it seemed; but such small-scale operation was discouraged; an operative should concentrate on broader trends... Where was the Underground?

They were waiting for him at the Circle Line station. In two excited minds, his own image glowed



back at him as though from a mirror; startled, he probed to sense a plan of action:

image of a man's back / warm metal-and-glass in sweating fingers / soft anticipated feel of the needle thrust through clothing into flesh / muscles tense in anticipation of a limp weight / a large sum of money / a woman / image of waiting car —

It seemed that someone wanted him: but he had a train to catch. There was a dictum of the Place which emphasized the importance of not using spectacular Talents except in cases of definite necessity. There was also a less emphasized corollary: in such cases, it was important that the Talent be used without hesitation. Accordingly, probing ahead into the Tube station, he 'ported—not into an empty space to which heads might turn, but straight into a crowd where his appearance merely provoked blinks, jostles and curses. These, with the sulphurous underground stench, combined to give him a powerfully nostalgic recollection of travelling by Underground long, long ago. —But why should anyone want him kidnapped? he asked himself in the carriage as it lurched to Paddington. There had been no information in the intending kidnappers' minds: someone had handed on a contract. Mysterious: but no more unfamiliar than almost everything else about the world of his birth. He concentrated on recalling the train he must catch.

Mars was a useless world: discovered, analyzed, abandoned. Nobody wanted it, and therefore it had come cheaply; the price was negligible compared with the upkeep.

A little older, a little more shrunken, Iwura sat hunched at his wide desk at the edge of the old Colony dome, a geodesic pleasure-dome which surprised

Iwura's infrequent visitors with its rich austerity. Like certain wealthy men of past centuries, he had found it convenient to retreat into the wilderness; and on Earth, the wildernesses were too crowded and too expensive.

He reached down absently to stroke the small dog Mien.

Above, the dark-blue sky was visible through high, clear panels. A tiny moon, whose name he forgot, could be seen some way off the zenith. Below, the little world tugged with pleasing gentleness and deference at Iwura's body. And to one side, the shrine remained, the photograph unfaded but glazed with layers of time, unreal, as though torn from a Victorian album.

Have patience, Sui, thought Iwura with the old embarrassment at talking to a dead image. Foolish, foolish! But the taking of Marron was unconscionably delayed. They were all incompetents . . . earth-pigs. A better quality of criminal must be procured. The instructions had been given. Iwura knew the value of multiple and devious approach. Of the subtleties he cherished as a racial gift, he had truly mastered only those of finance, where labyrinthine paths had led him to seventeen billion yen. Now if only his great revenge were a commercial venture, he would need none of these hirelings. . .

"Impossible!" they had said. "The psionic field is not electromagnetic, nor gravitic, nor yet related to either the strong or the weak nuclear forces. Only as an imaginary solution in the unified-field equations could the concept be even considered. The field *cannot* be blocked artificially."

If Marron were to be held once caught, the impossible was required. This was where Iwura had hopes: with the aura of seventeen billion yen about

him as surely as the psi-field surrounded Marron, he began to pull imperceptible strings. Or, more accurately, to adjust sluices of R&D funding: so that in research centres quite unaware of Iwura Electronics' influence, his project profited at the expense of others of more or less worth. The Scrambler project.

He was pacing again, the dog snuffling at his heels, the reek of a pine-scented joss-stick wafting about him. These thoughts were too well-worn. Iwura left the room.

He walked in the garden, a place of subtle and gorgeous harmony; so he had been told by experts. The effect still pleased him vaguely, after some years... Years! Sui had been dead now for years, and Marron lived. Could a grief last so long? He could not pierce the veil of habit to decide whether the grief or the hatred were still genuine. If either left him now, there would be a hollowness: and what would he do?

They came again and again, never to kill but to catch. They struck from cars and once from a copter; they lay in wait as Marron walked in darkness; and never once did they know *why*.

Common factors, thought Marron, picking his way through the New York wreckage where earlier in the day a food riot had raged. *Anaesthetic guns, sleep gas, rubber blackjacks; and never any hatred in their minds. They do their job.*

His now-automatic probe flicked efficiently across everyone who ventured near him in the streets. The violation of privacy involved might be frowned on in the Place, but to the whispers of conditioning Marron replied that here was a case of definite necessity. He was coming to appreciate the

double reason for the rule: to touch the minds of a hundred people in a day was a sure route to nightmare. He was learning, he thought, to dip gently (not too deep) into the soul: even so there came the occasional horror of a twisted nerve, a subconscious eruption . . .

Warning! Warning! He tensed and stepped up the search-rate. In windows, high up—he reached out to crush the weapon out of shape. Its owner was horrified, but— Another! and another! Ten of them, no, twelve. Hesitation. *You will not.* A dart struck him; he had been careless, he had not the experience to handle this multiple attack—definite necessity.

He 'ported over three thousand miles even as he collapsed, and arrived to fall unconscious in the place most familiar to him on all Earth: his old bedroom in his parents' house in Banbury.

He had never 'ported so far before. It took him a week to recover; but later on he came to think of it as a breakthrough in control. The tk abilities developed, if at all, long after the more common telepathy complex: but in emergency they could be vast. There was a story of an adept who had held up half a mountain when a landslide threatened. It broke his mind, of course. . .

Time passed.

Iwura John looked sadly at the bonsai, which was thriving. A present from an Earthside relative, it had been eighty years in the growing—the stunting; now Mars gravity was stimulating it to new efforts. *The world's tallest bonsai,* he thought ruefully. It seemed that the same stimulant effect was working on his wealth: in this last year, despite the huge outpourings on what science considered to be useless re-

search, the seventeen billions had multiplied with quiet incest to nineteen.

For four months now, the campaign against Marron had ebbed to the lowest level since his arrival from that classified location. Iwura had realized belatedly that the continual harassment was training Marron into a formidable fighter, and he had no wish for the man to become too adept. Since the encouraging reports leaked from the Geneva research centre, he had decided it was time to play the waiting game, to exercise a measure of restraint and cunning which he hoped might be called subtlety.

Plans had been made for Marron. It must be execution, of course, in an appropriately traditional fashion. . . Iwura had toyed with the equally traditional notion of torture, but: *I couldn't stomach that,* he admitted. This way was better. His man Keung (who supposedly possessed the samurai blood which Iwura envied) polished daily the heavy ceremonial sword. There would be a block as well, moulded to support Marron's neck and carved of the finest green jade. On one side would be the raised phonetic character representing the name of Sui: of course. Iwura could not quite recall what the pictogram looked like. As for the material . . . there was yellow jade, brown and white: but green, in Iwura's mind, was the color that jade should be.

Meanwhile, although the dome's systems circulated exceptionally clean and filtered air, the shrine of Sui had become very faintly filmed with dust.

The antique teleprinter began to stutter. It was another affectation of Iwura's: a fine absurdity, when the messages crossed space on the back of modulated laser photons.

SCRAMBLER FEASIBLE. ENGINEERING WORK BEGUN. PATENTS ARRANGED IN NAME IWURA ELECTRONICS. FULL REPORT TO FOLLOW. TANNENWALD: GENEVA: ENDIT.

Of course it had not been impossible. Iwura touched a senseplate and ordered a glass of old brandy. It was uncharacteristic; and he did not especially like brandy; but this was an occasion. Sipping delicately at the drink, he pushed aside the tapes recording failed attempts upon Marron. A phrase from somewhere came to mind: with careful archaism he thought, *I have the jesses for you now.*

Sometimes Marron thought of himself as like a TV star: all-powerful upon the public stage, and elsewhere nothing. Except that even on his stage he must remain anonymous. He held the forces from underneath space, energies which not even their users could comprehend—and the locks upon his mind would only allow their use in the line of duty or in the emergencies which were now so rare. But once or twice a month he left for some deserted spot, and, squatting amid rubble and ruins, indulged in furtive self-hypnosis. *That fragment of brick is my enemy,* he thought fiercely. *That brick threatens my life!* . . . again and again until for an instant the tumblers of his mental locks aligned and he was permitted a blast of tk power. The brick (or the bottle, or the shard of rusty steel) would crumble (or fly to pieces, melt, or vanish into orbit like an inverted meteor): for a moment Marron would know himself to possess in reality all the power of his oldest fantasies. Sometimes.

Secutor and Retarius. In the arena they circle, Secutor strongly armed with sword and shield, Retarius struggling, or so it seems, with his clumsy net and trident. The sword flashes fearsomely; the shield parries the trident's every blow. Retarius and Secutor. Feint after feint distracts the swordsman, while Retarius holds back the net for a single deadly cast. The net. Waiting.

Intolerable heat pulsed in the air. Scotland crackled with tensions, ready for the fifth time in as many decades to ignite in something close to civil war. So Marron sifted through Glasgow's barricades with five others of his kind (but none so strong, he thought, none so experienced in hate as he), sniffing out incipient riots which must be quelled, pinpointing terrorists of the Tartan Army, buying time for the negotiators who as always, as ever, were groping blindly for a path to peace.

Hate there was, but not nearby: following the paths of tension, he walked on and abruptly recognized a stamp of mind he knew too well: dispassionate, murderous, with a particular face fixed as target: Again! Wearily he reached out to crush the inevitable weapon.

As he swept around in search of more assailants—he would not be taken off guard—a man on the street far ahead vanished. A Talent? No: he could still feel the others burning somewhere at the fringes of his mind. . . . The man had not vanished.

The man had.

There and not there? Did his left eye tell a different story from the right?

He concentrated painfully, and discovered the source of confusion: the man was there to his eyes, but had vanished from his mind. This was impossible! Some form of scrambler, blocking field . . .

now that he was concentrating, he realized that a cone of space extending far out behind the man had vanished to his perception. Blocked! Other dead zones came into being as he hesitated. The coil of blankness was all around. He could not 'port into this; about him must be dozens of men with the scramblers; each surrounded by a private cloud. On the left loomed a building—the Albany Hotel—he could sense the near wall but a dead zone began within. His mind clawed at the wall; the facade crumbled inward; a break in the barrier! What emergency forced away the conditioning, there was nothing he couldn't do. But was that a whimpering in the ruins? He stared at the dust-clouded rubble. *You will not*— Waves of nausea ran through him, and a fear unknown since another hot day in Oxford.

No one had had time to move. *In the face of the unknown, always run.* Reeling, before a shot could be fired, he 'ported to his private sanctuary, the room in Banbury from which he still reckoned all distances—

—into a numbing void. Complete cutoff. They were standing all around him. No need for the sleep gas that sprayed into his face; without his abilities, unable to relate to space and minds other than through the eyes and balance-canals upon which he had never fully relied, he fell forward into dizzy blackness.

So that is what he looks like. Iwura John compared Marron's unconscious face with that of dead Sui. *Perhaps Sui would be wearing his hair in this new style if only he were alive.* But though he conscientously thought these thoughts, he found the son he imagined to be a vague shape only: memories of the reality had faded through the years. His kimono, worn from a vague sense of what was fitting, hung

awkwardly; he tugged at its folds and thought of his comfortable boardroom suit. Then his attention returned to Marron.

Soon to be severed, that head full of death. I win the game after all.

And a moment of doubt: *do I do this merely for my son? No! no weakness. I am Fu Manchu, inscrutable and malign.*

His mirror that morning had shown too many betraying lines. There was emotion there; and worse, uncertainty.

Marron groaned slightly. Iwura remained silent as he stirred on the richly embroidered couch, propped himself up on one elbow, shook his head.

"What the hell—" He reached to the scrambler on his back.

"You cannot remove it," said Iwura gently, and watched as Marron groped at the flat box anchored to the bone of his spine. There would be no error.

"Permit me to explain. The device on your back inhibits your unnatural abilities, but will do you no harm otherwise. It is necessary that it be so close to you, since its range is less than a metre, and—"

"It *hurts*!"

"My apologies. It will not be for long." The scrambler had been built in haste, with the emphasis on durability rather than comfort. Iwura did not wish to take chances. He himself and every man in the dome wore a similar box (attached more tolerably at the belt) in case of failure.

Marron looked up, shaking. "Why?"

Iwura told him, at some length, and tried hard to savour the telling. From a hot and bloody day at Oxford to the classified Place, London, Chicago, New York, a string of other locations terminating with Glasgow—Banbury—Mars—and, incipiently, the hereafter.

"A balanced game," he said. "You with the powers of a demigod, I with nineteen billion yen. It has been a long duel, my enemy." He was pleased with the speech, which a playwright had written for him.

"Iwura Electronics! Mars! You had the whole world on your side. Age too, experience . . ." He trailed off listlessly, perhaps realizing that nothing he said could make any difference.

"My son was nineteen, and a brilliant scholar. My son you destroyed at the age of eleven."

Marron tried feebly to leap at him, but was halted by the light chains holding him to the couch. Iwura smiled sadly and left the room. The game had yet to be played to its close.

. . .

To sit in a solemn silence in a dull, dark dock,
In a pestilential prison, with a life-long lock—

It was an exquisite cell, furnished with countless amusements and delicate sweetmeats. Marron stared at the lacquered wall. The steady thermal leakage of the isotope-driven scrambler grafted into his back was maddening, like a ceaseless toothache; the raw stitches hurt with every move. Maybe he could smash it by flinging himself against the wall, and die in a hot burst of radiation? Fat chance. He hadn't the strength, and the thought of the pain. . . (He had never realized to what extent he used his Talent to control the nerves of pain: the feeling was horribly new.)—Yet if he could take that damned carved-idol Iwura John with him, he might even stand the pain.

Somewhere within, he realized that this was not a logical thought: Iwura did not look particularly Oriental (despite the ridiculous kimono!), but again the lack of Talent made the difference: without deeper perception, all men presented Marron with similar,

impassive masks. A face is so inadequate for expressing emotion, when compared with a mind.

Awaiting the sensation of a short, sharp shock—

Use of Talent was the final remaining chance. If his all-too-personal scrambler failed, what could he do? He could not touch anyone screened. He could not, surely, 'port to Earth: no idea of the direction, even! He might break the dome, but that would do no more than inconvenience Iwura. Perhaps—again assuming the failure of his personal scrambler—he could take a tip from the science-fiction of his childhood and somehow sabotage theirs? —Control some animal and cause it to break Iwura's scrambler box? Useless, for nothing could get inside the field without itself becoming lost to him. And were there animals on Mars? An SF book was the place for this ridiculous scrambler: if only it had stayed there.

From a cheap and chippy chopper—

The sky glowed too dark a blue through the high panels, and a point of light moved too fast across it. Death beneath a Samurai sword, the head rolling and the blood spurting. He supposed that it would be quick.

—on a big, black block.

Then Marron frowned as two thoughts met and fused. A feeling of wonder slid over him—swiftly poisoned by fresh doubt. But again and again through the night, his mind returned to bathe childlike in that grim and impossible hope.

Each man now wore two scramblers. Keung, who would perform the act, had submitted with protests to wearing three. It was absurd that one unit could not blanket the entire dome; but with the present state of the art, the range seemed fixed and immutable. Iwura checked the points off in his head. Marron's own scrambler, anchored to the backbone

with rivets of stainless steel, was supposedly infallible; while at the failure of any scrambler, a battery of computer-aimed lasers would carbonize Marron's body . . . just in case. Still, Iwura wondered. The *I Ching* had not been encouraging. *Beware the consequences.* The wise man does nothing. The oracle's "personality", which tended always to balance and calm, could scarcely be expected to approve the thing he was about to do. Or rather (surrounded by the awful power of the yen) the thing he was causing to be done.

The chained, tottering figure was brought out. Approaching the block, Marron stumbled and almost collapsed; a stain of urine spread down one trouser-leg. Iwura frowned, and shifted on his light

folding chair. He had pursued this quest impassively, had he not? with the careful calm of a chess-player? (He had never learned to play chess.) Such emotion was out of place. It was a trick of the mind, nothing more, that Marron's terror reminded him irresistibly of how Sui might have looked, just before. . .

And what shall ye do in the end thereof?

Keung looked to him expectantly.

Iwura pressed his lips together for an instant and, shaking no less than Marron, gave the sign.

The block was of beautiful workmanship, to be sure, carved of some green stuff: soapstone? jade? Old Iwura had been thinking about this for a long time. Marron felt strangely light-headed—perhaps merely the low pull of Mars—the feeling existed independent of the fear. The world was very precious today, perhaps because with Talent smothered he perceived more clearly with the older, earthier senses. From the corner of one eye he saw a small and hairy dog, which waddled under the weight of a scrambler box: almost, he could have laughed.

A massively muscled Oriental stood to one side, stripped to the waist and leaning on a bright, ornate samurai sword. Marron looked across to Iwura John's eyes. Nothing there. Nothing.

It was a relief to be able to kneel and anticipate an end to the uncertainties and the dull pain of the nuclear battery (just a few degrees too many over blood heat). Unless, of course. . .

The shrunken sun shone through the transparent sections of the high dome. Only a minute or two now, surely? Marron stared at the tiled ground; the block's green stone was cool against his neck. Resting the weight of his head, he stared down, trem-

bling—and found that the pressure on his neck brought swirling blackness to his eyes. Blood to the brain cut off, of course; a lucky break; he could black out and die without fear. A faint voice encouraged him: *you-will-not—*

No! He raised his head a little, with an effort, and shook away the dizziness. A faint shuffling sounded as the swordsman chose his stance. *Now—* He twisted his head sharply sideways as the tiny hiss began. For an infinitesimal instant his eyes met Iwura's—clever devil sitting out of the way of the blood—and the eyes seemed tormented.

Thud.

A bewilderment of sensations: Kicked by a mule in the back of the neck, falling, paralysis, blows to the skull, dizzying motion, faintness and dying lights—

The momentum of his severed head, given by that last sideways twist, carried it some feet across the tiles. Fading nerves described a body numb and impossibly light. The scrambler's net frayed and broke. He reached out, and up, ignoring the blank zones protecting everyone in the dome—

dying, he channelled all into hatred of Iwura, most specifically applied. All that was himself remained and went into the thrust. The body shed like a lizard's tail—

would it be enough? no power left to tk his own head round, look a last time at Iwura so he would *know—*

killed like poor Sui through Fear—

and then there was nothing but

Thud.

Iwura John had not in his bloodthirstiest moments realized the thing could be so horrible.

Marron's head rolled accusing towards him, blood spraying from the inert body in unbelievable quantities. At that moment, he suddenly wished to put back the clock: judgement was too awful a thing even for a man of nineteen billion yen. (And bleakly ahead there stretched the hollow panorama of years to come.) Streaked with crimson, the head came to rest, staring at nothing, the lips working for an instant before settling to a travesty of a smile.

How much did he suffer? Iwura wondered in the moment of absolute stillness, as Keung wiped the blade. One would not die instantly; a few feverish thoughts would race through the brain before...

He could have done something, then! Out of the scrambler's range!

The masklike features, more poker-face than Oriental, crumbled for the first time: into humanity.

The scene was no longer sordid but invested with the grandeur of high tragedy. Patterns of blood glinted in abstract beauty upon the tiles. Iwura's old hands twitched slowly, and his vision blurred and sparkled. *Then . . . he forgave me?* Acknowledging a subtle perfection, he sighed, looked up into a dark-blue sky—

—which grew darker yet, swelling in monstrous eclipse and bursting into fire, too quickly, too quickly...

Guilt and shame were lost in shadow. He had no time to savour a doom so finely just, no time to raise his arms in a rueful welcome to Phobos as it fell.

—David Langford

WHERE THY TREASURE IS

by Fred Saberhagen

He would do anything for the ones he loved— even leave them... if he could.

It was a small private hospital, so Benedict Cunningham and his doctor had a small private elevator to themselves, going down.

"Call me at any time if you think any problems are developing," said the doctor. He was youngish and intense, and was carrying Cunningham's valise himself. "Any sort of problems."

Cunningham smiled. He had just turned fifty, and looked quite healthy and vigorous. A sun lamp, installed in his hospital room at his insistence, had maintained his golf tan during his stay. His new wig was so well made that only the very few who knew him well were likely to spot it as a difference. He said now: "We went into all the possibilities pretty thoroughly ahead of time, as you'll recall. And everything has gone well. I don't anticipate problems."

"Nor do I. But, since you're the first."

"I had better be the last as well. At least for some time to come."

"Of course."

"Don't look so grim, doctor. You're going to do quite well out of this." Cunningham's smile was faintly prolonged by the grim look he observed on the young face; if the man hadn't needed money desperately, he wouldn't have done this . . . .

A faraway look came into Cunningham's eyes. "Wait," he said softly. "I'm making contact with what must be another company. Oh. Giant . . . I think . . . it's got to be AT&T. Whole networks of metal . . . networks of finance . . . I can't describe it, any more than I could the others. But it's there, yes, it's definitely there. The whole structure . . . you know, there's one detail in all this it's just occurred to me to wonder about."

At that point the elevator door opened onto the ground floor lobby. Cunningham grabbed his valise from the doctor's hand and stepped out briskly, determined to impress the small group of waiting reporters with his smiling health.

"I'm fine," he assured them. "Just elective surgery to have a wen removed. Then I stayed over for my annual checkup and a little rest."

The doctor, speaking to the reporters in turn, issued a short and somewhat vague statement that revealed nothing about the unheard-of thing that he had really done. Then he walked with Cunningham to where Cunningham's chauffeur stood holding open the door of a waiting limousine.

Motioning the doctor to follow, Cunningham got into the car and greeted his wife with a hurried kiss. Shirley was a quiet, attractive woman a few years younger than her husband, with a dread of the press intense enough to have kept her waiting in the car today.

Her face was worried; the doctor, shaking her

hand hastily, wondered how much her husband had really told her.

One reporter was still watching, and Cunningham touched the intercom and told the chauffeur to drive away.

"What's the detail that's just occurred to you?" the doctor asked, as soon as the auto was in motion.

Cunningham raised his fingers to touch the deceptive fabric of his wig, where it covered the healed incision behind his right ear. New hair growth had made a start, and in a month or so the wig could probably be discarded. "Huss tells me that the transmitting device is concealed exactly where we wanted it at the Exchange; it should put me in contact with every corporation that's traded on the Big Board. But in fact the only ones I've been able to feel are those in which I own some stock."

The doctor relaxed slightly. "And about which you are naturally more concerned. We expected there to be all kinds of psychological interaction with the device."

"About which you may someday be able to publish."

"But nothing else bothers you."

"There's a . . ." Cunningham hesitated for just a moment. "There's a certain feeling, hard to describe. Like being spread out, diffused, that's the best way I can find to put it."

"You didn't mention this before." The doctor's voice was at once sharp and resigned.

"It's nothing, I just notice it a little more today. If it should be permanent, well, I can get used to it. Shirley, you should see that chimp in the lab. The device in his skull is just like mine, and it connects him electronically with a machine that delivers food. And he knows infallibly just when and where that

next banana is going to fall, and he's there to grab it every time. Believe me, I've got my eye on some ripe bananas already."

The last signature had just been inked onto the document that transferred twenty thousand hectares of Idaho timberland to Benedict Cunningham, and the transaction electronically recorded for the central data banks as the law required, when he pushed his chair back from the table and uttered a low exclamation.

"All right, Ben?" asked the man who had just sold him the timber.

"Yes, fine." Cunningham straightened his business collar. As far as he knew, he was all right; it was just that a new sensation had surprised him.

As soon as the timber-dealer had departed, Cunningham phoned the president of the newly formed Macrotron Engineering Company.

"Huss, I'd like you to come over to my office right away."

"OK?" Carl Huss's voice was guarded. "Something important?"

"I'm calling you, am I not? Get over here." He switched off without waiting for a reply.

Cunningham knew that his order would be obeyed. He had in effect given Macrotron to Huss in payment for the two cybernetic devices and the secret installation of one of them at the Exchange; but, as Huss well knew, Cunningham still held the financial fate of Macrotron in his own masterly hands.

"Have you added anything to the device at the Exchange?" Cunningham demanded, as soon as he was alone with the engineer.

Huss was an electronic genius and a rapid talker, even more nervous and younger than the doctor.

"Of course not. Nothing needs to be added. And If I did want to try out some improvement, I'd certainly tell you about it first."

"I should hope so." Cunningham frowned. "I don't suppose anyone or anything else could be causing interference?"

"The chance of that is so small—" Huss made a gesture of dismissal. "The technicians at the Exchange don't open up the Board once in six months now, the equipment has become so reliable. And when they do open it, they'll notice nothing to make them suspicious. I did a good job."

"All right, then. I just wanted to make sure nothing had changed."

"What's gone wrong?"

"Probably nothing." Cunningham shook his head. "It's just that I've begun feeling things, identifying with things, that aren't on the Board. Things that have nothing to do with the Stock Exchange."

Huss, unconsciously scowling, thought it over. "That's not electronically possible."

"It happens. I bought some timberland today, and the instant I owned it, it was as if a part of myself went there. That's the only way I can describe it. I can tell that there's copper under the soil there, a great deal of copper."

"I don't understand." Huss for once spoke slowly. "How can you know a thing like that?"

"I was hoping that you could tell me." Cunningham shrugged. "It's the same substance that I see in copper wires, but mixed in with rock and dirt and buried. I just feel it there. How do you know that your toenails are hard and nerveless?"

That afternoon Cunningham sounded out a couple of mining companies, making preliminary arrangements.

But his dream that night had nothing to do with

copper, or, as far as he could tell, with wealth of any kind. He was standing in darkness, paralyzed, attacked by some kind of tiny vermin that gnawed their way through his skin and then scuttled in and out through the holes they had made. He tried to move, but could only sway stiffly, his joints creaking. He could only endure, well past the point where any ordinary nightmare should have ended. Managing at last to get a clear mental image of one of his tiny tormentors, he saw that it had the face of a cartoon comedy rat, a discovery that for some reason added a sharp stab of horror. Cunningham woke up, in a cold sweat.

Shirley was standing beside his bed. "Ben, you were . . . calling. Are you all right?"

"I was dreaming. Yes, I'm all right." He wiped his face. Looking for his cigarettes, he switched on the bedside light, and became abstractedly aware of the worried expression on his wife's face. "Don't be upset about the car, Shirley. Those things happen."

Surprise registered in Shirley's eyes, then guilt. "No one was hurt. Ben, I, I wanted to tell you about the accident, but you've had so much else on your mind."

"It's all right," he said. The damage to the prized sports car was not severe; it amounted to some banged-up sheet metal, and a slight hidden strain on the frame, that not even the mechanic had yet detected . . .

But how did he, Ben Cunningham, know that?

The answer, of course, was that he felt it, in the same way he would know if his ankle had been wrenched slightly. The discomfort he felt now was not in his ankle, not anywhere in his body, but he felt it. While he slept, a part of himself had been pulled into the car.

There had been a bad dream too, a dream now

fading rapidly, a dream that had had nothing to do with cars . . .

Shirley, her voice hesitant, was speaking again. "Ben, I've never interfered in anything regarding business."

He grunted something.

"This time I would have, if I'd known when you went into the hospital what you really meant to do."

"Go back to bed, Shirley," he told her, crushing out his cigarette. "Everything's all right."

"Are you sure, Ben?"

"I'm just tired now; let me rest." He smiled at his wife, the smile that always reassured her, and then lay back and closed his eyes. She put out the light, and a few moments later he heard the door between their rooms close softly. A great woman. He would tire himself out, use himself up, go through nightmares, for her and the two boys who were away at school. Even if he never got to see much of them . . .

Tired, but he wasn't going to be able to go right back to sleep. He lay in his bed alone—he would never have been able to get the rest he needed, had he given up half his bed to another body's weight and movements and breath—staring up into darkness. He was now able to feel the twenty pairs of shoes racked in his bedroom closets (nothing like dressing right to make exactly the right impression) and with a little effort he could even tell which pairs needed polishing. Lying there motionless, he could feel himself being drawn, slowly, inescapably, into all the things that were in and about and of his house. The fireplace downstairs with its fading warmth, the Picasso print on the wall, the garbage in the undersink disposal. The concrete of the outdoor pool, drained for winter. The growing grass and trees.

One by one, all the things he owned were coming forward, each demanding its own portion of his being. He had the feeling that there was not going to be enough of himself to go around. His things were absorbing him into their own substances. He had told the doctor he would get used to feeling diffused, but the sensation was only getting worse.

He put his hands over his face in the darkness. He fiercely willed his own coherence and survival. What was attacking him was illusion; he still functioned. To build for his sons and his sons' sons he would find a way to come to terms with his new power. He had to. At last he dozed.

In his office next day Ben Cunningham began to feel burning and amputation and scarring; the sensations were not localizable to any part of his human body, nor were they generalized throughout it. He felt them, though, and they were real, physically real. He traced them to their origin in a part of his newly extended identity, and he knew before the phone message came that his new Idaho timberland was ablaze. The first copper-hunting expedition sent by the mining company had managed to start a forest fire.

That night he again stood wooden and swaying, infested by rat-faced mites. (Also moving about inside him were other, much larger creatures, but these were doing no damage at the moment and he could ignore them.) It was the tiny beasts with their tiny gnawings that were terrible. This time the image of the vermin stayed with him after he awakened, and he understood that they were rats, real rats. When one hungry rat found food in the form of one of the larger living things, Cunningham's nerves did not

feel the bitten baby's pain, for the baby was not his property. He felt only the baby's scream, reverberating in the shaky wood of the tenement.

"Hullo? Whatsamatter?"

"This is Benedict Cunningham. I want you to get busy and sell any building I own that could be called a slum. I know it's four in the morning. I don't want arguments and I don't want any delay. Start on it right now."

"What's Mr. Cunningham? Sell buildings, you say?"

"And don't haggle about prices. Get rid of them."

The hurried sale of the slum buildings relieved him of pain; but it did not free him. He was still gripped by the money from the sale, as by all the other money that was his. Parts of him stretched out, and then tied down, confined, in cage-boxes made of bars like the ruled lines in an old-fashioned ledger.

For another day or so he continued forcing himself grimly on along the road to greater profits. More cage-compartments and more bars. Making money had always been something he could do, and it was almost no trick at all now that he was wired into the Board. The connection was everything that he had hoped it would be, and more.

And more.

For Shirley and the boys, he clung to his determination to endure and adapt. But with every passing day, with every hour, he could feel himself going. Losing what tenuous contact he had ever had with people and music and food and sunsets. He inexorably diffused, becoming machinery and oil wells and expensive shoes.

The forest fire was out now and he had got out of the reach of the rats' teeth. But he could feel himself dying of diffusion. His body walked on, planning daily tasks, smiling when required, keeping socially active and presentable, but soon his shrinking core of self might be altogether gone, and against that fate his ego at last rebelled.

He tried first to save himself without really giving up any of his wealth. He switched off, by remote control, the unit implanted at the Exchange. It didn't help. He tried putting vast properties in his wife's name. But the pen marks and the electronic transfer of symbols that had got the rats out of gnawing range proved in this case ineffective. This time the things of his wealth maintained their grip on him, as if they understood that they were in every real sense still his.

"I *believe* I understand, sir. You want the books physically spread out on the table, opened?"

"Yes. And the discs from the computer." The symbols of wealth were concentrated even more intensely there. "And then move the table over to the windows, let the sunlight fall on it." He no longer cared a great deal if subordinates thought him eccentric or even insane.

He could feel the sunlight falling on the rigid records of his wealth. But not even the sun could thaw him loose from them.

These days he never worked late at the office. And when he came home, Shirley was always waiting for him, peering at him anxiously. Today she said: "Ben, if you don't make an appointment with a doctor right away, I'm going to make one for you."

"Don't bother, I've just made one."

* * *

"You couldn't remove it," was almost the first thing that Cunningham said on coming out of the anesthetic.

"Oh, I removed the device." The doctor's voice was weary, his face grim. "There was some involvement of brain tissue that I hadn't expected. How do you feel?"

"You might as well have left it in. I'm still being pulled apart."

By next morning, the doctor had a theory ready: some of the nine-tenths of Cunningham's brain that he had never used, that no one ever uses, had been stimulated to new activity by the cybernetic device. The components of the device were very small and subtle and new, and no one yet understood them very well.

"I'm not going to try to do anything more to your brain," he told Cunningham flatly. "What's going on may right itself in time. It probably will. That's all I can say."

The surgery hadn't been the doctor's idea in the first place. Cunningham didn't really want the doctor to say anything more now. He put on his wig again and left the hospital again, knowing that he had only a little time left. Whatever elastic might be left in his tough soul was failing now. There were moments, with his wealth stretching him in every direction, when a black cavity appeared in the center of his being. The cavity was nothingness, and that was his future.

Since surgery had failed, he could think of only one more course open to him that was (a little, at least) less desperate than suicide. As soon as Cunningham got home he called his lawyers and with

their help began to give things away. At first they worked at the job enthusiastically, eager to learn what the trick was going to turn out to be. Putting things in Shirley's name hadn't worked, and now Cunningham stayed clear of her and other relatives and chose charities.

At last, success. He could tell that this time he had found a method that was going to work for him. Each gift eased the strain, allowing a bit of humanity to return. The trouble was that partial relief was no longer enough, he had been too badly stretched. A tug on even one finger or toe is unendurable to a man who has been for days on the rack.

When his lawyers, puzzled by the continued absence of any tricks, pressed for explanations, and he told them that he planned to give it *all* away, down to the last penny, they called his doctor. For a while Cunningham feared there would be an effort to have him committed. But the last thing the doctor wanted was fuss, possible investigations. He backed up his patient as sane and competent, and the lawyers eventually went along.

Not before they had spoken to Shirley, enough to give her some idea of what was going on.

Naturally, when Cunningham confirmed that he was giving everything away, she was stunned.

"Of course," he reassured her, "you're not going to have to worry personally. You'll come out of it with a fine settlement."

"A what?"

"Understand, this is business," said Cunningham, using the magic word that would always forestall any more questions from his wife. "You *have* to divorce me if you want to keep anything at all for yourself or for the boys. I can't bear to own the least thing any longer." And even as he

spoke, in the back of Cunningham's mind was the faint, terribly fragile hope that Shirley might elect to stay with him, even existing as he saw himself about to do on the charity of some distant relatives. He could still own a bite of food and put it into his mouth and not feel real pain; that was about the feasible extent of his net worth right now. But it would be unthinkable to come right out and ask Shirley or his sons to exist like that.

"Divorce you, keep anything," she repeated vacantly, in extreme horror. "But Ben, I'll never leave you. I don't care that much about money."

He hadn't really dared to hope . . . with shaking, tearful tenderness he reached for Shirley's hand. "Think carefully, dear," Cunningham murmured honorably. "Everything I've done has been for you and the boys."

"For us?" Astoundingly, her love exploded into wrath. He could not have been more surprised if she had shattered like a bomb. "For me? Don't tell me that. In the beginning, maybe, but not when you had a hole drilled in your brain to make more money. Not then! Go on, kill yourself, or give it all away to ease yourself, but never say that it's for me!"

"I . . ." Just then the phone began to ring. Cunningham answered it mechanically, and the voice of one of his lawyers said: "Ben, the last things are ready for your signature. But I still can't see a man like you going through with this."

"I'll call you back," said Cunningham slowly, and hung up. Meeting Shirley's angry, wondering eyes, he felt a touch of new terror. The power of self-extension was still his, in a form he had not thought of until now.

It came to him that there were treasures he had not yet dreamed of knowing.

It came to him also that the cage-bars of the ledgers, the prison domains of the magnetic discs, had just this moment eased their strain.

"Mr. Cunningham? You said two hours ago you'd call us back. You didn't, so I took the liberty of calling . . . the papers are ready as you requested. We're all waiting."

"The papers." Cunningham sounded impatient and happy at the same time. His voice was that of a man being disturbed while at some joyful occupation. "Oh, the rest of the giveaway papers, yes. I think you might as well tear those up."

The pain, as in memory, of a rat bite came and went. It hurt, yes, but . . . Cunningham turned off the phone and rolled on his other side to look at Shirley. He found that now he could look through her eyes at himself as well. He wasn't handsome any longer, if he had ever been handsome, and certainly he was no longer young. But her eyes seemed content to rest on him.

"It's all right now?" Shirley asked.

"It's all right," Cunningham assured her. "How long have you had this backache?"

Shirley's eyes widened. He could feel the change in her eyes as well as see it. The accompanying thoughts, however, had to be deduced. Until she said: "You're spreading out again."

"Mark," he said with closed eyes, "is playing baseball. Just got a good hit, he's running the bases hard. It feels really good to be fifteen and run full speed."

"Mark is—? Oh, my God. You're going the same way again, only now with people."

"Not the same. And Luke, he's talking to a girl."

Cunningham was inside his older son, seeing the girl, and—yes, dimly, in foreshadowing of a future clear reality, he could go as far as looking through the girl's eyes back at Luke. Cunningham was spreading out again, slowly, farther and farther. But it was not the same as it had been with money and with things. Now more, vastly more, than went out was coming in.

"With people. Oh, my God, what are you going to do? You can't give *us* away."

"Fat chance. Forgive me, Shirl? for trying to do that once."

"Ben. Where are you now?"

"Right here, Shirl." He opened his eyes. "I'm in bed with my wife."

—Fred Saberhagen

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RAMBLINGS

by Poul Anderson

"I decided some time ago that I had won to precisely the kind and degree of fame that suited me."

After a third of a century in it, I find the writing trade as weird as ever. Unpredictable, amusing, challenging, infuriating, lonely, sociable, totally liberated, harshly disciplined, deskbound, adventurous, a kaleidoscope at large in the universe—it is not a life for everybody. Anthony Boucher used to say that a prospective writing career is like a prospective marriage; if the person can possibly be talked out of it, he or she should be. Sometimes I myself wax a little wistful about such other lines of work as anthropology and oceanography. On the whole, though, I'm glad that nobody ever convinced me.

People do seem to be interested in writers, not because the latter are necessarily flamboyant—most aren't—but, I suppose, just because their lives are so full of oddities. A couple of times in speeches I have reminisced at length, in anecdotes mainly funny,

about colleagues. That was not to make any friend the butt of a joke, merely to share with my audience the laughter we two had shared long ago. Maybe I should write these recollections down while I'm still here to do so. (No great rush. I plan on being around for many years to come, annoying the hell out of all collectivists and neo-Puritans.) At the moment, though, my remembering happens to be more personal. How has it felt to be a writer, as distinguished from a human being interacting with other human beings who chance to be writers too?

Don't worry, I shan't bare my soul or anything embarrassing like that, simply offer you a few disjointed memories and musings.

For instance, first starting out, quite young and vulnerable, I got immensely annoyed whenever some older man would ask me patronizingly, "Well, are you working now, or still writing?" In due course I evolved a reply, delivered in the smuggest possible tone: "Why should I punch a time clock when I can live without working?" Do beginning free-lancers nowadays get this kind of insult?

More well meant was the question which still crops up every once in a while: "Where do you get your ideas?" Oftimes it took the form: "Where do you get those crazy ideas?" For this, I'd steal a line from a Claire Boothe Luce play and, tapping my forehead, answer solemnly, "Out of nothing."

To those nebbishes who offered a notion, or an autobiography, with the proposal that I write it up and we split the profit, I learned to respond: "What do you do for a living?" and, when they said, "X," tell them that I was willing to find a place where they could do a job of X, and we'd split the profit.

The large majority of people, of course, are gracious and well worth talking with. I have always enjoyed science fiction conventions, and mainly for

this very reason. However, of late I have tended to avoid the principal ones. They have grown so big that it's well-nigh impossible to get to know an individual, or even get together for any length of time with an old friend, in that maelstrom. I also wish the current craze for autographs had never come about. It's making it more and more difficult for a professional to relax and circulate freely among attenders, many of whom would like some conversation with him or her. There should be a rule that, except for specified autographing sessions, pros are not to be pestered in this fashion.

Otherwise I don't think they should have any prerogatives vis-á-vis the fans. In fact, when somebody is more or less worshipful, I am naturally touched, but then do my best to turn the encounter into one between equals. The suite which Science Fiction Writers of America commonly maintains for its members at these events has become a blessedly stress-free place precisely because there are no ranks within it. It does not represent special privilege, any more than does a suite kept for some different group such as First Fandom. After all, a lot of us began as fans.

And, to repeat, most of the attenders at a convention are delightful in every respect. I have formed lifelong bonds of affection with quite a few, not to mention a marriage which is now approaching its fourth decade.

Many contacts with readers have been through the mail. Most letters received from them have been one-shot affairs—a comment, question, or request demanding no more than a brief, polite answer. Still, they are pleasant to get, an evidence that there are folk out yonder, not in the limited circle of fandom, who care.

A number have led to absolutely fascinating cor-

respondences, which have gone on for years. They come from experts in various fields, original thinkers, all sorts of unique individuals. I have been charmed, enlightened, sometimes had my own thinking turned completely around. Some correspondences have begun with a meeting in person, as at a convention; some have begun in the mails and led to eventual meetings; in a few cases, I have yet to encounter the body of a personality that has scintillated at me for a long while.

In this connection, I decided some time ago that I had won to precisely the kind and degree of fame that suits me. More would presumably mean additional money; it might be nice to draw that, but then again, it might not. As is, we in this house have seldom lacked means to pay for any goods and services we want, and a bigger income would at the very least entail more responsibilities. Meanwhile, I am well enough known in my community and elsewhere to be as publicly influential as I care to be, which isn't much. "Elsewhere" ranges around the globe, and especially covers the classes of people who interest me the most. I would a lot rather get the VIP treatment in a scientific research center, which happens pretty often, than in a college English department or New York literary cocktail party. (No sour grapes here; nobody since St. Paul has been all things to all men.) The mail is not so overwhelming that we must resort to printed reply forms; instead, I have leisure to follow through on whatever part of it looks promising. We have no need of a chain link fence to keep off intemperate admirers. When we travel, we are just another middle-aged couple, and nobody bothers us—but when, for example, we reached the Dordogne valley, we got the kind of tour of the prehistoric sites that

the President of France gets if he asks for it.

So, by and large, I am well content with our material and social circumstances. This includes job security. I *can't* be fired. True, I can become totally disabled, or die prematurely, or have my markets vanish out from under me; but no one is immune to that sort of thing. As has been said, "This world is a dangerous place; hardly anybody gets out of it alive." We have taken what measures we reasonably can to protect ourselves against contingencies. They aren't invulnerable, but they are a hell of a lot more dependable than the frauds, such as Social Security, which the government forces on its captives.

Am I, then, content with what I have done thus far in the way of writing? Of course not. Another saying has it that every writer worth his salt always hopes that his best creation will be the one he's working on right now.

Or she, naturally. Or they. Collaborations are funny things, also resembling marriages in that no two teams are alike and there is no predicting how any given combination will turn out.

Technically I haven't done much collaborating. In several instances of a story with a joint by-line, including my first, I did the actual writing, but someone else supplied enough in the way of ideas that I felt a published credit was proper.

To date, the only colleagues with whom I have worked all the way down the line have been Gordon R. Dickson and Mildred Downey Broxon. The differences here are illustrative. When Gordy and I wanted to do a Hoka story, we'd open a beer or six and talk it out at length. Then he, having the more inventive sense of humor, would dash off a first draft. I, having perhaps in those days a more meticulous sense of logic, would do a second draft,

throwing in whatever additional jokes occurred to me. That was usually it.

When "Bubbles" and I undertook our two joint projects (to date), *The Demon of Scattery* and "Strength," we too discussed matters till we had a general idea of where we were going. Then we'd first-draft sections alternately, from the points of view of two different characters, male and female; but each would ruthlessly criticize the other's latest offering and call for changes. Most of this was necessarily done by mail, because of geographical separation. (When Gordy and I worked together, we both lived in Minneapolis.) Eventually we'd meet in person with our mass of bescrawled manuscript and, by turns typing and looking over shoulders, produce an integrated revision. It will be interesting to see what comes of our next project, since it will not have any such convenient alternation of scenes.

Those are my formal collaborations; but neither has been anywhere near as important as the informal one I have had with my wife Karen for more than a quarter of a century. A few times, she's published things that were entirely her own, and I wish she'd do more; we don't need the money, but the field needs her touch. A few other times, she's contributed so overwhelmingly much in the way of thinking, phrasing, and the like, that it was impossible not to share the by-line. Mostly, though, she has gathered facts for me, including the facts of whatever else might already have been done along the lines I'm considering. (I don't read a lot of science fiction any more, nor have I time to keep up with all the scientific journals and such.) She's not only backstopped notions of mine as they came forth, she's proposed brilliant new ideas. As the rough draft has piled up, she's read it, made further

suggestions, and picked countless nits that I have agreed were undesirable. She's caught more, as well as typos, when helping me plod through the galley proofs. She's fended off phone calls and corporeal intrusions. She's borne with the manifold strangeness of a writer, and even come to understand them. (When we were first married, I explained that at times when I was stretched out on my couch in the study, staring vacantly at the ceiling, I was hard at work and must on no account be disturbed. She agreed to respect this . . . until I should start snoring.) Mainly, she's been herself.

It will be *very* interesting to see what comes of the full-dress collaborative novel we are planning.

There are at least two more kinds of informal collaboration, also of more lasting importance than the ordinary sort. The first is between the writer and other writers whose work he reads, though they may be unreachably far off in space and time—learning, being inspired, suffering a healthy measure of helpless envy, or just getting a chain of associations under way that results in a fresh concept. But this is too large and subtle a subject to tackle here.

The second is between the writer and his characters.

Again, individual variations are infinite, and I can only speak for myself. Not being a mystic, I do not believe that my characters originate anywhere but in my mind. Even those who are historical figures are simply my interpretations of the data avilable to me. Nevertheless, I know for a fact that they can take on a life of their own.

This means the major figures. Usually a tale needs some who are mere spear carriers, as the operatic phrase goes—names hung on them, perhaps, and action assigned, but no real personality, or at most a

bare touch of it. The classics of world literature are full of them, too. The writer simply does not have the room to let them express themselves, any more than he has the time in real life to get acquainted with everybody he encounters.

As for the living souls whom the story is about, that is a different matter entirely. How they come into being depends on the writer. Bubbles tells me that she "sends to Central Casting" for hers, and suddenly, there they are, usually not much like what she had in mind. Myself, I try to invoke them more gradually, by such devices as sitting down with a notebook and dreaming up their biographies. Doubtless there are numerous other methods. The point is that, if the writer has succeeded, they do come into being, and have a strong tendency to take over the story.

Speaking personally again, I always want to know in a basic way how that story is going to go—where it will start and where it will end—because experience has taught me that else I'm likely to get stuck with a half-finished mess that isn't going to go anywhere. (This is not true of all writers; we are a fantastically variable breed.) As a rule, I can maintain this much control, because I have evoked people to whom that general direction comes naturally. However, as for scene-by-scene detail, they know what they want far better than I do, and I have learned not to interfere.

For example, in writing *Tau Zero*, I had a clearly defined framework, the spaceship doomed to fly ever closer to the speed of light. I even had a rather sketchy novella to expand; but the people in it were little more than names and roles. The rigidity of this was paradoxically liberating, since in doing the full-length version I could first let them grow in my

head, then turn them loose and watch what happened.

Sometimes characters play jokes on me. I swear that the Tom Lehrer allusion, "Lobachevsky published first," near the end of *Operation Chaos,* had never occurred to me until suddenly it sprang out of the typewriter and Karen broke the privacy rule to come in and ask why I was laughing so hard.

Now eventually the characters, like every other part of the story, must leave the warm, self-congratulatory brain of the author and venture forth among readers. There they are on their own and how they fare depends solely on them. Some, like Hamlet, end up claiming more reality in many minds than most flesh-and-blood persons do. The vast majority, of course, are evanescent wisps at best.

Which will prove to be which, no contemporary can tell. How many people today know Henry James' finely crafted characters, and how many do *not* know Sherlock Holmes, whom Arthur Conan Doyle regarded as a potboiler? The canons of literary criticism give no help in predicting. (In fact, only two kinds of critic are worth a writer's attention. The first is the kind who signs checks. The second is time—but by then he's dead.)

As for my own people, all I can say is that a few of them have attracted some attention within the science fiction and fantasy world, and report a few specific instances of feedback to me.

Undoubtedly the favorite is boisterous, bibulous Nicholas van Rijn. True, certain readers can't stand him, but that means they don't ignore him, either. A French reader hated him at first, because he was too much like arrogant types whom this man had known in his youth in the colonial empire; but the same

man at last, reluctantly, got to liking the old bastard, sort of. He always liked Dominic Flandry, in spite of the latter's being a pure son of a bitch, and admitted that part of the reason for this feeling was that the character was so Gallic. In fact, Flandry appears to have a substantial following.

His opponent Aycharaych has acquired a small fandom too, which is dominated by young women. Don't ask me why. Obviously, something more than the pointy ears is involved, but what, I have no idea.

I was a bit disappointed when nobody except a few political libertarians seemed to understand Donya of Hervar in *The Winter of the World.* However, lots of readers have identified with Lucifer and Eloise in "Kyrie"—but then, surely most of them know what the further identification is. Several old soldiers have told me how clearly they saw before them the colonel in "No Truce With Kings," which is especially gratifying to me since it happens that I have never been a soldier myself.

The most curious case is probably that of Caitlín Mulryan in *The Avatar.* Now I saw her simply as including among her various attributes a bachelor girl sort of sexual morality. It was no big thing in the story, just an individualizing trait which, heaven knows, occurs frequently enough in real life, where it is not a particularly recent phenomenon, either. I expected that readers would take far more interest, pro or con, in her opposite number, Joelle Ky, who was pushing the limits of intellect and paying a high price for it.

Instead . . . well, of two who happen to be friends of mine, both mature and scientifically oriented men with stable home lives, one remarked that Caitlín was among the most loathsome people he had ever met, the other said he was in love with her. I can

recall no review of the book which did not dwell at some length on her conduct, whether to denounce or excuse it, while hardly any review had anything to say about the material, drawn from the frontiers of present-day science, which was far and away the principal concern of the book. A lady critic published a piece hundreds of words long which was almost exclusively a tirade against her, including the suggestion that I get my nose out of my heroine's crotch. Even if I found the idea of such a position attractive, which I don't, assuming it in partnership with a fictitious person is scarcely feasible. I fear the lady critic got a trifle overexcited, and can't imagine why. After all, my wife, my daughter, my 82-year-old mother, my devoutly churchgoing sister-in-law, and a good many more quite respectable women read the story without feeling that Caitlín is likely to contaminate precious bodily fluids; some of them sing her songs at conventions.

Indeed, it seems strange to me that anybody should take her peccadillos seriously, in an era when such writers as Farmer, Heinlein, Le Guin, Leiber, Spinrad, Sturgeon, and Yarbro explore sexual byways that really are far out. Lester del Rey declared in print that girls like Caitlín exist only in adolescent fantasies, Perhaps this tells us something about Mr. del Rey's past life, in which case I feel rather sorry for him.

But it may just be an example, among thousands, of the awesome power of that genre called "literary criticism" to generate gibberish, even when it is practiced by writers. An outstanding case that came to my attention is Joanna Russ' piece on *The Demon of Scattery*. She attacked it because it showed a woman eventually coming to be on good terms with a man who had bitterly wronged her, as if this has

never happened in the real world or at least as if the fact that it has sometimes happened must never be mentioned. She also condemned the tale for being set in a brutal era, which is true, without the authors doing so for purposes of advocating reform, which would be a little pointless inasmuch as the era is eleven centuries in the past. Bubbles refrained from remarking to anyone but her husband and me that this isn't 1984 yet, and we are still free to choose whatever setting a story calls for. I'm afraid that here Ms. Russ let her ideology run away with her.

In the course of several generally pleasant paragraphs about *The Merman's Children,* Gerald Jonas complained that its version of Faerie is too much like Marin County. Apart from the sexual license, which is there because it's in the medieval legends on which the novel draws, I fail to see any resemblance. Absolutely nobody commits suicide by dropping his biometer into his hot tub.

Mind you, I'm not mad at any of these individuals. I simply wonder why they bother with criticism, when they could be writing stuff worthy of their great gifts.

Before you remind me that I have done occasional reviews and a literary survey or two myself, let me make clear that an essay on a book, an author, or a field need not inevitably be bad. It can be quite informative and, in the hands of somebody like George Orwell, brilliant. (I do not claim that mine were.) Absence of dogmatism and jargon, respect for fact and logic, and good, clean prose are what distinguish such work from literit.

If you think that here I am playing a semantic game, defining words to suit my purposes, you're right. Why not? Critics do it all the time.

An editor who himself has an advanced degree in

English once observed to me that a prime reason why critics rarely say anything meaningful about science fiction is that nearly all of them are style-deaf, and if ever there was a field crammed with stylists, it is contemporary science fiction. True, though naturally it does not apply to real writers such as those I have mentioned.

Anybody can tell when a job of surgery has been botched, but it takes another surgeon, with innate talent as well as training, to appreciate and understand fully the successful performance of a difficult operation; and nevertheless he might fail to do so, if only because his mind is full of his own affairs. The analogy is obvious.

It follows that a fledgling writer can't learn the rudiments of the trade from anybody except an established one. Having seen a number of promising talents smothered by a load of academic theory, I always advise young persons who dream of becoming writers to study anything they choose in college, except creative writing.

Journalism is generally safe, because straightforward journalese is language skillfully employed. Granted, attempts to tell a newspaper story poetically are usually embarrassing, but some reporters have done powerful writing—for instance, Ernie Pyle—and a number of journalists have produced splendid fiction—for instance, Clifford Simak.

Otherwise the sole writing school I know of which produces a reasonable proportion of graduates who succeed in becoming writers, is Clarion, and this hardnosed institution is run by pros, not professors. If more exist whose records are comparable, I would be interested to hear of them.

In the long run, writing, like any other trade, is learned only by practicing it. An experienced writer

who also happened to be a good teacher could surely have steered me clear of many dreadful mistakes I committed early on. I was doing my best from the beginning, and getting published, but have since then learned enough about such matters as the use of English that I no longer consider the production of my first few years readable. (Luckily, the science fiction public of those days was more tolerant!) Some wise counseling could have taught me things that, in the event, I had to learn the slow and hard way, by trial and error. But soon I would have had to strike out by myself, regardless, and become my own instructor in everything beyond the most elementary matters. I gather that they know this at Clarion.

Not that I have any wish to join the staff for a season, or to teach anywhere else. Sometimes, when a friend has been having a story problem, I've managed to suggest a solution, but I've never felt able to say anything worthwhile about something so intimate as character or style.

My two times as an editor showed me that this isn't for me either. Teaching and editing are admirable professions, but who's good at everything?

There is a field in which I believe I've contributed a little, getting writers their rights. Believe it or not, I'm all for joint action on common problems, provided it's voluntary. (I oppose the closed shop on principle, as I oppose everything unnecessarily compulsory.) For a long time, no organization was doing anything; what writers' groups were present had gone fainéant.

Those were the days when a certain paperback published, that had issued several things of mine, discovered that through a wretched technicality in the copyright law it could reprint *The Lord of the*

Rings without paying Tolkien a cent, and proceeded to do so. When I heard about that, I decreed it had printed its last Anderson unless it mended its ways. Some time later it wanted to acquire rights to a book by me that Doubleday had done in hard covers. This was a tough decision to make, since refusal would put my editor at the latter house, who was and is a fine person, in an awkward position. I did veto the deal anyway, and Doubleday made no fuss. Later I heard that this incident had something to do with persuading the offending company to make amends to Tolkien. Meanwhile my own book had been picked up by another paperback outfit which, ironically, paid a larger advance than had been offered by the first.

I refrain from naming the miscreant because it was later purchased by a different firm with a higher ethical standard, and does not now deserve to be tarred by an old brush.

Well, eventually Science Fiction Writers of America came into being and started doing real things, and after several years I was induced to run for president, and for my sins won the election. Never mind the details of what happened next. Many of them still make me flinch. What I found myself with was chaos. Nota bene, this was not, repeat not the fault of my predecessors. In their various ways they had done a wonderful job, as witness the fact that I did think the organization worth working for. Indeed, they had done so well that it had, all unnoticed, outgrown its original structure to the point where it was virtually unadministerable: at least by anyone of my admittedly mediocre administrative talents. A lawyer whose advice I sought told me this very commonly happens to voluntary groups, and more often than not destroys them.

So I bumbled along from crisis to crisis, but meanwhile strove to get a consensus for reorganization. At the end of my term, the most basic reforms were enacted. My successor, Jerry Pournelle, spent his time in the barrel—as we have come to describe it—putting them into practical effect, bequeathing a strong machine to those who followed him. Most of the credit for saving SFWA is rightly his, not to mention the heroic work he did later as head of its grievance committee. However, I feel entitled to a smidgin of pride myself.

That is the only Worthy Cause to discuss here. Like most people, I contribute to several, but as a citizen, not a writer. A possible exception is the National Committee on the Treatment of Intractable Pain, on whose advisory board I serve. (It's mainly lobbying to get the use of heroin legalized for terminally ill patients, a practice followed in most civilized countries. If you feel like making a tax deductible donation, the address is P.O. Box 34571, Washington, D.C. 20034.)

But do I not, in addition, make my work a propaganda vehicle for things I favor? The assertion has frequently been seen, as accusation or accolade depending on whether the person making it agreed with what he thought I was advocating. By and large, though, it simply is not true. At most, I have set forth my views on this or that in an occasional nonfiction piece or letter to the editor. What I do for a living is tell stories.

Granted, we all of us, writers or not, must speak from our personal philosophical platforms. Therefore it is possible to consider a body of work and make certain inferences about its creator. It does not follow that such inferences have any relationship to reality.

As remarked earlier, my characters are not me. As a rule they are entirely different from me, starting with some being nonhuman, or human but female, and going on from there. They have their own lives to lead, within the situations of their particular stories. Those situations are not necessarily ones of which I approve, or even believe to be possible. For example, I would not like to live in the world of Hrolf Kraki, and indeed would not likely live long in it, but the people of the tale take their circumstances for granted and would be equally lost in our world. In the case of *The Merman's Children*, not only do I myself deny that there ever was a Faerie, I don't think it is bad that science has abolished such concepts from our beliefs. We have lost something thereby, but have gained far more. However, there was this story to tell, of these imaginary beings and how *they* felt about the matter.

Others may have great messages to deliver. All I do is daydream, and find words with which to share those dreams.

A few times they have been nightmares (to scramble metaphors) and it has been quite a terrible effort to write them down. One short story, of a length which ordinarily would take me a day or two to first-draft, took more than a week, because I could only bear to handle a couple of pages on any given day ("The Visitor"). Yet for some obscure reason, obviously not financial, it had to be written. In happier and commoner instances, something has had to be written because the writing of it would be irresistible fun.

In fact, I decided long ago, after several bad experiences, not to write anything I don't really feel like writing. Not only is life too short, but the results of reluctant effort, though publishable, have never

pleased me, nor have they been among those that readers remember and that keep getting reprinted. Thus, even from a crassly commercial standpoint, it pays to be your own man or woman.

Of course, as indicated above, the "feeling like writing" may be an out-and-out compulsion to do a grim job. At best, the search for the exact right words is hard work. I could take considerably less trouble, and still produce saleable material. Few readers and scarcely any critics would notice the difference. But those few are the readers for whom I write, though I hardly ever hear from them—those, and myself.

It may be letting down the side of certain old pros, including me, who have always made a point of sounding cynical or, at most, noncommittal about their art; nevertheless, I hereby state that we care about it as much as those of our colleagues who make the declaration publicly. After all, we have our share of what Thorstein Veblen called the instinct of workmanship.

More and more as the years go by, I find myself involved in business matters, contracts and investments and whatever else. The money is gratifying and the stress is, usually, minimal compared to the toll exacted by writing. Just the same, I tend to get grumpy whenever something like that arises. It does take up time without giving any particular emotional satisfaction. Damn it, I'm a writer!

To you readers who have made that possible, my sincerest thanks.

—Poul Anderson

(WELCOME, Cont.)

It was inevitable, really. You see, from the beginning, Destinies has had a level of sales comparable to a "hot" anthology or a mid-range novel, while it has required a degree of editorial effort equal to what six or eight novels call for. About now book people are wondering just how we afforded all the big names, high-grade paper stock, artwork and fancy layouts. Answer: Jim Baen became more than a little unpleasant when questioned on this subject —and since science fiction generated just a whole lot of cash flow, he was indulged.

But I'm not with Ace anymore, and only a magazine-editing junkie could rationalize such a misallocation of a publisher's most precious resource: the time, energy and enthusiasm of a major acquisitions editor.

Speaking of major acquisitions editors, my replacement at Ace is Susan Allison. She was my assistant for a couple of years, and I hated it when she up and left for a cushy berth at a rival company. Note well that she was not at Ace when I left—she was chosen to head up Ace's sf line from among a whole raft of outsiders because she was considered the most qualified applicant.

As for me, I was made an offer I couldn't refuse: a cunning appeal to my two greatest character flaws, greed and vanity. "Jim Baen Presents," indeed.

See you.

—BAEN

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