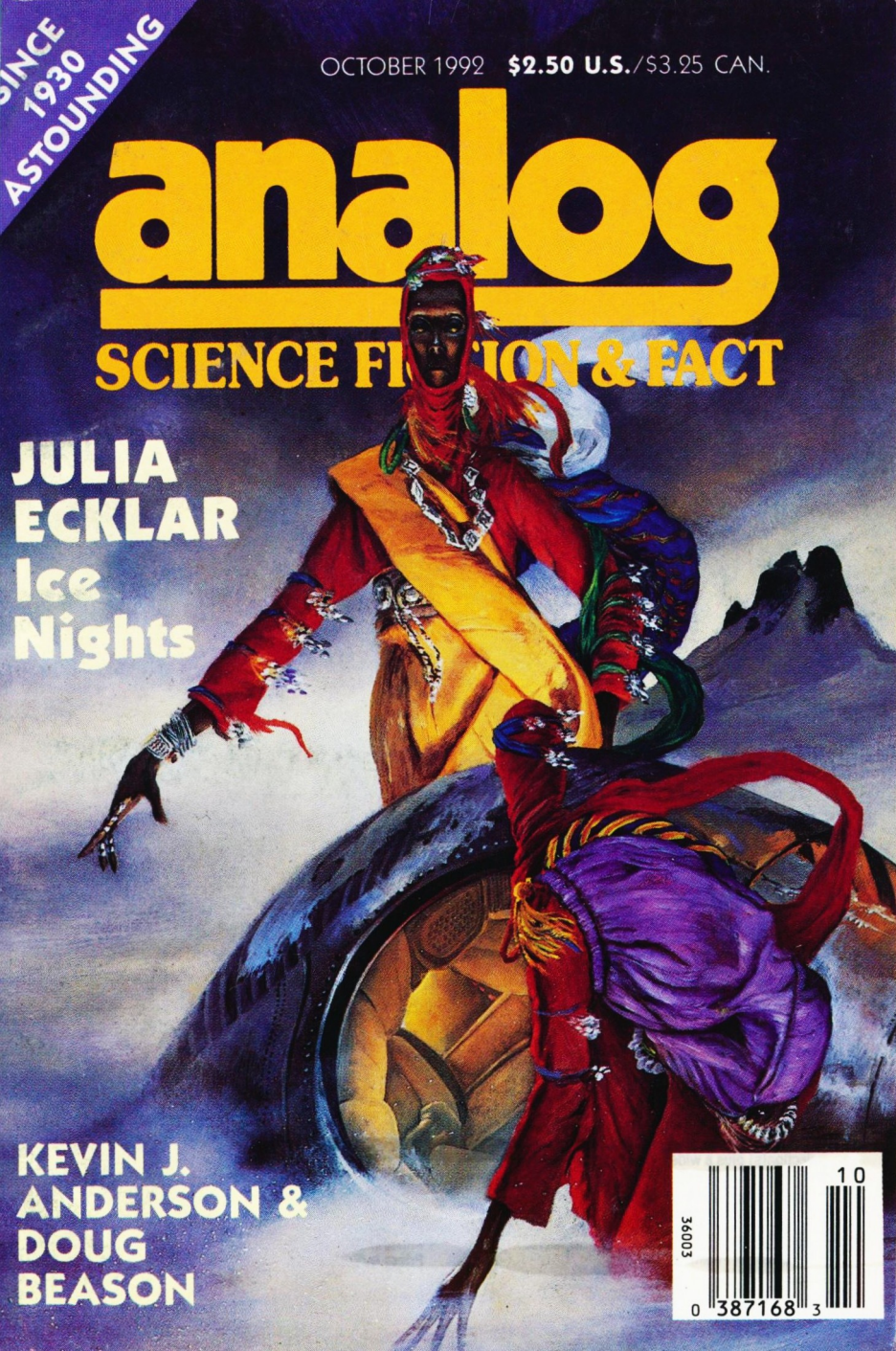
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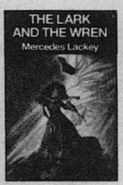

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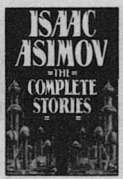

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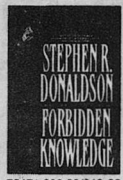

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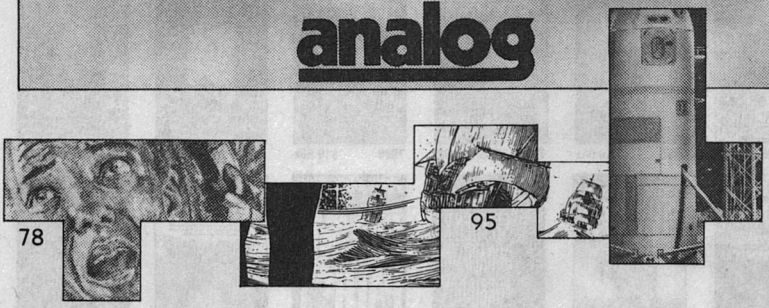

Vol. CXII No. 12
October 1992

Next issue on sale
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Novelette

Science Fact

Short Stories

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Editorial

EX POST FACTO ETHICS

Stanley Schmidt

One of the important protections provided to United States citizens by their Constitution is that against ex post facto laws. This does not quite mean, as it may sound, a blanket prohibition on any and all retroactive legislation. It does, however, protect us against such horrors as doing something considered innocuous today, such as mowing lawns on Tuesday, and finding that next week it's a capital offense—even for people who only did it last year.

Ironically, no such restriction seems to apply to the current fashion for passing judgment on our ancestors (who are no longer able to defend themselves). Presumably you, like I, have recently been hearing a great deal of condemnation of people long dead for violation of "ex post facto moral laws."

The most obvious example, which prompted the timing of this piece, is the swelling chorus of Columbus-bashing as we approach the quincentennial of his "discovery" of America. There's no shortage of others, though, such as students and teachers railing against George Washington and Thomas Jefferson because they kept slaves.

To most of us now, slave-holding seems self-evidently indefensible. It would be hard to deny that many of the things that happened to Amerindians* in the wake of European contact, for some of which Columbus was personally responsible in his later years, were tragic and, with hindsight, should have been avoided. To us, they look obviously and blatantly immoral; and many

*I choose this term as the least objectionable semantically of the available choices. "Indians" is clearly ambiguous and potentially misleading. "Native Americans" is only slightly less so, since the Iowa-born son of Swedish immigrants is just as much a native American as a pure-blooded Apache. "Amerindian" may be cobbled together from historical roots which are themselves misleading, but it at least has the virtue of being a single word that never means anything else.

people, perhaps rightly, regard moral laws as objectively real and taking precedence over criminal or civil law.

In evaluating people's actions historically, it is necessary to look at the total effect of those actions, insofar as that can be determined. But in deciding how historical figures should be judged as individual human beings, once as real and alive as you or I, is it really fair to condemn them for violating moral principles that didn't exist or weren't known when they did what they did?

Not that Columbus or Washington or Jefferson is likely to give a fig what we think, at this point. But if we want to have an accurate picture of history, part of the "coloring" of that picture is the moral judgments we make about it—so those, too, need to be made with care. And even though at least most of us will eventually be as oblivious as our ancestors to what our descendants think of us, many of us are motivated at least in part by the desire to be viewed kindly by our heirs. If we are to have any hope of achieving that, or of judging our ancestors as they deserve to be judged, we must look at people's actions in terms of the moral context in which they lived.

And that, though many balk at admitting it, evolves.

Many people would argue that basic moral principles never change—but people's perception and understanding of them does. Consider a physical analog or two. We cannot dismiss Isaac Newton as incompetent because he didn't know about the Michelson-Morley experiment or the photoelectric effect. We cannot dismiss ancient believers in phlogiston or a geocentric universe as stupid because they didn't take account of observations or theoretical models not available until long after their deaths. We can judge the quality and importance of their contributions to understanding the universe only in terms of what they did with the knowledge available to them.

What the current Holier-Than-Practically-Everybody contingent is trying to do as it rewrites history is very much like demoting Newton to "unimportant dabbler" because he didn't understand quarks. There's no way he could reasonably be expected to suspect the existence of quarks, much less understand them.

Is it any more reasonable to expect a slaveholder to flatly reject the concept of slavery if he was born and raised in a culture where slavery has always been taken for granted by everyone he's ever met?

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Some would say yes. (It's so *easy* to make such judgments of *other* people!) People must strive to do what is right, they tell us, regardless of social context. Conformity is not an excuse. What everybody else is doing is irrelevant; if it's wrong, *you* shouldn't do it. Ironically, we hear this even from people who advocate strong pressure to make others conform to what *they* think is right. But we also hear it from people who try very hard to avoid unnecessarily imposing their tastes and values on others, and to determine what they should do and then do it despite social pressures. The ability to do the right thing in spite of peer pressure is often seen as a measure of strength of character. I have often taken such a position myself, and I suspect you have, too.

However . . .

There's more to it than that. While "everybody else is doing it" is no excuse for doing something you *know* you shouldn't, it's not always easy to know. People's ideas of what they should and shouldn't do are shaped at least in part, intentionally and otherwise, by social pressures. Societies build things like schools and churches for the express purpose of inculcating their generally accepted moral standards and values.

And likely as not, later generations will blame the students of those schools and churches if they behave as they were taught—*because generally accepted standards and values change.*

Even if there exists a body of moral law that can reasonably be viewed as universally applicable and time-invariant, the people of any particular time and place are no more likely to have a complete and perfect understanding of it than they are of the analogous body

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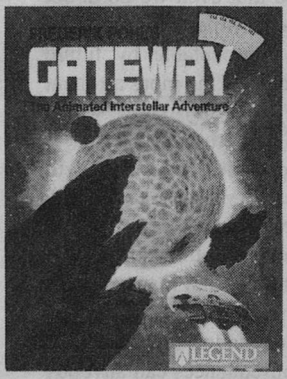

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of physical law. It now seems self-evident to many of us that people should not enslave others or base their treatment of them on skin color—but history shows that these "self-evident truths" were attained only through long and bitter struggles, vestiges of which still smolder and occasionally blaze. Washington and Jefferson were close to making the breakthrough; there is evidence that they were at least somewhat aware of the disharmony between the institution of slavery and the principles on which their new country was based.

The important fact, too seldom realized, is that the jump from where Washington and Jefferson lived to the conviction that slavery is flat-out, intolerably wrong *is* a major breakthrough. It's as large and difficult a paradigm shift as the jump from Newtonian physics to relativity and quantum mechanics. You *cannot* sensibly say, "Everybody should have known it and acted accordingly," and expect to be taken seriously.

If we really want to see our ancestors as they were, and form fair opinions of their character, we *cannot* expect them to have known and believed everything we know and believe. We have to recognize that there were major paradigm shifts between them and us, and that those are very, very difficult. If we want our descendants to think well of us, we had better hope they understand that, too.

Key question: To what extent are people responsible for their own ethical decisions, and to what extent can they be forgiven for basing them on the prevailing beliefs of the times and places in which they lived?

The current fashion seems to be a hard line of making no allowances for the latter and demanding absolute infallibility, by *our* standards, in the former. But those who hold that hard line would be well advised that even we no doubt hold ethical views which will be found primitive and unacceptable by future generations. Some of the more arrogant among us are sure they know which ones those are and are busily trying to reform everybody else. Only time will tell which ones they *really* are. Those of us who care what posterity thinks of them had better hope that posterity is more understanding than many of us!

One more question, directly relevant to the Columbus matter: how far down the chain of consequences can anybody be expected to look in deciding on a course of action? How remote and indirect an effect can be used to say, "You should have known better!" and justify punishment (or, if it's too late for that, historical blacklisting)?

Some of the more extreme Columbus-bashers look at the plight of the Amerinds and the smog over Los Angeles and conclude that Columbus was wrong even to leave Spain. This is a monumental leap of logic. Do they *really* think Columbus could rationally have been expected to foresee, even dimly, any of that? If you look only at what he and his advisers could know or surmise before setting out, it's very difficult to see any moral objection that could reasonably be made to his first voyage of exploration *per se*.

Later, his claiming of occupied lands, kidnapping, and enslavement of

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natives were clearly reprehensible by our standards. Even they were less clearly so by those of his contemporaries. At that time, the nature and status of the native Americans was a genuine puzzle. Many Europeans honestly did not know whether they should be considered and treated as human beings like themselves, or as something else. The fact that we see no puzzle there does not change the fact that they did.

Admittedly they too often chose the answer most convenient for their own greed. (How fortunate that nobody ever does *that* any more!) Controversy over the Amerinds's nature and status grew quite heated in Columbus's lifetime—see, for example, Fra Antón Montecino's famous sermon in 1510, arguing passionately for the natives' full humanity and against the Spaniard's brutality. But what people of our time too easily forget is that it *was* a genuine controversy, with sincere and fervent belief on at least two very divergent sides.

In the long run, of course, the consequences of contact between the Old and New Worlds were not nearly as simple as they are often made to seem. Benefits as well as evils flowed both ways, and the simplest reasonably accurate description of the net effect is that the two formerly isolated "Worlds" became one, with both its components forever changed in myriad ways. It's almost certainly true that the Amerinds bore more than their share of the suffering. That is profoundly regrettable, and it's something we should try hard to make sure never happens again. But it's highly questionable how much personal blame should be attached to Columbus, and most doubtful that his staying home would have prevented it. The historical forces at work were far larger than any one man. Change is inevitable on a living world, and often somebody gets hurt in it.

A strong case could be made that one important measure of a culture's value to its inhabitants is the ability to cope with change—including surviving contact with outside influences. I realize that some will insist on taking that statement as a disparagement of Amerindian cultures, but it isn't. There is much in those cultures that I would like to see ours learn, and I think very few cultures on our planet have yet developed the kind of strength and resilience they're going to need in the future. It's something we all should work on. (Unfortunately, hardly anybody except science fiction writers has thought much about it yet, so our withstanding contact with "superior" aliens would be largely dependent on *their* having learned, and taken to heart, the appropriate lessons.)

What scares me about the kind of thinking that holds Columbus's expeditions were wrong *per se* is that it could lead humanity to huddle forever on Earth for fear that it might meet and (shudder! gasp!) contaminate somebody out there. This would be a pathetic solution to a poorly conceived problem. Intelligent, vigorous beings *will* explore, and if there are others out there, that *will* lead to contact. The answer is not to cower away from that possibility, but to learn from history and take pains to do it right next time. ■

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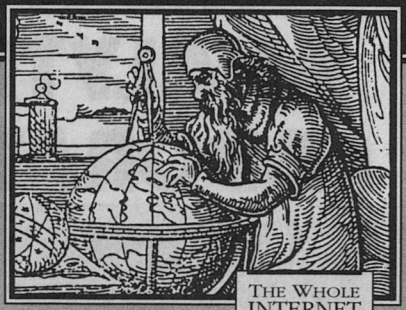

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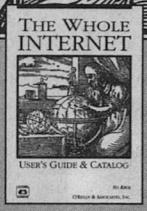

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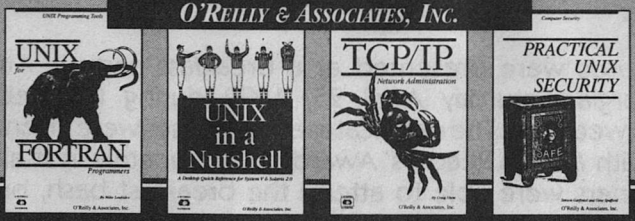

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From left to right: Tina Lee, Stanley Schmidt, Dean McLaughlin, Chris Haas-Heye.

Here's a recap of our winners just in case you missed the announcement in the July 1992 Double Issue:

"Ode to Joy," *Dean McLaughlin*—Best Novella/Novelette

"The Cold Solution," *Don Sakers*—Best Short Story

"The Mote in NASA's Eye," *Charles Sheffield*—Best Fact Article

(tie) December: *Nicholas Jainschigg,* for *Glass Houses*

Mid-December: *Kelly Freas,* for "Try a Light Touch"—Best Cover

The awards were presented at a breakfast party in Atlanta, Georgia, Saturday April 25, 1992 during the Nebula Awards weekend. The certificates and bonuses were given out along with *IAsfm*'s Readers' Awards. Unfortunately, not all of our winners were able to attend the breakfast bash, but a good time was had by all.

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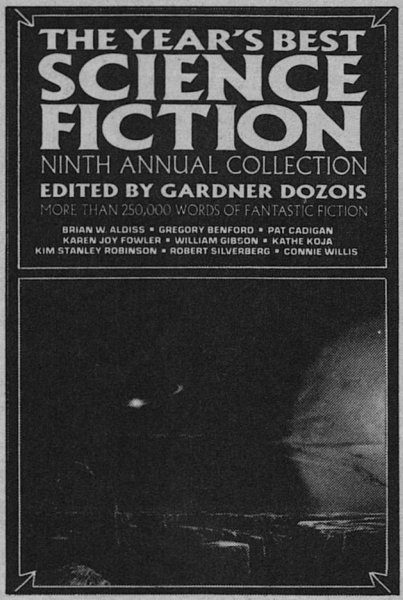

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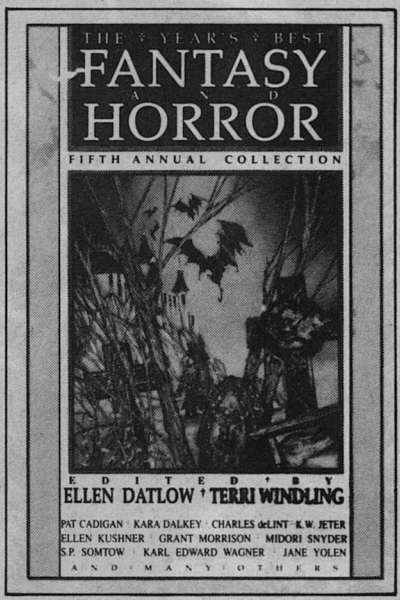

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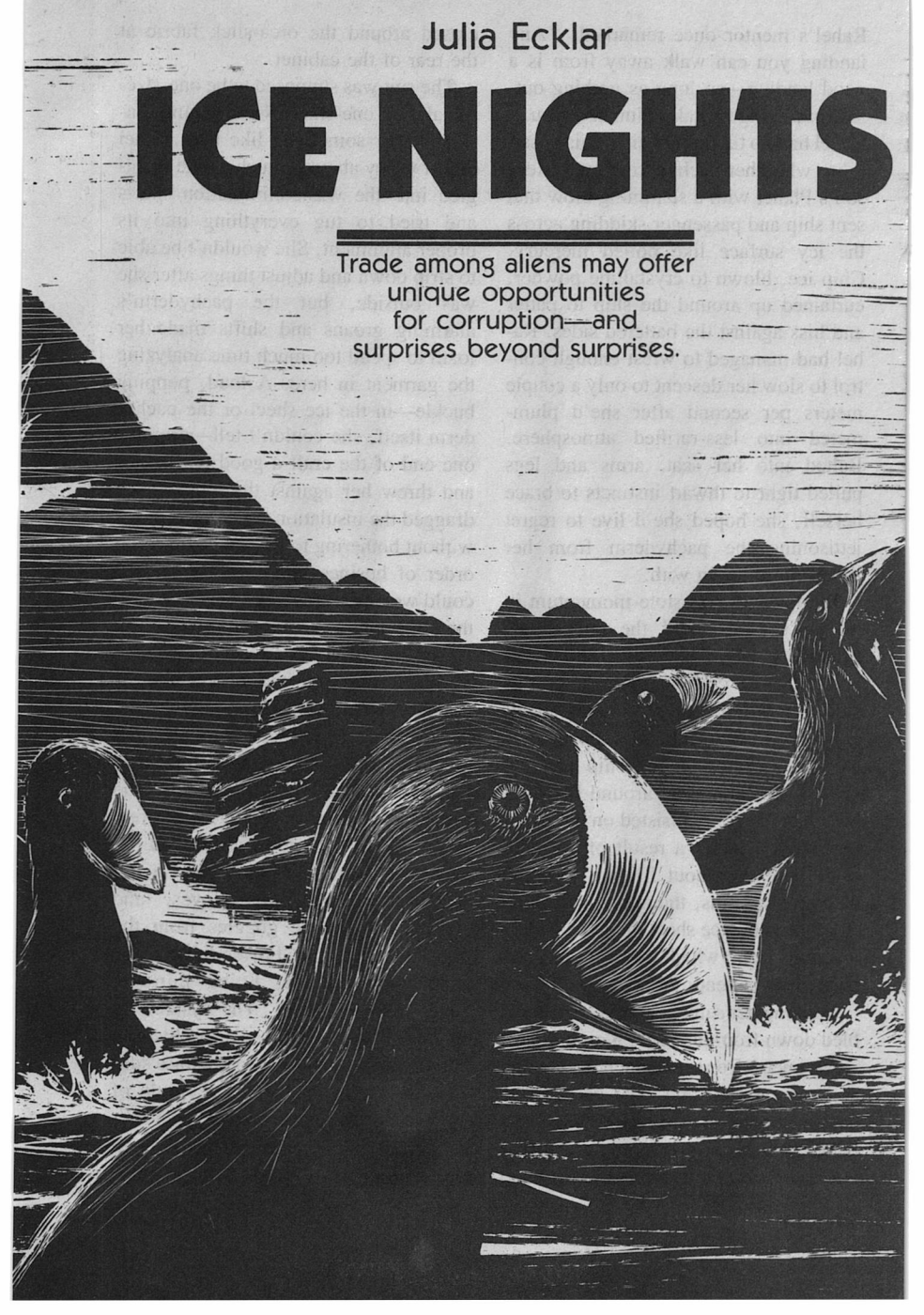

Rahel's mentor once remarked, "Any landing you can walk away from is a good landing—so long as nothing outside is waiting to make a lunch of you." Rahel had no time to consider this possibility when her pachyderm struck Reyson's Planet with a slamming blow that sent ship and passenger skidding across the icy surface like boiled mercury. Chip ice, blown to crystalline powder, curtained up around the ship to patter and hiss against the battered sides. Rahel had managed to wrest enough control to slow her descent to only a couple meters per second after she'd plummeted into less-rarified atmosphere. Belted into her seat, arms and legs pulled tight to thwart instincts to brace herself, she hoped she'd live to regret jettisoning the pachyderm from her jumpship to begin with.

Bumps and jolts stole momentum in jarring spasms, until the tail of the pachyderm languidly overcame its front and the whole craft nearly heeled on its side as it bumbled to a groaning standstill. The hull ticked and popped—Rahel couldn't tell if the ship actually shifted directionlessly around her or if her inner ears only insisted on the phantom movement as a result of the wild ride. Thinking about friction heat and damaged systems, though, she decided that out on the ice sheet might be a safer location from which to wait out the pachyderm's death throes.

Popping her safety harness, she stumbled down from the cockpit on legs still weak-kneed from too much adrenaline and not enough time. The door to the equipment locker came open on her first bang, and she was stripping out of her boots and trousers even before her hand closed around the orca-slick fabric at the rear of the cabinet.

The suit was supposed to be one-size-fits-all, or one-size-fits-everything-reasonable, or something like that. Rahel didn't worry about it much as she struggled into the waste-elimination shorts and tried to tug everything into its proper alignment. She wouldn't be able to strip down and adjust things after she was outside, but the pachyderm's alarming groans and shifts made her loath to spend too much time analyzing the garment in here. A loud, popping buckle—in the ice sheet or the pachyderm itself, she couldn't tell—dropped one end of the craft a good half meter and threw her against the locker. She dragged the insulation suit over her legs without bothering to straighten up. First order of business was to survive; she could worry about being comfortable in the i-suit later.

The suit front sealed with one swipe of her hand, and the hood fit tight around her throat and head. Holding the breath filter away from her mouth with one hand, she used the other to jam her hair beneath the edges of the suit. The tactic only partially worked, and a few errant shreds of dark bangs tickled her eyebrows as she stamped into boots, snapped on skin-tight gloves, and snatched protective goggles from the floor of the locker. "Power down," she shouted to the AI, fitting mirrored lenses over her eyes. The system responded by plunging the pachyderm into darkness, loss of inboard noise suddenly elevating the hiss and spittle of blown ice to even louder than her breathing. She snagged the pack with her testing gear by habit as she bounded

out the door.

Wind caught her like a rough tiger, tumbling her to the ice and challenging her to gain enough traction to scramble farther away. Fractures and upthrusts cracked a crazy-quilt pattern in the ice around the listing pachyderm; she wedged both hands between broken plates and pushed up on all fours. If the ice plates meant to shatter and drop her ship to the bottom of Reyson's polar ocean, Rahel wanted to be as far away from the event as possible. She could always find out later how well an i-suit took to soaking.

A few hundred meters away, where the icescape was no longer jumbled and canted, Rahel turned to look back at her pachyderm and survey the damage. The wind still pushed at her, and her equipment pack bumped her hip with a numb, persistent rhythm, but the i-suit really did keep out the cold, so neither her eyes nor her lungs had frozen solid upon dashing outside. She supposed she should be grateful for such little things right now.

She couldn't tell how far back the pachyderm had actually touched down. A twisted scar of melted ice trailed the ship, its surface already milking up a glossy white as melt water refroze. Not good—that would no doubt be visible from orbit, a long, sparkling ribbon that snaked from one end of the ice sheet to the other. The Colony patrol wouldn't even need IR equipment to pinpoint her crash site, and the impacts made by her jettisoned cargo were probably just as visible.

She chucked at the ground beneath her with one heel. Ice sprayed around her leg in a twinkling of sudden diamonds, whisking away on the ever-present wind as quickly as she'd kicked it up. Rahel grunted. The wind might just scour the evidence away, given the time and snow to do it. It was like a desert out here, all dunes and ripples and ghost siroccos that flashed between grey and brilliant white in the weak sun. A whole world, sketched in black and white. She tapped on the IR function in her goggles and looked down at the sleek white i-suit sheathing her hand and arm. Snow-spattered rock and ground showed up only as patchwork puzzles of nearly-black; the outline of her equally dark hand barely registered against that heatless chaos. That meant both color and insulation would conspire to render her invisible to search, almost as if she didn't exist.

Not an encouraging thought, all points considered.

Switching back to standard visual, she checked out her lonely crash site. The pachyderm rested nose-downward in ice as dirty and rumpled as a rucked-up sheet. Steam feathered around its edges, but it didn't seem to be sinking, and the ice showed no signs of lessening its hold and letting the pachyderm go. In fact, the blossoming frost on the ship's hull looked like the possessive beginnings of ice-lock. Rahel felt the same frigid tendrils creep through her chest, playing with her breathing.

What if they didn't come looking for her? What if the Colony or the mazhet only hunted down her cargo of *eisborne* coffins, snatched up what they wanted of the booty, and left Rahel alone out here to fend for herself? How would she get off-planet then?

Suddenly shivering from more than

simple cold, she swung the pack to the ice beneath her and sat down on it to think about how stupid she'd been to get into this mess in the first place.

When she'd landed at the Colony on Reyson's Planet yesterday, it was not quite 0400 according to her ship time. She'd squinted against the sun on her way off the people mover from the spaceport, combing over-long bangs away from her eyes and wondering how Colony Central would have felt if she'd waited until her own version of "business hours" to apply for their asinine permit. Running stupid errands like this was the only thing that ever made Rahel wish she had a traveling companion of some kind.

Not far down the street stood the real-wood building she'd been told was Colony Central. Garish, angular store fronts—most of them empty—bordered a main street far wider than the meager foot traffic required. It was almost as ridiculously large as the spaceport. Obviously, Reyson's Planet had thought they'd see a lot of visitors when they designed their Colony lay-out. The facilities looked mostly unexploited, though, an uneasy mixture of clean, well-kept facades without the friendly wear and tear of human usage.

Colony Square, as the spaceport mech had described it, apparently didn't exist anymore. (So much for updating electronic memories.) A sculpted artificial landscape took its place—a jumble of off-kilter slabs and water-filled depressions, surrounded by a ditch some good ten meters across. Rahel recognized it as an old-style containment habitat even before she glimpsed the pair of matched vertebrates sharing it. It was the animals, though, that actually made her slow down to take a look.

Externally, they appeared to be felids, although Rahel doubted they were of Terran origin. Both stood a good meter at the shoulder, with fine, square heads and short, nervous tails that flashed white when flicked. Velvety hides paled from sand to cream where they approached bellies and leggings, and cheek ruffs matched the thick white fur that spread across their feet between their toes. The only darker markings on them were the kohl streaks sweeping from eyes to somewhere beneath their ears.

Rahel guessed they'd been somebody's pets for a while. Midday sunlight glinted off hock-cuffs and toe rings; huge, tapered ears jingled from lobes to black-tufted tips with various sizes of gold and silver jewelry. They blinked eyes the same dusty brown as their coats, studying her without the slightest sign of interest or alarm.

"You guys are desert cats," Rahel informed them, leaning her elbows against a chest-high railing that had no doubt been put here to keep spectators from falling into the pit. "Somebody ought to tell your architects you aren't going to do much lounging around in water holes or climbing on slimy old rocks."

One of them flicked an ear. The jangle of its motion sounded like a handful of loose change.

"Not that either of you seem worried."

Someone laughed from a good distance behind Rahel. "I wouldn't bother if I were you." Rahel turned to find a

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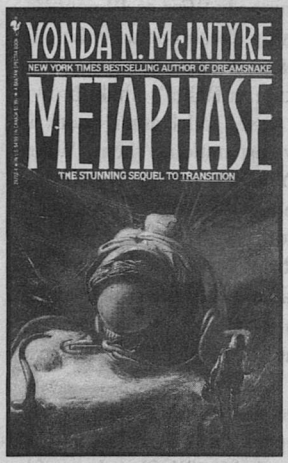

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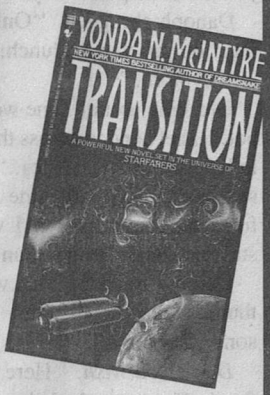

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pudgy older woman in a well-cut suit crossing the wide thoroughfare to join her. Although faded, her tightly curled hair was still red, her eyes still a friendly grey-green. "I think they're trained not to give up caravan secrets."

Rahel didn't waste time glancing back at the habitat. She knew the difference between thinking aloud in front of an animal and actually communicating with it. No sense encouraging some layman's anthropomorphizing just for the sake of small talk. "These yours?" she asked, hooking a thumb back at the exhibit.

"You could say that." The woman offered her hand, then seemed more amused than flustered when Rahel made no motion to take it. "I'm Meis Danoph," she said, returning her arm to her side, "Colony prelate. Welcome to Reyson's Planet."

Well, that was one thing taken care of. Digging into her field vest for the permit chit she'd gotten at the spaceport, Rahel asked, "Do you greet all your visitors personally?"

Danoph shrugged. "Only the ones I meet on my way to lunch. That isn't a lot anymore."

Glancing around, one would suppose not. Rahel handed across the permit chit in lieu of further niceties. "One of your spaceport mechs told me I had to file for a parking permit if I was going to stay planetside longer than two hours."

Danoph took the chit with a smile, thumbed on the display. "Here to do some shopping?"

Don't you wish. "Here to get a ship fixed. You guys had the closest mech 'port when my system went down." She leaned back against the containment railing, fingers drumming on the metal. "Seems a bit chintzy to charge a person for planetside parking when you're already charging them for time and parts on a ship repair."

Her insinuation was wasted on the prelate, though. "Is this information correct?" Danoph's eyes flicked over screens of registration data.

Rahel shrugged. "Far as I know."

"So this ship doesn't actually belong to you." Danoph lifted her gaze from the chit, taking in Rahel's khaki-brown outfit, field vest, and leather boots as though only just noticing them. When she said, "You're a proctor for Noah's Ark," she made the words a statement, not a question.

"Which brings us back to where we started." Rahel jerked her chin back toward the in-progress enclosure and its bored feline occupants. "Are these yours?"

Danoph leaned a little to one side so she could peek past Rahel's narrow frame. "The habitat?" She shrugged. "Of course. The duacs, no. They're with the mazhet caravan."

Rahel remembered the daisy chain of gaudy transports taking up most of the slips at Reyson's 'port, and nodded. "Do the mazhet have to pay for their parking?"

Danoph smiled—a harmless politician smile that neither cut nor burned. "The mazhet have a special arrangement."

Somebody else always had a special arrangement. "So why are you building a shoreline habitat for some merchant caravan's desert cats?"

"Because the duacs aren't the intended tenants." The older woman

folded her lips into a somewhat more satisfied smile. "And I'll bet you're wondering who is."

Rahel snorted, but took back the chit when Danoph offered it. "The thought had crossed my mind."

"Then I'll tell you what." Danoph shoved her hands into her suit pockets in that calculatedly casual way politicians had when trying to bond with the common masses. The gesture always made Rahel want to dump out their pockets to prove there was nothing really there. "Why don't you let me buy you lunch? We've got a native sea bird here that tastes like a chicken except that its the size of a pony." She smiled winningly. "You can't come all the way to Reyson's Planet and pass up on a hesper fillet."

It was too early in Rahel's subjective morning to think about food without her stomach rolling. "No thanks."

"Then let me at least show off our latest zoological acquisition for you. You'll get your curiosity satisfied, and I'll see what I can do about your parking permit."

Never look a gift politician in the mouth. "Why do I get the feeling there's more to this invitation than meets the eye?"

Laughing, Danoph flapped the front of her expensive suit when she spread her pocketed hands in a conciliatory shrug. "Because, my dear, you're a smart girl who learned a long time ago that nothing in this world comes for free." She pulled one hand from her pocket to gesture back the way she'd come. "Shall we?"

Rahel had never actually seen a mazhet, although she'd heard of them, of course. Color swept in a livid cacophony from floor to mazhet skull, swathing a seven-foot-tall body in fabric enough to clothe a small circus. What Rahel could see of the mazhet beyond the robes and bangles looked basically humanoid, but cadaverously thin, and brown as the mud after a rain. He—she? it? Rahel wasn't sure—turned when Danoph opened the door, and huge, whiteless eyes glistened like black oil amidst otherwise minimalist facial features. Its face and spiderlike hands were the only parts of it not hidden beneath a magenta under-robe and an overlay of rainbow-striped silks and clashing ribbons. It raised one hand, five fingers spread, and the ringing of its caparisoned sleeve nearly drowned out the rapid tick-clocking of its voice.

"Is there some problem, Prelate Danoph, that you return so soon?"

The human words hadn't come from the mazhet, but from the slim human male who hurried to join them from within the mazelike collection of equipment that filled the room. Despite a head shaved to sport only a silky brown topknot, he was still more conservatively dressed than the mazhet, his simply-cut outfit spun in shades of turquoise, aqua, and peacock blue.

"There's no problem, Oro." Danoph aimed her smile at the mazhet, effectively ignoring the small man now positioned just behind and to one side of the alien. "I just ran into a friend I thought might like to see our setup."

Rahel snorted. Only in politics could you go from "stranger" to "friend" in the course of crossing a Colony plaza.

The mazhet rickety-clicked another

string of pops and glottal sounds. Beside Oro, the human stood as still and impassive as marble for all that his voice radiated enough distinct emotion for the two of them. "Friendship has no place in business dealings."

Danoph quirked a little grin. "That's all a matter of syntax, I'm afraid." Then, more formally, "Oro, this is Rahel Tovin, a proctor from Noah's Ark. Ms. Tovin, meet Oro, Speaker of Prices for the mazhet caravan." She indicated each of them with a polite nod, but gave no hint that something like shaking hands would be appropriate.

Willing to live with that, Rahel instead waved toward the mazhet's human companion. "Who's this?"

The mazhet blinked its huge eyes slowly, and Danoph glanced between Oro and Rahel as if trying to gauge the right moment to intervene. Rahel waited, not sure what was so hard about this question, until the human himself finally flushed and volunteered in a whisper, "I am *dhaktu*. Ignore me."

Danoph angled her head closer to Rahel, keeping their communique human-to-human now that the other side had started it. "The *dhaktu* are the mazhet's translators—'the invisible voices.' You're supposed to pretend like they aren't there."

"Ah." Rahel saluted the small *dhaktu*. Leave it to people to build whatever little ego-holes they needed. "Keep up the good work."

"Ms. Tovin is here to see our cell cultures," Danoph continued to Oro, as though the little interruption had never occurred. "She deals with things like this all the time in her work, and I thought she might be able to give us some pointers."

Rahel eased forward a few steps, leaning around the mazhet to peer at the equipment behind it. Oro slid fluidly in front of her to block her view, but not before she had a chance to identify at least two full banks of cell cloning chambers.

"This is not advised," the *dhaktu* announced in translation of Oro's clicking.

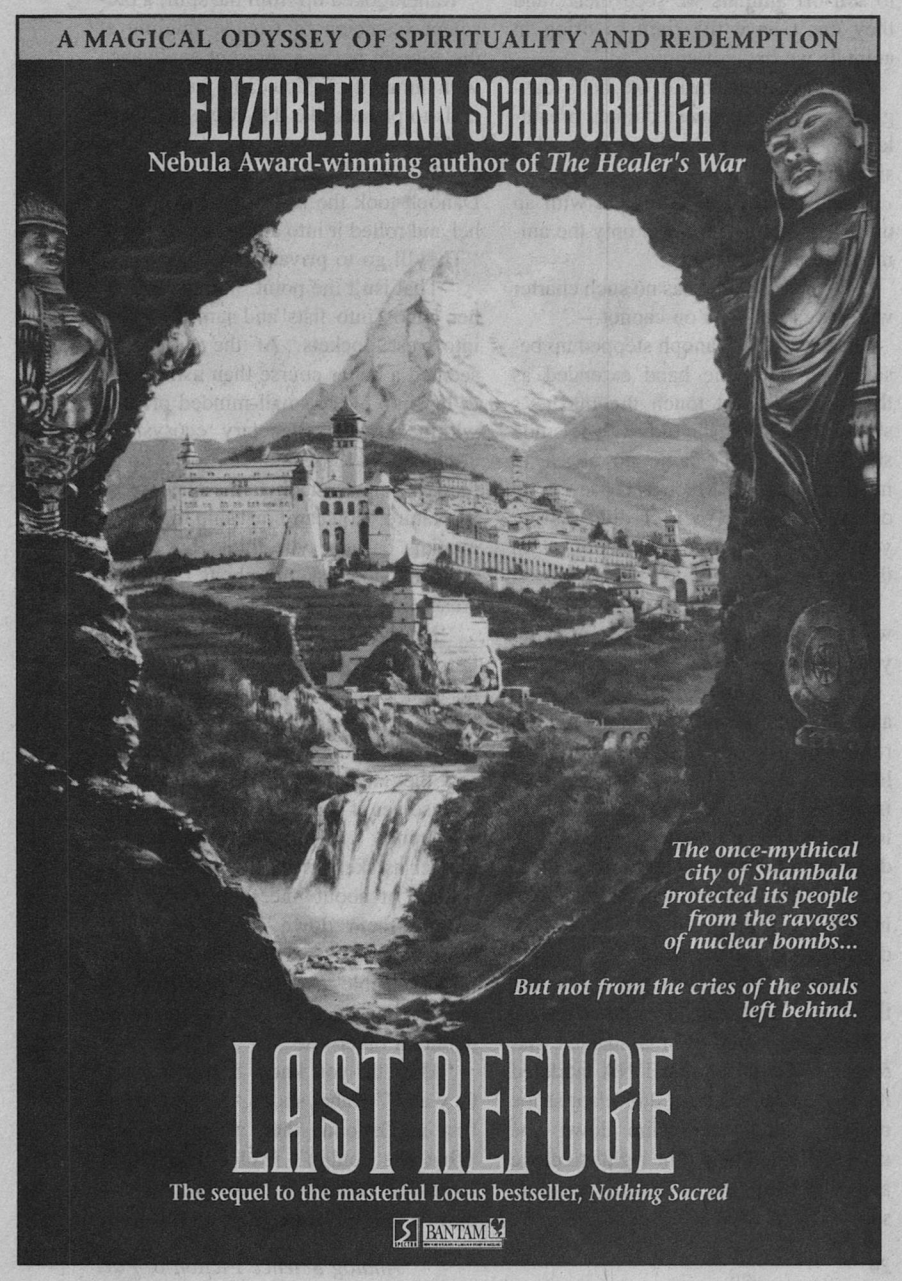
"Don't get your burnoose in a knot." Rahel ducked around the tall mazhet, pretending she couldn't recognize that its explosion of jewelry-bright gestures meant it was unhappy with her boldness. "I won't touch anything."

"You work for a company which often seeks to restrict mazhet trade," the *dhaktu* translated in mimic of Oro's strident protest. "Damage might be caused without your touching."

"Noah's Ark only restricts your trade when you try to mess with animal populations." The cell cultures ran in age from brand new to almost sixteen weeks. Because she'd promised not to handle anything, Rahel didn't try to call up projection data on the reader. It was obvious they were shooting for a mature animal, though, and not just a sheet of organ cells.

Oro made a noise remarkably like a human sniff. "Colonies should have the right to barter with whomever they choose."

"Except for when they're bartering with goods that don't belong to them." Rahel straightened, and turned to face the mazhet. "Noah's Ark *owns* those planets, Mr. Mazhet—the colonies we stop you from trading with only have charters there. They don't have the right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to sell off animals we seed there, and they don't have the right to bring in animals we haven't approved."

Oro cocked its head; the bells dangling from its headpiece chimed breathlessly. "Mazhet deal in many things besides animals."

Rahel returned its comment with an un-belled shrug. "But it's only the animals we interfere with."

"Reyson's Planet has no such charter with Noah's Ark. You cannot—"

"Look . . ." Danoph stepped up beside Oro with one hand extended as though she might touch the mazhet's sleeve for all that she didn't. The smile she flashed Rahel came no closer to making contact. "Much as I love a good debate, Proctor Tovin, I didn't bring you here to argue trade restrictions with the mazhet."

Just as well. Rahel wasn't in love with the subject, either. "Then why did you bring me?"

"For this." Danoph abandoned Oro and the *dhaktu* only long enough to rummage a nearby desk top and shake loose a wrinkled flimsy. The mazhet's immobile face looked no different than it had the moment Rahel walked in the door, but Oro's hands had drifted up to chest height, pressed together as though in prayer except that the fingers drummed arrhythmically.

Rejoining them, Danoph shook out the flimsy and extended it to Rahel. "That's the spin from a mazhet *eisborne*." The unfamiliar DNA laddered its way up the sheet, a dark data stripe running straight and slim down one side. "We've bought the rights to clone and distribute the *eisborne*, pending success with what we're doing here."

Rahel looked up from the spin, a prescient suspicion of trouble tingling at the edge of her ever-present annoyance with humanity. "You can't just sell animals to planets like they were pieces of art."

"We won't sell them to planets." Danoph took the flimsy back from Rahel and rolled it into a tube in one hand. "They'll go to private owners."

"That isn't the point." Rahel wound her hands into fists and jammed them into vest pockets. At the time, that seemed a better course than using them to lay into every small-minded primate within range. "Planetary ecosystems are balanced things—the ones set up by the Ark just as much as the ones set up by Nature. You can't just ship in foreign animals because you think they're exotic or cute. Ask me about rabbits in Australia."

"No, no, no—you don't understand. Pets." Danoph flashed a smile rehearsed to be both mollifying and confident. "We're selling the *eisborne* as pets. They won't be able to reproduce, and they won't be fit to take care of themselves if turned loose anywhere." Apparently taking Rahel's hateful glower as skepticism, she bent to level a hand at about knee-height. "We're scaling them down—about one one-hundredth their current size, to make them feasible as household companions. They're just too expensive to maintain otherwise."

"How do you know how expensive they are?" Rahel shot a searching glare first at Danoph, then at the mazhet. What she couldn't read on both their faces was enough to make her stomach burn. "Have you got a full-sized

specimen?''

Danoph's gaze flicked sideways toward the mazhet, almost as though she hadn't meant it to. Oro moved not at all.

''The mazhet do,'' the prelate finally admitted. Oro creaked some broken sound that the *dhaktu* didn't translate. ''Right now, we're working off specs and collected samples. We'll take possession of the existing *eisborne* after work here verifies we can get what we want from them. Within agreed cost parameters, of course.''

Of course.

''The mazhet have promised us these are the only animals in existence, so no one else will be able to do what we do. We'll have a solid monopoly.''

A surge of focused anger burned all along Rahel's bones, finally cracking free as words. ''I'm not going to help you destroy an entire genotype just so you can supply pets to any idiot who wants one.''

Frowning, Danoph said, ''That's all right. I don't want your help.''

Caught off guard by the prelate's confused admission, Rahel felt her insides coil the way they always did when she got cornered by anything. ''Then what am I here for?''

Danoph shrugged, her hands coming primly together in front of her. ''To see what we're doing, so we can show off.'' Another shrug lifted her broad shoulders. ''I thought you might be interested.''

Rahel snorted, folding her arms and leaning back against the counter behind her. ''Bullshit. Anybody who wants something that simple is either stupid or maneuvering. You don't seem very stupid.''

Her mask of polite attention never wavered, but the prelate at least had the honesty to blush. ''I think that's rather cynical, Proctor Tovin.''

Rahel grinned at her, not meaning it to seem friendly. ''Is it?'' She jutted her chin toward Oro. ''Where did you get it?''

Danoph stirred a little uncomfortably. ''Get what?''

Leave it to the politician to answer while her cohort the businessman only blinked wisely. ''The *eisborne*,'' Rahel persisted, not taking her eyes off Oro. ''The full-sized specimen you're using for down-sizing and the mazhet are using to procure samples. I want to know where they got it.''

Oro clicked sharply, briefly.

''That is not your concern,'' the *dhaktu* said.

Rahel shrugged. ''That depends.'' Pushing away from the counter, she leaned toward Danoph with her arms still folded across her chest. ''The one loophole in your plan, Madame Prelate. The Ark owns a lot of animals who are struggling as the last few of their kind. If the mazhet lifted this *eisborne* off an Ark-owned planet, that's poaching. That's stealing. That's *illegal*. We can confiscate everything you have here.'' She twisted a look back at Oro. ''Including your full-sized original.''

If Oro considered that a threat, it showed in neither the mazhet's muted clicking or the *dhaktu*'s translation. ''It came from nowhere you would know.''

''Prove it. Let me see it.''

''No,'' Danoph interjected sharply.

Oro's single click translated simply as, ''Unacceptable.''

Rahel tossed her hands in the air. "Then I'll look for you all on the legal net." She slipped past Danoph and the mazhet without touching either on her way toward the door.

"Wait a minute." The prelate moved quickly to cut her off, still composed and in control despite a face made almost honest with concern. "We don't have possession of the *eisborne* yet." Her voice came out low and grudgingly, as though she didn't want Oro to hear for all that the small room assured it would. "The mazhet are storing it in a neutral location until we finish negotiations—that's their rule, not ours." She met Rahel's dark eyes unflinchingly. "It isn't fair to punish Reyson's if it turns out the mazhet have lied."

"Mazhet barter. Mazhet do not lie." Oro didn't leave the rack of equipment to join them, but its body trembled with agitation, multi-hued vestments shivering with whispered ringing. The *dhaktu* stood in almost-mimic of his mazhet's stiff stance. "Noah's Ark should not be here, should not interfere."

"What's the matter, Oro?" Rahel wondered if reading emotion into any of the mazhet's gestures was any different than people thinking their cats were happy because they appeared to smile. "Don't you trust me?"

The mazhet blinked at her, black eyes glossy and unreadable. "No deal has been constructed between us. Trust is irrelevant."

"Good point." Slipping the permit chit from her pocket, Rahel flicked it to Danoph. "Well, I kept up my end of the deal—I looked at your stupid zoo project. Now you keep up yours." She nodded toward the *dhaktu* and Oro, and couldn't help her scowling. "I can't say it's been a pleasure doing business with you."

The mazhet click-popped a quiet answer, and the *dhaktu* bowed almost double in reply. "May it be so before the finish."

After an hour or so of sitting out on the arctic ice sheet, Rahel finally decided the pachyderm wasn't going to sink beneath the tundra. Standing, she picked her way across the rumpled ice and let herself back inside the ship. She had a lot of things to do before she let Danoph or the mazhet find her—it was time she started doing some of them.

The pachyderm's chameleon came up without protest. She ducked outside to make sure the layer of photocells actually reflected the surrounding landscape enough to camouflage the vehicle, though, not willing to trust the inside readings. Confident her craft would be mistaken for another chunk of ice amidst many, she let the outside hatch hang open while she collected what she needed of her gear. Any heat leakage from inside—not to mention the external dissipation still steaming up the cracked ice plate—couldn't be prevented, so she might just as well try to equalize what temperatures she could before walking away. With luck, nobody would search these ice sheets for at least another several hours.

She snapped on a bioscan bracelet, took her testing pack, her notebook, a snooze rifle, and the grav-dolly. She stuffed the dolly in her pack and swung the rifle over one shoulder, keeping the notebook in hand for the sake of locat-

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ing the larger system's projected landing sites for the cargo. The closest coffin was still more than ten kilometers away. She kept the notebook tucked under her armpit in a vain attempt to protect it from the cold, and occasionally tipped her face toward the sky in case something in its dusty, watery brightness could guide her. No such luck. She had to satisfy herself with believing the notebook's instructions while threading a path among blow-holes and dunes of snow.

Trust—even of some hand-held machine and its data—didn't come easily just now.

She'd gone back to her ship after meeting Danoph and the mazhet, burning to be able to slam the jumpship's sliding hatch. Instead, she tore off her field vest and slung it across the bridge toward the passenger's chair. It struck the edge of the seat with a soft, unsatisfying sound, then slid into a heap on the floor.

The Reyson's mechs had 'linked her while she was in-Colony. They'd finished their tinkering, her jumpship was operational, she could leave anytime she chose, just 'link traffic control for clearance whenever she was ready. Oh, yes—and they'd debit the repairs to Noah's Ark, along with any slip rental fees necessitated by late departure. She erased the note with a snort, not even bothering to acknowledge.

Behind that, she found a message from the mazhet. Rahel assumed the face on the screen wasn't Oro, but didn't know for sure how to tell. Scarlet and vermilion scarves poured in livid waves from its tight, turbanlike headdress, and a veil of woven chains and ribbons fastened at cheekbones and nose to hide every feature but its eyes. No audio—neither mazhet clacking nor *dhaktu* words—accompanied the image for all that the comlink indicated a full AV channel. Sounds of distant industry occasionally invaded the signal, though, rumbling an unknown counterpoint to the mazhet's silence. After some forty-five seconds or so, the 'link was simply broken. No follow-up message had been received.

Rahel swore and erased that message, also. Let the mazhet have their fun being mystic and alien; she had other things to worry about.

Punching up the quick-code for Noah's Ark, she threw herself into the pilot's chair and let momentum spin it while waiting for her call to go through. She only made a rotation and a half before friction slowed her to a stop.

"Impatient and angry, as always."

She kicked off with one foot, swinging the last half-turn to face the comlink. Her mentor, Saiah Innis, smiled in a show of even white teeth. "How goes life in the land of safaris?"

Rahel didn't bother plastering on a pleasant expression for him. In the years they'd known each other, Saiah had seen her smile genuinely at least a dozen times. That should be enough for anybody. "People suck."

He laughed, probably the only person in the world who could do so without annoying her. "So you've told me. What is it now?"

She explained about Danoph, the mazhet, and the engineered *eisborne*. All the while, she twiddled with the jumpships's slumbering guidance con-

trols, glared past the ship's front viewport as though there was something there besides the various robot mechanics who whirred and fretted over someone else's repairs, running up a stupendous bill while their Colonist owners no doubt jerked the ship's owners around.

"You're sure they intend to destroy the original specimens?"

Rahel shrugged, an answer she meant to be almost as good as a nod. "They say it's too expensive to keep them, and the prelate talks a lot about preserving her monopoly. Once they've designed perfect genetic material for their midget model, what will they need the originals for?" That would mean yet another animal irretrievably erased by humanity's headlong rush for short-term profit over long-term gain.

She didn't need to say that to Saiah, though. He understood. "I don't suppose they could be convinced to sell the full-sized originals to us?"

"Not a chance. They'll worry we intend to threaten their business by designing mini-*eisborne* of our own."

Saiah's white brows slashed down into a frown. His skin color fell between Rahel's dusty olive and the mazhet's polished walnut, making his expressions impressively severe when his eyebrows came into play. "Noah's Ark doesn't work that way."

"They're businessmen." Rahel kicked the edge of the control panel, to no particular effect. "They don't care how we work."

"Did they let you see it?"

Rahel shook her head.

"Then I don't understand what you want the Ark to do." Saiah folded his arms—frustrated, Rahel knew, with the situation, not with her. "They say they didn't poach it—they aren't going to introduce it into a natural environment—they're following regulations for household pets." He spread his arms, palms up, in a gesture of hopelessness. "If they destroy the original *eisborne* genotype, it's going to be a damned shame, but the Ark can't stop them if the *eisborne*'s not a Terran animal."

Planting both feet on the floor, Rahel leaned over the console to confide in the comlink. "But it is."

Saiah reared his head back, eyes narrow with skepticism. "You said you never saw the animal."

"I didn't have to. I saw the DNA. The prelate showed me a spin—"

"They let you keep it?" he asked eagerly, and Rahel had to shake her head with an aggravated frown.

"No, they just showed it to me. For about a minute. That was enough, though—I *know* a Terran sequence when I see one."

"Oh, Rahel . . ."

She pushed upright again and scowled at him. "Don't 'oh, Rahel' me. I'm not some first-year journeyman who's never had to sequence a spin on my own. I *know* what I saw!"

"All right, fine," he allowed. "But we can't very well get a restraining order on the strength of, 'Tovin's sure about this one.' Get me facts, Rahel. Get me evidence, and I can do something."

She felt her cheeks burn with a mixture of anger and something she didn't care to try and name. "But in the meantime you won't do shit."

"I can't." She knew the remorse in his eyes was genuine, but it still made

her want to spit. "I'll check the Net for evidence of poaching at any of the Ark's planets, but if that comes up negative, there isn't much else we can pursue." He sighed, a deep, paternal sound that she'd grown used to through the years. "I'm sorry, Rahel, but the law is the law. Just like Nature, it's for the good of the overall, not the individual. You're old enough to know that. So finish your ship repairs and—"

She slapped off the 'link with the back of one hand, watching Saiah's image implode on itself and vanish. She'd cut him off enough times before not to worry about how he'd take it. Still, whether he knew it or not, he'd given her the guidance she'd needed.

"The good of the overall," she mused at the empty screen, drumming her fingers on her thighs. What if the overall was only one animal? And an individual was the only thing spanning the gap between continuance and extinction?

She locked up the pachyderm so the repair mechs couldn't wander inside, then headed back for Colony Central with a snooze pistol in her pocket. "Evidence," she grunted.

Fine. If evidence was what Noah's Ark wanted, that's what they were going to get.

Rahel knew the *eisborne* had to be nearby. Danoph's people would have noticed if the mazhet were constantly hopping to some other continent, and the cost of obtaining test samples alone would have prohibited anyone buying the beast if the mazhet had stored the *eisborne* out of atmosphere. Realistically, that left only the mazhet caravan and the Colony itself.

The mazhet had insisted the hiding place was neutral, though, which ruled out the caravan. Within the Colony, there was only one place Rahel could think of where someone could hide something one hundred times the size of a dog and not have the locals know about it—in the zoo habitat constructed to house the creature when it was finished.

She backed the pachyderm out of the jumpship's cargo bay and returned to the Colony in the middle of planetary night. The suspension coffins were in the hollow chamber beneath the unfinished habitat, just as she'd suspected. Temperature control, water circulation, feeding and waste removal equipment filled the circular chamber. Nothing active, nothing set, just enough machinery to hint at what everything would one day be. She wove between boxes and reinforcing columns, aiming for the oh-so-faint hum of electronics on the other side of the chamber.

Four silver-grey suspension coffins, in stacks of two and two standing taller than her head, were crammed against the farthest wall. She stood off to one side, trying to let as much light as possible leak in from the outside door as she felt along the chests for something familiar. Except for a flat readout screen—too faint to read in the dark, even with her goggles—the coffins were identical and featureless. Most likely not of human manufacture, then. "Damn." She'd been hoping to at least identify which poachers were working with the mazhet.

Untangling a small grav-dolly from her belt, she fitted it to one of the upper coffins and carefully lifted it clear of the

others. It torqued strongly to one side, and she was forced to stop and readjust the dolly in search of a better balance. That done, the path through the cluttered maintenance chamber required surprisingly little rearrangement. Apparently, the mazhet wanted to leave themselves convenient access, too.

The coffins stacked not at all neatly down the pachyderm's center aisle, two of them aligned head-to-foot, two wedged kitty-corner atop the others. Shoving the final coffin into place, she dogged the hatch, made sure the chameleon was running, and applied for launch clearance while still on her way back out to the spaceport.

Reyson's spaceport bloomed, flat and empty, at the brim of the horizon. The mazhet caravan made a ruddy smudge of the slips far to Rahel's starboard, but the rest of the field was as white and empty as a salt flat. Rahel grudgingly let the 'port automatics take the pachyderm's controls, winding her hands together into a single fist beneath her chin and waiting for launch control to give her jumpship clearance.

Outside her parking slip, the 'port let her fly the pachyderm again. She eased the smaller craft past her jumpship's bay doors and bumped the hitching bolts that served as the pachyderm's dock. It clunked into place with a rough shudder, and the jumpship's comp 'linked through to announce, "Docking complete. Launch request noted. We have not received required clearance. Shall I begin pre-launch tests?"

Rahel popped her safety harness and bounced to her feet. "Do that. Buzz me as soon as clearance comes through."

"Aye aye."

Wrestling the suspension coffins out of the pachyderm proved easier than jamming them in. Rahel moved as fast as the weighty crates would allow, floating them to hitching positions and bolting them into place in preparation for a hasty launch. If she had time between securing her cargo and getting that damned clearance, she could start downloading whatever the brains in the coffins would give her. That way, even if Danoph or the mazhet showed up to thwart her escape, she could have enough data squirreled away in her own systems to give the *eisborne* genotype a fighting chance.

Thoughts of the mazhet reminded her of the caravan half a 'port away and made her stomach twinge. "Clearance?" she shouted to the jumpship.

"Not yet."

"What's going on outside?"

A monitor mounted near the ceiling danced to life. On it, thin shreds of mazhet color drifted from various points of their caravan to collect together like autumn leaves around a twig. Rahel wondered if they'd received word already about what she'd done. The image was too small to tell if the *dhaktu* was among them, but who knew what other ways the mazhet had of obtaining and disseminating information.

"Shit."

The jump ship, at least, knew enough to ignore that.

"Get us ready to back out of the slip. I want to be on the field when that launch clearance comes."

By the time she reached the jumpship's bridge, the mazhet had strung a scrambled joseph's-coat of color all over their end of the spaceport. Mechs

and admin robots hurried to intercept them, boxy bodies intermixed with slender aesthetes. Rahel wondered if the robots intended to deflect any sign of mazhet aggression, or if they'd just as quickly turn to help the traders once informed of Rahel's actions. She had a feeling she could kiss her launch clearance good-bye once that happened.

The first of the machine folk hadn't even come within clicking distance of the mazhet, though, when the jump ship broke through her worries to announce, "Launch clearance accepted. Prepare for departure."

Her already thrumming nerves zinged with fresh tension. She snapped into her safety harness without even bothering to seal the inner cargo bay doors. "Standard approach on first available gate." Launch pressures pushed her back into her seat as the jumpship coursed steadily upward. "Get me out of system and onto a down-and-dirty route to Eden, quickest you can find." To Eden, she sighed, and the Ark's political immunity.

Watching the mazhet recede from specks, to ribbons, to cloud-obscured visions of nothing, Rahel allowed herself a tentative pat on the back. After all, she'd managed to snatch the *eisborne* off-planet. At the time, that seemed like more than half the battle.

Then, in Reyson's lower stratosphere, the jumpship's systems failed.

The winking of a dozen scarlet lights seized Rahel's attention with a silent terror somehow more frightening than sirens. She slapped aside the monitor she'd been using to review jump gates and talked herself through a board diagnostic. Nothing came up—nothing ran. Like someone had pulled the ship's brains and forgotten to put them back in again.

Fear and anger clenched a bitter taste in her back teeth. She brought up one foot to kick the console edge so hard it twinged her knee. "They told me you were fixed." Leaning back in the pilot's chair, she drummed both heels against the panel, visions of the upcoming surface collision lending vehemence to her useless gesture. *"They told me you were fixed!"*

Yes, they did.

When the thought bloomed, she froze, both feet braced against the panel. "They did," she said aloud, and the sound of her voice startled her into standing. The 'port mechs had told her the ship was fixed, hours and hours before she even acted on her cock-and-bull plan to steal the *eisborne*. The bastards had given her launch clearance after she broke into Colony property, had held off the mazhet long enough to let her get out-Colony. Hell, Danoph handed her the *eisborne* puzzle in the first place, for no reason any politician or businessman would consider reasonable.

A new surge of fury made her punch the empty chair. Somebody had just located and stolen a commodity from somebody else, and a certain Noah's Ark proctor had been the unwitting agent. Rahel had a feeling she also knew which somebody's neck would be in the noose if fingers had to be pointed—and if she survived the crash. She wished she hadn't confined all of her deceased terrier's dog toys to the pachyderm; she could have stood with

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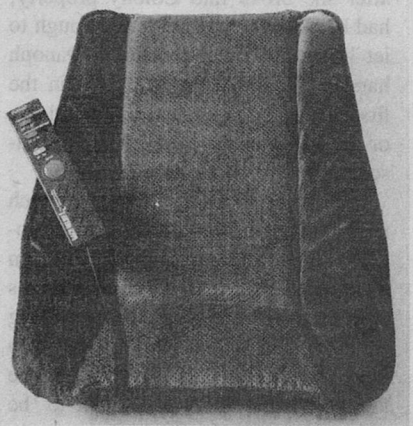

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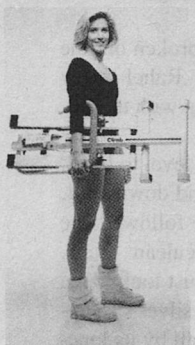

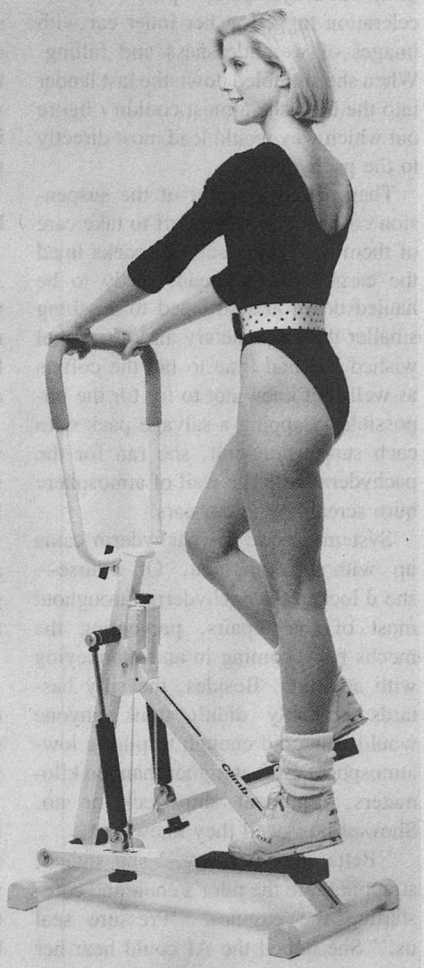

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something to throw right now.

The route back to the cargo bay was short and unusually treacherous. Manufactured gravity kept her feet on the deck, but the jumpship's planetward acceleration tugged at her inner ear with images of weightlessness and falling. When she stumbled down the last ladder into the bay, she almost couldn't figure out which way would lead most directly to the pachyderm.

Then, catching sight of the suspension coffins, she veered off to take care of them first. Auto-salvage packs lined the cargo bay bulkhead, ready to be hauled down and strapped to anything smaller than a planetary aircraft. Rahel wished she had time to tag the coffins as well, but knew not to try for the impossible. Slapping a salvage pack onto each suspension unit, she ran for the pachyderm with the wail of atmosphere burn screaming in her ears.

Systems inside the pachyderm came up without complaint. Of course—she'd locked the pachyderm throughout most of the repairs, preventing the mechs from coming in and monkeying with anything. Besides, the silly bastards probably didn't think anyone would be stupid enough to pilot a low-atmosphere craft at higher than ten kilometers, imminent shipwreck or no. Showed how well they knew her.

"Better than nothing," she sighed, strapping into the pilot's chair and cold-starting the engines. "Pressure seal us." She hoped the AI could hear her above the growing roar from the outside hull. A sudden, gentle push against her eardrums was as good as an answer.

She patched into the cargo bay's system from the pachyderm and blew the bolts on the coffins, one by one. They'd survive the dumping, she assured herself—even human suspension units were, by definition, built to preserve their contents through almost anything short of a nuclear blast. Besides, so long as cell cultures could be harvested from the *eisborne*'s bodies, the species wouldn't truly die, so the lives of the individual animals were somewhat optional.

She didn't feel quite the same about herself, however.

I'm not going to be some stooge just so you can queer a business deal, she thought across the kilometers at Danoph. The pachyderm shuddered as its last restraining bolt blew free. *Just see if you find these* eisborne *before I do.*

She jettisoned the contents of her bay without a single thought for her own safety. Beyond, of course, a half-formed hope that the pachyderm wouldn't shear apart under the stress and that she wouldn't end up falling to ground like the suspension coffins and their unknown, precious cargo.

When she reached the broken outline of the first shock ring, Rahel knew something had gone wrong with the salvage pack.

Hopping gingerly from level to level, moving slowly forward and downward, Rahel felt as though she followed the stringer of some herculean stair. Christ—the impact site must look like a bull's-eye from orbit, the silver suspension coffin thumb-tacked all by its lonesome to the center of a dozen jagged, concentric circles. Rahel only hoped enough of the coffin had survived to yield up either data or physical samples.

Or both.

She slid down the last few meters of break-up, faintly smelling a bitter mixture of burnt metal and ozone despite the i-suit's breath filter. The coffin waited half-buried in the ice, saved from having gone completely nose-down by the salvage pack still attached to one side. Rahel approached it cautiously, leery of burning a hole in her suit. Something had skated alongside the coffin on at least part of its ride down; a palm-wide scar tore deeply into the casing, and one side of the salvage pack had been twisted loose and broken. It was a wonder the cargo hadn't vaporized on impact.

Sliding the rifle off her shoulder, she banged at the ice around the coffin with the butt. Cracks raced about the surface on her first blow, and it took only half a dozen more to loosen the coffin enough to rock it over onto its side. It landed with a less impressive crash than earlier, yet even that little more proved too much for the damaged salvage pack; it skittered off to smack against an ice spar and fall still.

Most of the coffin's control panel had shattered away, and the readout screen wouldn't waken no matter how she poked and pried at it. Plugging in her notebook helped a little. The coffin accepted the notebook as a download peripheral, but wouldn't let her override its systems through that keyboard to pop the tank. Rahel flicked her eyes across the images flashing from coffin to screen to memory and beat back a twist of guilt. Nothing in the data stream gave any indication that the *eisborne* inside the unit had survived. She'd just have to hope the other three coffins had fared better.

Once the download was finished, she attached two different signal tags to the coffin's lid, then two more to opposing sides near the bottom. The tags wouldn't transmit until blipped by an Ark query signal, but she'd at least be able to relocate the coffin whenever she wanted to come looking for it. Assuming she ever got off Reyson's in the first place, of course, or that the Ark ever let her return.

She worked the grav-dolly under the coffin and lifted it as gently as the rocking wind allowed. Frost snapped white splinters like demons' breath on any exposed metal surface; even the touch of her i-suited hands left shriveling dark fingerprints in the crystal patterns. She wished the pachyderm hadn't entombed itself so soon after touching ground. When it came to disposing of four suspension coffins all over Reyson's arctic, even a grav-dolly wouldn't do much to relieve her from the walking and the weather and the somber, wailing white.

Her notebook map promised ocean a mere two hours' walk eastward, and, with it, the promise of sheltering water for the damaged suspension coffin. Rahel tried not to think about how far that would put her from the pachyderm while she towed the damaged coffin over gravel packs and frozen snow. She'd almost decided to just give up and bury the stupid thing in the snow when the unmistakable stench of sea brine and guano crept through her breath mask to make her sinuses cringe.

She crested two more icy knolls before the coast itself came into view. At first she thought it completely rocky, volcanic-black boulders flecked in be-

tween with snow. Then a cry went up at her arrival, and the animals all rolled to their feet amid slapping wings and a sound like the rubbing of old, wet leather.

"Chickens the size of ponies," Danoph had described them. Rahel paused at the edge of the hesper rookery and let the coffin bump her gently from behind. They'd make small ponies, Rahel decided, measuring only a little more than a meter-and-a-half from head to tail, and barely able to stand on their giant, paddlelike feet. They bore the slick feathers and pinless wings of classic diving birds, and the water behind them proved it, boiling with the backwash of hundreds of retreats. Good thing it wasn't clutching season, when uncounted poults would have given the hespers something to stick around and fight for.

Rahel picked her way among the few brave birds who'd stayed, guiding the grav-dolly and its coffin around old rock-and-down nests and the worst of the chalky feces. At the edge of the ice, she tipped the dolly away from her until the coffin broke loose of its own accord and plunged into the slushy black water.

"Sorry," she murmured as the bubbles sheened up in its wake, then broke and danced away. "It wasn't supposed to work out this way." As if human apologies and ill-spent intentions ever undid the damage done by carelessness and human pride.

Out in the ocean, uncounted hesper heads bobbed on the seesaw waves, gossiping among themselves while she turned and trudged back the way she'd come.

* * *

Clashing colors enlivened the arctic horizon like crocuses braving a late-spring snow. Rahel counted nine stick-thin figures and four shivering duacs before dropping belly-flat to the ice with her testing pack beneath her. Dammit. She'd hoped to have a chance at hiding her data before either the mazhet or Danoph arrived.

It looked like only mazhet so far—lots of flash and color, no one short enough to pass as human. Not even the little *dhaktu*. That meant the mazhet had probably savvied that Danoph wasn't exactly on their side. Rahel fingered the edges of her notebook with its contraband genetic data and wondered which side would leap to claim her if it came down to a debate.

She pumped up the magnification on her goggles and scanned the pachyderm's crash site, trying to decide how long the mazhet had been there. She'd left the site five hours ago herself, and would have been longer if the dimming sun hadn't conspired with her lack of sleep to drive her back to the pachyderm and its promise of warmth and shelter. Even so, the mazhet didn't seem to have done much with the site beside land a sleek, gaudy in-atmosphere hop beyond the pachyderm's nose and track footprints all over the refrozen landing scar.

Corkscrewing curtains of snow hissed across the tundra between them, blocking all but the clamor of alien fabric from Rahel's sight. Still, she could see enough through the blowing torrent to discern the pachyderm's blurry outline. The mazhet hadn't mistaken the chameleoned ship for an iceberg, though. They moved about it with ease, disappearing into its invisible image,

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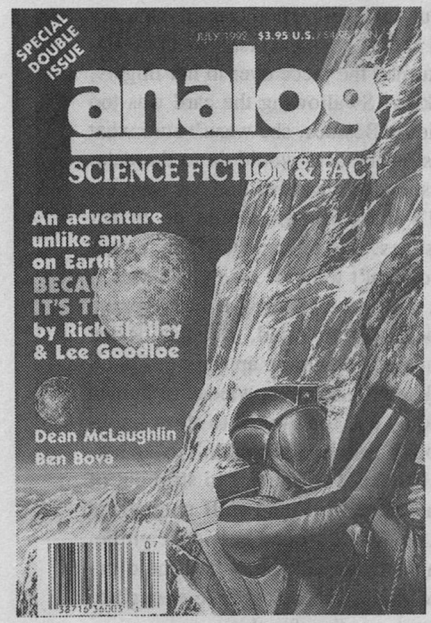

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absently stroking its camouflaged sides. It bothered her that they hadn't deactivated the chameleon. They must recognize it for a device, and not some normal state for the airship. Humans found it distracting to try and navigate around a machine that continually tried to reflect its surroundings and hide itself—didn't the mazhet?

She waved one hand to chase the thoughts away like a pestering fly. The whole point of calling a race "alien" was so you wouldn't waste your time trying to figure out why they did things. No sense forgetting about that now.

She crabbed backwards to the last gravelly bank, slipped behind it to sink down on her heels. Mazhet at her home base severely limited her options. She didn't want to wander back into Reyson's wilderness with nighttime threatening and no pachyderm to come back to. Still, she didn't want to hand herself over to the mazhet just yet, either. If they were anything like humans, they'd search her, take her notebook, and leave her right back where this whole thing started—with a useless jumpship, a couple of feuding businessoids, and a genotype facing extinction. She was starting to feel like the proverbial wolf, willing to chew her own leg off just to escape what she'd stepped into.

First order of business, then: hide the *eisborne* data. She squinted around at the cracked ground and dirty snow. Not really a lot of reasonable hiding places, especially if she wanted to find the notebook again after the mazhet dragged her back to the Colony and had her shipped far, far away. No, she had to keep the data on her. On her, and someplace the alien mazhet wouldn't know to look for it.

She pulled the pack between her knees and tugged it open. Hiding the whole notebook was damned unlikely. Hiding just the data, however, might have some promise. She popped the memory card from the notebook's back, catching the two-cm wafer in her lap while she rummaged the pack with her free hand. It was hard to feel tiny details through the i-suit gloves, but she recognized the hard squares of fresh memory cards when she found them in their customary pocket. A new card slipped into the notebook with a click, and she stuffed the notebook deep into her pack in an effort to make it look hastily hidden. What good was concealing information if you didn't drag a few red herrings across the trail?

But that still left the used memory card and its priceless *eisborne* data. Rahel turned the piece over in her fingers, thinking. Swallowing the card was too obvious. Besides, she wasn't sure what her stomach acid would do to the data, and she didn't want to find out what the card's sharp corners would do to her intestines. Best to skip that, then, unless she couldn't think of anything better.

A few other bodily orifices sprang immediately to mind, not that Rahel found them any more appealing. For all she knew, mazhet knowledge of human anatomy was too limited to allow a useful body search. She couldn't make herself believe it was smart to strip out of a one-piece i-suit and stuff contraband data anywhere around her pelvic girdle, though. Later, maybe, when she'd decided things were desperate enough to warrant courting frostbite.

Ducking her head, she scanned the

length of her body. Nothing there offered inspiration. No pockets, no secret compartments, no jewelry—

She paused, angling a look at her right wrist and the narrow bracelet outlined beneath the i-suit skin. The bioscan.

Pinching the memory card between right thumb and forefinger, she fumbled with her left hand to peel back the long glove cuff. Arctic wind sliced unprotected skin with phantom razors, and she worked the bioscan loose as quickly as she could. Freed, it dropped straight into her lap before her wrist had done more than turn threateningly ruddy. She jerked the glove closed again, and renewed warmth crept over her skin in a flush of tiny prickles.

The Ark had designed the bioscan to warn of approaching life forms, not to be field dismantled. Cursing the lack of finger nails on her i-suit gloves, Rahel finally snapped aside her breath filter to attack the backing with her teeth. Cold air tickled at her throat and lungs, billowing warm steam around her goggles and nipping her lips with numbness. No, this wasn't a good environment to get stranded in, even with an i-suit. She applauded her wisdom at keeping the outfit on. If Danoph or the mazhet didn't find her soon, she'd end up having to turn herself in—whether or not she hid the *eisborne* data—just to avoid freezing to death. Not a pleasant thought, no matter which outcome she imagined.

Spitting the bioscan's backing into her lap, she tipped the open compartment to catch the dimming light. There wasn't a lot of extra room in there—certainly not enough to tuck in a data card from some completely other piece of equipment. She took the card gently between her teeth and poked a finger at the bioscan's insides. Maybe she could make room, though.

The procedure, of course, required struggling completely out of her glove this time. Mindful of the data card, she resisted clenching her teeth against the cold. Her smallest fingernail fit under one of the bioscan's processor chips, and she managed to pop it out after only two attempts. It clattered out of sight amidst the ice-cracked gravel beneath her.

The data card fit a bit too snugly into the vacated slot, but fit it did. Which was just as well—the bioscan was probably useless now, and not worth keeping if it couldn't at least protect the *eisborne*. She smiled a little while snapping the cover back into place, barely able to squeeze the fingers of her bare, cold-whitened hand.

The bioscan felt chilled against her wrist for a long time after she'd wriggled back into her glove and refitted her breath mask. She didn't want to idly wait for the mazhet to tire of her pachyderm and abandon it, but she didn't know what else to do. Pulling her knees to her chest, she wrapped her arms around them and sighed. If nothing else, it would be dark soon. Certainly the mazhet would go back to their ships then, leaving the pachyderm alone long enough for her to get in and bounce a message back to the Ark. That was all she needed—one message, and the time to send it.

I think I'm beginning to hate this place.

Bowing her forehead to her i-suited

knees, she closed her eyes and settled down to wait out the mazhet.

Rahel jerked awake to dark confusion, at first not realizing that she'd just come up from sleep. A whistle of wind raised knee-deep snow mist all around, and, above her, a sky so clear it looked painted on splashed starlight across the tundra. She unwound herself onto all fours, muscle stiffness and growing alertness hinting that she'd dozed longer than just an hour or so. Chilled by inactivity rather than weather, she held herself very still and listened, trying to determine what had jolted her awake to begin with.

It came again, from the north—first as a bone-deep thrumming in the ground, then as a rising howl that itched to the roots of her hair. Thank God for albedo and light-sensitive goggles: snow and ice glowed bright as day against the rocky ground, and the hop that flashed across the horizon blazed with running lights and reflection. A different hop than the mazhet's, though—broader, monochrome, emblazoned with the Colony sigil. Danoph's people. Damn. She'd been hoping for at least a little more time.

Rahel twisted to watch the hop roar out of sight behind her. No search lights cut threads through the darkness, which meant they were probably using IR. Gathering her feet underneath her, she hoped this i-suit was as thermal-tight to their equipment as it was to hers.

A crumbled *chuff* of sound billowed out of the silence left by the hop's wild passage. Barely a disturbance, really—just a rhythmic something that nearly evaporated when she listened for it too hard. Tapping up her goggles' magnification, Rahel squinted across the ice field in search of some color, some movement, some sign of either human or animal.

Nothing. Only permafrost, and gravel, and mound after mound of icy, dirty snow.

She started to turn toward the now-vanished hop, and a triangular flash of black bounced up from one snow mound like a lazily tossed chunk of coal. She focused on it directly, squinting. Not until it changed trajectory mid-flight and swung to face her did she see the glitter of eyes, and recognize the black leather triangle as a nose.

The animal behind the face snapped into focus, her eyes suddenly able to distinguish a square, quadrupedal form against the camouflaging snow even at nearly a kilometer away. Nostrils fluttered the air in her direction, and almost-canine jaws continued to chew on a mouthful of broken ice.

Rahel climbed to her feet, dragging the snooze rifle up with her. She didn't want to shoot anything, but there was no sense being foolish. This was obviously a predator, with great, well-formed incisors and claws as long as her fingers all over its dinner-plate paws. Thick, snowy fur barely stirred in the wicked wind, but it swiveled round, tiny ears to follow every shift in her movements. It measured almost two meters at the shoulder, three meters from nose to rump, with hindquarter musculature that promised phenomenal endurance and power. Jesus. It massed 500 kilos if it massed a gram.

When it swung into motion, pacing parallel to her—watching, but not ap-

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proaching—something tickled in the depths of her memory. Something that knew not to mistake this thing's lumbering amble for slowness, for sloth. Something that remembered six months spent tagging Terran *Ursus arctos* specimens several years after their reseeding on a wild-park planet named Cephes.

"You're Terran," she whispered. The same swinging gait, the same mighty shoulders, the same intelligent stare as this creature had characterized every one of those darker, shaggier cousins. Rahel couldn't believe evolution on Reyson's had so completely paralleled evolution on Terra. Not when she could vaguely recall static graphic overlays from research on that old apprentice project—not when another, more reasonable explanation waited only a suspension coffin away.

"You're Terran," she said again. "I don't know where they got you, or how they got you, but I've seen you before, and you're Terran." She rested the butt of the rifle by her foot and cupped her hands across the muzzle. "You're *Ursus maritimus*, and you've been extinct for almost 300 years."

How the Colony's IR equipment missed the *eisborne*'s heat signature, Rahel couldn't begin to guess. Maybe they'd discounted it as some native animal, reasonably assuming Rahel herself would show up as a much smaller hot spot on their sensors. Bringing up the IR on her goggles, though, revealed she had more in common with the *eisborne*'s signature than she'd expected—the *eisborne* had none.

Rahel switched back to visual, and the *eisborne* reappeared. "Neat trick," she murmured. She'd have to remember to check Ark files for other animals impervious to IR. That was one nice bit of insulation, and without even the benefit of state-of-the-art thermals or long underwear.

Moving slowly around the edge of her sheltering ridge, she peered back toward the pachyderm to check on the mazhet. She saw no lights staining the snow or sky, even under full magnification, but the pachyderm's chameleon had been shut down. Nearby, the takeoff burn from the mazhet's hop made twice-frozen ice gleam like glass. The mazhet could be anywhere, then. If they were smart—and Rahel had a feeling she could safely count on that—they'd left someone behind in case Rahel decided to return. Which meant she didn't dare walk down there with an *eisborne* so close by. Damn, but this was getting complicated. She liked things better when all she had to worry about was hiding a data card and three unsprung suspension coffins.

The Colony hop screamed by overhead again, and Rahel caught herself ducking into a crouch as though that would conceal her. She shouldered her equipment pack as she straightened. Two fly-bys down, too many yet to go. Watching for the *eisborne* to take the bait and follow, she struck out southeastward across the open ground.

The *eisborne* scraped loose another chunk of snow with its paw, tiny black eyes tracking her as she moved clear of the ridge. Hungry, Rahel guessed. Who wouldn't be, after God only knew how long in a suspension coffin? She wondered if the *eisborne* possessed the patience to stalk her all the way to the

seaside hesper colony. While losing it on the tundra might work almost as well, she preferred to disguise the *eisborne* amidst a great source of warmth and movement. IR should blur all to hell along the coastline, and the hespers themselves would form a sort of visual camouflage for the larger *eisborne*. On top of that, the predator would have a hiding place complete with buffet and wet bar for as long as it cared to stay. If only the damn thing would quit playing in the snow and follow.

Stopping, Rahel pivoted to face the *eisborne* squarely. "Come on, you stupid shit." Its great bulk shifted from foot to massive foot, and it drifted its head to one side as though squinting at her from the corner of its vision. "For crying out loud, I'm a tenth your size! What are you afraid of?"

As if alerted by her voice, the *eisborne* swung away to gallop out of sight in the opposite direction of the hespers. Rahel opened her mouth to swear in frustration, only to be silenced by the shush of padded footsteps behind her.

She turned, finger sliding to the snooze rifle's trigger, and impacted with some great force as if she'd met it at orbital speeds. The equipment pack over her shoulder absorbed enough of the blow to burst in all directions, but not enough to keep her from smashing to the ground in an explosion of shock and snapping bone.

Pain seared through rib cage, shoulder, arm, and she squeezed off a spray of rifle fire in primitive muscular reaction. An avalanche of snowy fur barreled over her prostrate form, grinding bone against bone and pounding grey over her vision as it pinned her to the ice beneath enough weight to stop her breathing.

Then it sprawled to a halt on top of her, immobile.

Anguish stretched her on a tightrope between wakefulness and darkness. Trying to raise her head, trying to swallow a boil of nausea, Rahel could barely identify the mass of smelly white fur that buried her. She fell back flat again, almost laughing.

Bigger even than the first *eisborne*—more than twice her body length, and taller at the shoulder than she herself stood—it snoozed for now, but would wake again too soon. She listened to the sound of hot liquid hissing over frozen ground by her ear, and knew she was hearing her own blood. Lots of it, no doubt. The *eisborne* only grunted in its sleep and sighed.

My fault for dismantling the bioscan, she told herself as her vision squeezed down to nothing.

Still, if she was really lucky, the *eisborne* would wake up before she did.

When consciousness finally drifted over her again, Rahel found herself warm, able to breathe, and in at least a little less pain than when she last remembered.

The L-shaped room was bright, and filled with mirrors. The sparkling scent of faint perfume curled over her, but no one stood nearby to murmur reassurances while she struggled to sit up. Her left arm had been strapped, elbow bent, to her side. Shoulder and ribs screamed shrewish complaints about the position, but Rahel thought it unwise to undo her savior's handiwork just yet. The "bed" on which she'd awakened was just the

lounge in a women's restroom, after all—she didn't trust such medical care to hold together through much handling.

She'd been stripped out of her i-suit, dressed instead in an over-large grey T-shirt and men's undershorts. Her hair fell loose across her cheeks and forehead when she rocked forward to catch her head in her hand. Inside the body of the shirt, the fingers of her pinned left arm twitched slightly, responding to some injury just beyond the realm of simple pain. They'd taken her gear, of course. Nothing that tied her to herself or the outside world had been left in view.

When a door somewhere behind her whisked open, she didn't even bother to raise her head.

"None of this had to happen, you know," Danoph said.

Just thinking about turning made her shoulder sing, so Rahel waited for the prelate to move around in front of her before looking up. "Bits and pieces of it, maybe. Overall, you underestimated the Ark if you thought this would be easy."

"Well, I certainly underestimated you." Danoph set a lumpy canvas bag on the floor next to a chair, then turned to seat herself as though ready to conduct a job interview. "How's your arm?"

Rahel touched her elbow beneath the loose shirt. "Hurts."

Danoph nodded with what looked like honest sympathy. "I'm not surprised. I've got a pilot with paramed training who set and patched whatever he could, but you'll still need a doctor to look at that. There's a lot of connective tissue damage in the rotor cuff."

Rahel snorted. "So you locked me in your ladies' room."

Danoph favored her with a tolerant grin, not even moving her hands from where they rested, neatly folded, in her lap. "You're not locked in."

"Isn't denial of medical care considered inhumane under the Second Convention?"

"Nothing's being denied you, Proctor. What kind of woman do you think I am? You'll get medical care as soon as we get back to the Colony."

"Which will happen," Rahel guessed, "just as soon as you get whatever you want out here."

Danoph's only response was to reach beside her chair and heft the pack in one hand. "It's been searched, of course, but nothing was taken." She leaned forward to swing it between them, letting it land with a *thump* at Rahel's feet. "It would have made things easier if you'd stuffed some piece of conspicuous evidence where I could find it, but I didn't really expect that."

Rahel fumbled one-handed with the pack's mouth, trying to keep both concern and too-pure neutrality out of her face. Notebook and bioscan both sat near the top, the first with both memory cards pulled, the latter with its backing askew. She used her thumb to pry the bioscan open without lifting the device. The hidden card was still in its slot, and nothing else in the device seemed disturbed.

"So?"

Danoph's voice made her heart jolt, but she finished latching the pack shut without hurrying. "So? What?"

"So where are the coffins?"

Rahel raised her head, surprised more by the thin slice of irritation in Danoph's voice than by her question. "You've got to be kidding. What do you care?" She pushed the pack off to one side with her foot. "Get new coffins from the mazhet."

Danoph's lips pressed into a frown. "That isn't funny."

"Nothing's funny." God, her arm hurt so bad she didn't know whether to throw up or cry. "You and the mazhet want to destroy an entire genotype just for the sake of a business monopoly, and you tricked me into helping you. Prelate, I'm laughing my head off."

"You? Helping?" Danoph rubbed at the bridge of her nose, a surprisingly human gesture for someone involved in this sordid business. "The mazhet would laugh to know how badly I bungled my working relationship with you." Such as it was. "Trust me, Proctor Tovin—with more help like yours, I'd be forced to retire."

For all it was nice to know she'd managed to inflict some damage where damage was due, Rahel couldn't imagine it was just the cost of search time and fuel—or even four state-of-the-art suspension coffins—that had Danoph staging this negotiation. "You didn't get it." She couldn't help sounding amazed, anymore than she could help laughing when Danoph flushed and glanced off to one side. "You didn't pick up the *eisborne*."

The prelate sighed and pushed to her feet, a certain amount of humor shining through her embarrassment, although not much. "We're in my private hop and the thing massed in at 700 kilos! Where the hell were we supposed to put it without a coffin? You're lucky we managed to get it off of you." She leaned back against one of the mirrors, arms crossed, and waited while Rahel bent to put her face in her lap, wishing it didn't hurt so much to laugh. "Did you know they didn't show up on IR when you took them?"

Rahel shook her head. That spiked enough additional discomfort to make her gasp, and finally stilled her laughter. But the little bubble of amusement inside her didn't go away. "I'll bet the mazhet did."

"So are you saying the mazhet let them out?"

"No." Rahel pushed against her knee with one hand to sit upright. "I'm saying they let themselves out."

Danoph snorted and started to pace again.

"Those coffins are designed to pop either when told to or when exposed to environmental conditions that favor their occupants. Since you made sure I didn't know anything about the *eisborne*, I couldn't very well have picked what environment to drop them in." She grinned again, enjoying Danoph's frustration. "I guess it's your fault for shooting me down over the arctic."

Danoph acknowledged that with a sigh. "All right, fine. But assigning blame doesn't get us back the *eisborne*."

Rahel shrugged her one good shoulder. "And neither do I."

Danoph paused behind her chair, hands on its back, brows crumpled with frowning. "It's to both our advantages. Four animals won't make a viable population here—your genotype will still die out, and now there isn't even a modified

gene set for you to fall back on."

"I didn't have it to fall back on in the first place."

Danoph stared at her a long time, the muscles along her jaw twitching faintly with her thoughts. Rahel stared back with her own thoughts as well hidden as she could make them. It was easy to disguise almost anything underneath enough pain.

"Are you going to make me get mean?" Danoph finally asked.

Rahel nodded. "I guess so."

"All right, then." Moving around the chair, Danoph settled herself again and wound her hands into a fist in her lap. "You've attempted interplanetary grand theft—four counts—with items either the mazhet or Reyson's could legally prove we owned. You've succeeded in local grand theft on at least an intercontinental scale. You've trespassed, violated several intra-atmosphere safety regulations, and I can probably pull out some old environmental laws to slap you for leaving ship litter all over our arctic." She shrugged, obviously not having to put too much thought into this list of offenses. "That's not even taking into account your poor attitude and repeated rudeness. I don't think even Noah's Ark can double-talk you out of this one, honey. You've broken so many local and interplanetary laws, I could make a second career just out of keeping you and the Ark in court."

Rahel tried to ignore the slow twisting in her stomach, thinking through everything Danoph had said. "I hate politics."

"I know you do." The prelate sounded amazingly sincere in her sympathy. "That's why we're going to reach some sort of equitable agreement before any of this has to get ugly."

Rahel gusted a little laugh. "I don't know what you think I have to barter with. The *eisborne* are loose—I can't fix that for you."

Danoph cocked her head, shrugging. "Maybe not. But I'm betting you can find the coffins." She fished into her jacket pocket to pull out an Ark signal tag between two fingers. "I found these among your gear."

Rahel glanced at the tag, looked back at Danoph. It hadn't occurred to her to count her tags when she checked through her equipment.

"If you really didn't know the coffins would pop," Danoph said, "you tagged them before you dumped them or you don't deserve your job. So I'm willing to let you walk just for pointing them out to me." She flicked the tag onto the lounge next to Rahel, returning her hand to her lap. "Surely you have some way to trigger these from outside your ship."

Rahel stared at the tag, a little uncertain what was being asked of her and leery of walking into some trap. "You don't want me to do that."

"But you can?"

She looked up to find Danoph peering at her with intense interest. "Sure I can." She tested the offer again: "But I don't think you want me to."

The assertion seemed to strike Danoph as funny. She smiled and spread her hands in hopeless offering. "And I don't think you want to go to jail." Crossing her arms, she shifted to sit more erect in her chair. "Why don't you weigh both those options, then you

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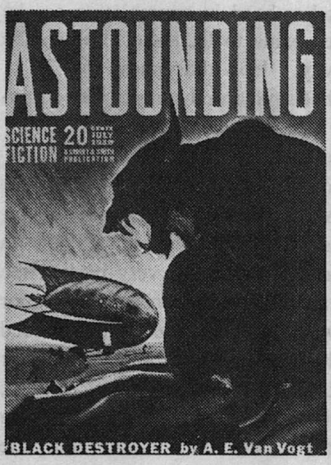

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tell me where we're going."

Not where you think. Rahel bent to unstrap the canvas pack again, hoping this would be the last time for the sake of her injured arm. The notebook powered up at the touch of her thumb, and she blipped a widespread tag query for display against a Reyson's map.

Every Ark tag on the planet shone back a silent signal. The notebook screen displayed each brilliant spot as a winking star, the collection of them at Rahel's feet coalescing into a glowing cluster.

Tracing the tags from the pachyderm would have been easier, of course, but Rahel could simplify the readout enough to suit Danoph's purposes. Blanking out every tag but the few still attached to suspension coffins, she turned the notebook toward Danoph to display the fresh, uncluttered screen.

The prelate rose from her seat with a smile. "You see?" She took the notebook in both hands. "Environmentalists can learn politics after all."

"What good is believing in evolution if you don't occasionally practice it?" Rahel moved one foot to scoot the equipment pack closer without actually looking down at it.

Danoph laughed with genuine delight as she moved toward the outside door. "I'm glad we could come to an agreement about things."

Rahel snorted. "Sure. So am I."

"You'll understand, of course, if I ask you to make yourself comfortable here until we've located the coffins. Would you like anything?"

"Food would be nice."

"Done. How about more painkiller?"

Her shoulder tightened its painful grip as if to encourage her agreement, but knowledge of the silent, shrieking tags beneath her seat overrode it. "No, thanks," she finally sighed with a wan, tired smile. "I think I'd just as soon stay clear-headed. For later."

"You are easily the most troublesome woman I have ever met."

Rahel stood, her pack already waiting at her right hand. "I take it the mazhet are here?"

"You know they are." Danoph shook her head in appreciation as she stepped aside to let Rahel through the doorway. "How did you do that?"

Rahel smiled and gripped her equipment bag. "Sorry—trade secret."

The hop was bigger than Rahel expected, maybe half the size of her jumpship with no huge chunks of volume eaten up by cargo bays. Danoph led her down a tight, very unship-like hallway toward a wood-paneled door that waited already ajar. Rahel noticed that the prelate was careful to match her own casual gait to Rahel's painful limp, but decided not to waste energy being grateful for this consideration until she saw where they were going.

The doorway opened onto a small conference room, complete with pedestal table and hand-tooled chairs. Warring colors filled the far end of the room in the form of three caparisoned mazhet and their little *dhaktu*. Rahel recognized Oro's magenta under-skirt and brilliant yellow headdress from their meeting back at the Colony. Another mazhet, swathed exclusively in pungent blues and orange, stood with both hands resting on the *dhaktu*'s narrow shoulders.

Between those other two, the vermilion and scarlet mazhet who had left the silent message on her comlink waited with such quiescence even its masking screen of chains didn't jingle.

Rahel settled carefully into the chair Danoph offered her, not waiting to see if the mazhet would do the same. They didn't.

"Proctor Rahel Tovin, this is the *dohke* Pij." Danoph gestured slightly to the tall apparition in scarlet. "The *dohke* Pij owns the mazhet caravan parked on Reyson's, not to mention the *eisborne* you so recently attempted to steal."

Rahel raised her hand for a single wave. "Hi there."

The chains on Pij's face veil chimed sweetly as it looked from Rahel to Danoph. Its liquid clicking almost vanished in the ringing.

"In what location is the merchandise?" the *dhaktu* translated from his place on Pij's left.

Danoph glanced unhappily down at Rahel, who only raised her eyebrows in lieu of having anything to say.

"Well . . ." the prelate admitted slowly, "we haven't exactly determined that yet."

Oil-slick eyes turned back to Rahel, and this time she felt the mazhet's attention fasten onto her like sunlight to a stone. One of the three traders started a thin, private ticking that the *dhaktu* made no move to translate. The other two added to the rattle until all voices braided into a single sound, then stopped again.

The *dhaktu* said into the silence, "You were aware, Proctor Tovin, of the arrangement between Prelate Danoph and the mazhet?"

Rahel nodded, trying to decide on which of the party she should be focusing her attention. She decided to stick with the *dohke* Pij on the theory that anyone who owned an entire caravan was probably *de facto* in charge. "After you prove the *eisborne* can be downsized, Danoph pays you whatever she agreed to pay you, and you turn over the four full-sized specimens for her to have her way with."

The *dohke* Pij clicked and rang its reply. "Knowing so, for what reason did you relocate this merchandise?"

"I wanted to keep the deal from going down. But that's not why the theft occurred."

Three pairs of huge, whiteless eyes stared across at her, but none of the mazhet so much as jingled. Finally, the *dhaktu* whispered, "Confusion."

Rahel pretended not to notice the apprehensive frown Danoph flicked her way, scooting forward on her chair to keep eye contact with the mazhet. "Your business associate, Prelate Danoph, decided she'd like your deal better if she didn't have to pay you. So she pushed my buttons, got me all stupid and human, and I did the dirty work for her—I stole your *eisborne*."

"You have no proof I planned anything," Danoph interjected smoothly.

Rahel waved the protest aside. "This isn't a court of law. I don't need proof, I just need them to believe me." Although who could tell just by looking at them? "I think you were supposed to go looking for me back at Noah's Ark," she went on to the *dohke* Pij. "Either that, or you were supposed to believe I'd gone down with my ship, and all the

eisborne with me. Whichever, Danoph was left with her merchandise, and you guys . . .'' She shrugged one shoulder and sat back in her seat. ''You guys were skunked.''

Pij blinked once, slowly. ''But you did not succeed in this.''

Rahel shook her head. ''No.''

''And she did not succeed in this.''

''No.''

''And the *eisborne* are still alive on Reyson's Planet.''

Most of them, anyway. Rahel nodded, not sure what all this was leading up to. ''Somewhere, yes.''

Pij turned its onyx stare on Danoph. ''Reyson's and the mazhet must reach agreement on who will bear the cost of recovering the merchandise.''

''I'll accept the cost.'' Danoph tipped her head as though conceding a well-made point. ''My misjudgment incurred it.''

''This is equitable.''

''Wait a minute!'' Rahel stumbled to her feet, catching herself against the table to glare across at the mazhet. ''I just told you that Danoph tried to queer your deal—and you're still willing to do business with her?''

Pij's veils rang a glittering counterpoint to its speaking. ''An agreement was negotiated. Prelate Danoph's attempts to circumvent that agreement do not negate it.'' It raised one hand toward Danoph in a shower of bright sound. ''She knows her actions will impact all future dealings.''

Rahel barked a bitter laugh without waiting to hear how Danoph might respond. ''You guys just don't have any ethics at all, do you? Those *eisborne* are stolen property—!''

The *dhaktu* clapped his hands to underscore Pij's interruption. ''The mazhet negotiated purchase of the *eisborne* on the understanding that the merchandise was without connection to Noah's Ark.''

Rahel dropped back into her chair, head pounding. ''That's a lie.''

The mazhet bent toward the floor until riots of fabric shrouded their faces. The *dhaktu* hovered behind them, hands making fists at his neckline. ''Proctor Tovin,'' he offered in a tiny voice, ''mazhet cannot lie.''

''Then the poacher who sold them the *eisborne* did.'' She waited for the mazhet to raise upright, but only Pij straightened to peer at her. ''The *eisborne* is a Terran animal,'' she explained, trying to blank the accusation from her voice long enough to keep Pij's attention. ''I know Terran DNA spins when I see them, and I know Terran body configurations when I see them. Since Noah's Ark owns the rights to all Terran DNA not currently tied up in humans, that means somebody stole those *eisborne* from us. I don't know where or how, but they must have.''

Pij coughed a single sound. The *dhaktu* said simply, ''No.''

Danoph moved to put her back to the mazhet, her scowl focused strictly on Rahel. ''When did you have a chance to study *eisborne* DNA?''

''On the ship.'' The lie came surprisingly easily, with no hesitation at all. ''After I stole the coffins, I dumped the data and linked it straight to the Ark.''

Danoph drew back somewhat, eyes narrowed. ''You didn't have time.''

''Prove it. Make your deals with the mazhet and let me go home.'' She

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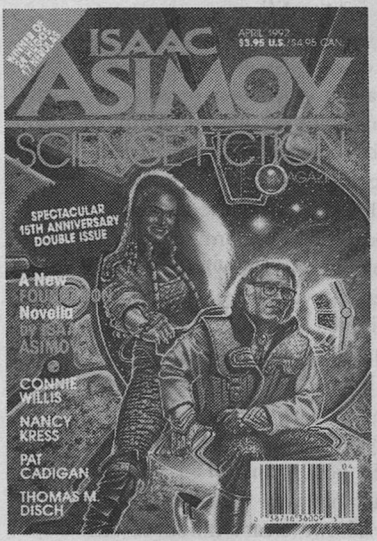

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smiled and watched Danoph's veneer of pleasantry falter. "You'll know in a year or so whether or not we can really bust your *eisborne* monopoly."

"What do you want from me, Tovin?"

Pij's brittle clicking caught all their attentions even before the *dhaktu* translated. "She wishes to barter."

Not so alien after all, these mazhet. Rahel grinned across at them, tapping the end of her nose.

Danoph waved aside the suggestion. "She hasn't got anything to barter." But she paced away from the table with her arms folded tight to her chest.

"I've got plenty to barter. The Ark has the power to completely wreck your plans for marketing the *eisborne*. We've got better cloning facilities, whole planets of breeding space. We could produce *eisborne* so cheaply, you couldn't even give yours away." Rahel made sure Danoph turned to find her smiling warmly, relaxing as best she could in her chair. "Of course, if we can come up with some equitable arrangement, none of this ugliness has to happen."

The mazhet abruptly broke formation, moving toward the door in a flurry of musical movement. Rahel felt her heart drop, unhappy with losing a barter chip so soon after orchestrating its arrival.

The *dhaktu* glanced at her on their way to the door. "You've instigated barter with the prelate," he said hurriedly as they passed. "It isn't allowed that they overhear your barter."

Rahel snapped her fingers, wishing she had two hands to leap up and grab the mazhet with. "Not so fast, *dohke*. This is a deal for you guys, too."

Uncomplimentary colors swarmed together at the doorway, and three sets of liquid eyes fastened onto hers.

"Everybody ready?" When no one protested, she held up one finger and began. "First—the mazhet leave the *eisborne* loose on the arctic sheet, and Danoph considers that fair delivery of the merchandise." She quirked a wicked grin at the prelate. "She even pays you for them."

"Wait a minute—"

"In exchange, Noah's Ark will conduct a habitat evaluation of Reyson's Planet to determine the suitability of adding the *eisborne* to this environment. Free of charge."

"Uh uh." Danoph stuffed hands into jacket pockets, auburn brows crumpled with displeasure. "The whole intent of our agreement was so my people would have unlimited access to *eisborne* genetic material for our program."

"You'll have it," Rahel assured her. "Sample the ones you have living out here, maybe twice a year per *eisborne*. Let us fix your spins when you pull them, and that way you'll keep your captive *eisborne* clean. Introduce artificially variegated specimens every now and then, and you'll have more unique genetic material than you know what to do with inside a few years. And all of it will belong to you."

She watched the prelate's eyes focus inward as though reading through layers of language no one else could see. "All right," she said finally, feeling the words with the edges of teeth and tongue. "I can agree to that."

Rahel threw a questioning glance at the mazhet, and Pij responded by

sketching a meaningless gesture in the air. The *dhaktu* said, "This is equitable."

"You still haven't said anything about my marketing plans." Leave it to a politician to keep matters firmly focused on self-interest. "What assurance do we have that Noah's Ark won't undermine our monopoly the first chance it gets?"

Rahel sighed, regretting her earlier threat on Danoph's future marketing. It had seemed a good idea at the time. "So long as you keep up your side of the bargain, the Ark won't care two beans about your business."

"Not good enough. I want a fee."

"A what?"

"A fee," Danoph said, "a fine. Something to dissuade the Ark from dealing in household domestics, especially *eisborne*." She brought her hands out to lace them stubbornly across her chest. "If Noah's Ark ever produces or distributes *eisborne* of any size in any capacity outside of the Ark's already established functions, Noah's Ark will pay to Reyson's Planet a fine equal to the then-current market price for Reyson's Planet and all its holdings."

It was scary how easily the snare of language spun out of her. "Are you *nuts?*"

Danoph grinned like a fox. "Not even slightly."

"A quarter your going price." She didn't even want to hear what Saiah Innis would say when she tried to explain how all this related to what he'd asked her to do. "Maybe not even that much."

Danoph sighed and her arms fell to her sides. "My Colony's entire economy is riding on the future of our *eisborne* business. If that falls through, we lose everything, including the planet. You agree to full price, Proctor Tovin, or you agree to nothing. No deal."

Something in the area of her stomach started to chew itself into knots when she pictured the *eisborne*'s brilliant construction diluted to something the height of her knee. "Full price," she sighed. It wasn't like Noah's Ark would ever want to develop mini-*eisborne*, so what could be the danger? Besides telling Saiah about all this, of course. "We have a deal?"

Oro broke from the other two mazhet, the *dhaktu* scurrying to stand at its side. "The barter is not finished." It placed itself in front of the *dohke*, both hands splayed to its chest as though surprised by its own clattering words. "In exchange for mazhet compliance in all above-mentioned considerations—" the *dhaktu* blurted the words in an anxious, breathless rush "—Noah's Ark will deliver back to the mazhet all four stolen suspension devices, intact."

Rahel was surprised to feel embarrassment warm her face. "One of them's already wrecked."

"Then Noah's Ark will pay for damages to that unit."

That seemed only fair. "OK."

Oro swept its robes close around it, and all the mazhet finery in the room seemed to catch the sound and sing it. "These dealings are acceptable to all parties involved?"

Rahel glanced at Danoph in search of some annoyance, but saw none. "Sure." The prelate only nodded.

Pij fanned elongated fingers across

the crown of Oro's head. "This is equitable." Then it turned in a dervish of ribbon, silk, and golden chain, and whisked past the little *dhaktu* without pausing to bid them good-bye. The other mazhet followed as though beaded to their *dohke*'s skirts, leaving the *dhaktu* to murmur amenities as he closed the door behind him.

Rahel felt all her carefully-hoarded adrenaline wash into her feet, and sat back in her chair with the shallowest sigh she could manage. It probably wasn't good to let Danoph see how relieved she was to have this over.

"Not bad for a first barter session with the mazhet. You do this evolution thing pretty well."

She opened one eye to squint up at the prelate. "When can I retrieve my pachyderm?"

Danoph laughed and offered her a hand in standing. Rahel accepted it without actually wanting to move. "You can have your pachyderm after you've been with a doctor, and I've been with a lawyer, and both of us have heard from Noah's Ark about their acceptance of our arrangement." She shouldered open the door and held it wide for Rahel. "Once the Ark has sent a ship and somebody to escort you home, you can have your pachyderm and whatever's inside it."

Rahel grunted something that was close to amusement, rubbing at her injured shoulder. "You make me sound almost dangerous. What do you expect me to do?"

Danoph left her to enter the ladies' room on her own. "I have no idea what to expect from you, my dear. That's entirely the problem."

* * *

Somehow, the tundra didn't seem so imposing in full daylight. Rahel tugged her parka tighter around her shoulders, wishing she'd been able to get her left arm down a sleeve but understanding that moving the injured limb wasn't a good plan just yet. Behind her, the pachyderm groaned and hissed as three of Reyson's spaceport mechs labored to cut it free from the ice. One of the *eisborne* had appeared at the edge of the horizon, nosing occasionally at the scent of warm bodies but not venturing any closer.

A new warmth appeared at her elbow. "That's a nice animal you've found there." Saiah Innis followed her distant gaze.

Rahel lifted one shoulder, not looking away from the *eisborne*. "The mazhet found it, but thanks anyway." It folded slowly, awkwardly, its hindquarters standing upright as it pushed itself chest-first across the dirty snow. "They really aren't in our data base? Not anywhere?"

Saiah shook his head. "We've compared spins from all four specimens, but there's no Ark record of the *eisborne* anywhere. Widdier admits he recognizes the photos." His smile flashed white across his wind-burned face as the *eisborne* fell completely prostrate, legs in the air. "He says it's definitely genus *Ursus*, though, within a few million years of species *americanus*. That's the closest he's willing to come to actually calling it *maritimus* for right now. Ask him again in a week."

The *eisborne* rolled lazily to all fours again, sniffed once more in their direction, then turned and lumbered away.

Rahel tried to picture it among the vanishing ice fields of Earth—tried to imagine how it could have been rescued from there so many years before Noah's Ark was even born. "I wonder where it came from."

"I hope we can find out." Saiah turned away to glance at the pachyderm, obviously without interest now that the ursid's playful show was over. "Whoever relocated them, however they relocated them—have you ever imagined what other treasures someone like that might have saved?"

Rahel thought about a paper picture she'd once seen of tiger-striped wolves in the rock-and-steel confines of a big city zoo. She thought about descriptions in an ancient seaman's log of birds that stood as tall as humans, and about the soft wings of flying rodents that the night skies had taken for granted. She thought of all the damage she'd lived her life regretting mankind could never undo, and she nodded with a wistful smile.

"Yes," she said, "as a matter of fact, I do." ■

IN TIMES TO COME

● November is *Analog*'s official "relaunch" issue as a Dell Magazine, when our "look" will take on some new features that we hope you'll like. It will also, of course, have a fine line-up of the kinds of stories and articles you expect from us, at once entertaining, thought-provoking, and with an educated eye toward the future.

The lead novelette is "Embracing the Alien," with cover by Bob Eggleton, wherein Geoffrey A. Landis throws some folks into a predicament fraught with shocking surprise and a profound moral dilemma. You might say it gives new meaning, on an unprecedented scale, to that old cliché about "If you had it to do over . . ."

On a completely contrasting note, John Stith's harried detective Nick Naught is back, in a delightfully silly whodunit titled (appropriately enough) "Naught Again." We'll also have a haunting short story by Vonda N. McIntyre, another award-winning writer who got her start here but has been too long absent from these pages, as well as shorter appearances by G. David Nordley and Charles Sheffield. Rounding things out are Dr. Stephen L. Gillett's look at Titan as an abode of life, and the penultimate part of Kevin J. Anderson and Doug Beason's novel *Assemblers of Infinity.*

Martyn J. Fogg

A PLANET DWELLER'S DREAMS

"Fixer-uppers" may be the most important part of the planetary housing market!

Introduction

Many of you reading this article would like to believe that the stars are our ultimate destination. One day, a branch of our species, taking with it other life forms from Earth, may embark upon the grandest odyssey of all: a million-year galactic diaspora, traveling from star to star, exploring, discovering, and learning, gradually dispersing throughout the spiral arms and disc of the Milky Way. It is possible to imagine an almost infinite variety of settings within which our space-faring descendants might choose to settle. However, what will the overall picture be like, where will our homes of the future be?

If the imaginations of science fiction authors are to be a reliable guide, the answer is *other planets about other stars*. Extra-solar planets remain a major theme within SF. The majority of future histories, whether composed of one novel or many, see planets as being the fundamental building blocks of interstellar empires.

Yet this has not been taken for granted by a large fraction of space scientists who speculate over interstellar colonization. Especially from the mid-seventies onwards, after Gerard O'Neill's pioneering work on space colonies, the emphasis of many has switched to the *colonization of space itself*. By this I mean the construction of large, free-floating, artificial habitats, enclosing an environment comfortable for human beings. One can think of these space colonies as being extra-terrestrial city states or daughter bio-

spheres of the Earth—miniaturized maybe, but still large enough to support a population of thousands of people.

O'Neill's cohorts coined the term "planetary chauvinism" to attack what they saw as an outdated view that planets are the natural goal of any future space colonization effort. Their reasoning is quite persuasive: space is rich in solar energy, which is free; space is rich in easily accessible raw materials, asteroids, comets and the like, which are also free; and planets share an unfortunate property called a gravity well which makes travel to and fro much more expensive. An additional ingredient, when looking at the interstellar perspective, is that theoretical studies of the likely abundance of Earth-like planets about other stars indicate that they may be very rare.

The most optimistic study to date was that of Stephen Dole of the Rand Corporation, who published a report in 1964 which estimated that about 1 in 200 stars possess a habitable planet. This means that we would have to search, on average, about 25 light-years of space to locate such a world. In contrast to this, William Pollard of the ORAU Institute for Energy Analysis estimated that only 1 in 100,000 to 1 in 10,000,000 stars may be encircled by an Earth-like planet, requiring a search for a needle in a haystack 200 to 1,000 light-years in radius! Thus, argued the space colony enthusiasts, planet dwelling as a life-style will be outgrown by the human species. Instead, large colony-starships known as "worldships," such as Arthur C. Clarke's *Rama*, will travel the space lanes setting up shop in any convenient star system (for almost all are likely to possess asteroidal material) where a new, entirely space-based civilization can be established.

As I said, their reasoning is very persuasive, but as many SF authors have implicitly recognized—and they *do* have to entertain us—it is rather boring! Personally I'd rather live long-term on the outer skin of a large ball of rock than on the inside of a smaller metal can. I confess therefore to being a reactionary planetary chauvinist with an interest in re-engineering those planets that don't suit into a condition where they do, a process called *terraforming*. Having conducted and published terraforming related research for several years, I decided to look at the potential effect of terraforming processes on interstellar colonization. Now obviously, a starship is not going to have the capability to terraform any terrestrial planet it finds and so, for the dreary logic of the space colony brigade to be overcome, there must exist a large extrasolar population of near-Earth-like worlds, planets that would be easy to terraform.

Is this possible, or even likely? The study I completed and published in the April 1991 *Journal of the British Interplanetary Society* (vol. 44, p. 183) suggests the answer might be *yes*.

DEFINITIONS

A problem with comparing past estimates of the prevalence of habitable planets is that the relevant studies on which they are based all adopt a dif-

fering meaning of the word "habitable." So, before we go on any further, I'd better define what I mean.

We're going to speak of three different types of terrestrial planet.

1) *Habitable Planet* (HP): A world with an environment sufficiently similar to the Earth as to allow comfortable and free human habitation.

2) *Biocompatible Planet* (BP): A planet possessing the necessary physical parameters for life to flourish on its surface. If initially lifeless, then such a world could host a biosphere of considerable complexity without the need for terraforming.

3) *Easily Terraformable Planet* (ETP): A planet that might be rendered biocompatible, or possibly habitable, and maintained so by modest planetary engineering techniques and with the limited resources of a starship or robot precursor mission.

Now, it is plain that these three planetary categories are nested: (1) being a subset of (2), being a subset of (3). Clearly the Solar System at the present time contains just *one* ETP, which also happens to be a habitable planet, the Earth. However, this was not always so. The history of our Solar System as revealed by planetary scientists suggests that early on, two other planets could have been included within the groupings defined above. With a sample of more than one, our ability to extropolate to the likely situation about other stars is much improved. The best way to approach this problem is by studying and understanding the history of the Sun's *ecosphere* and the planets within it.

* * *

THE ECOSPHERE AND BIOCOMPATIBLE PLANETS

One can define the ecosphere as that zone surrounding a star within which conditions are thermally compatible with life. It is a finite volume with inner and outer boundaries: too close to a star and a planet's water exists as vapor, too far away and it is permanently frozen. Since we assume a crucial requirement of life is the presence of stable liquid water on a planetary surface, then the ecosphere is the place where we might expect to find biocompatible planets.

The boundaries of the ecosphere are obviously controlled primarily by the amount of radiation received from the central star. (The Earth receives about 1,370 watts per square meter of solar energy, an illuminance known as the solar constant, which I shall denote below by the letter **S**.) However, the luminosity of the star itself is not constant over long time scales but gradually increases throughout its main sequence lifetime. Our Sun was only about 70% as bright 4.6 billion years ago, when new born, than it is now, and so the ecosphere is not a static volume but one which expands gradually outwards. Planets can thus move in or out of the ecosphere as the central star evolves; moreover there are processes of planetary evolution which can result in a planet losing its liquid water so that, even though it may remain in the ecosphere, it ceases to be biocompatible. Therefore, as we shall see, the dimension of time, as well as distance, is of importance in our discussion.

One problem is that we don't actually know the true extent of the Sun's ecosphere. As astronomical theory has advanced, estimates of the width of this biocompatible zone have fluctuated. Before the space age it was thought that Mars and Venus might be biocompatible, implying that the ecosphere extended to their orbits and maybe beyond. By the mid-seventies, modeling of terrestrial evolution was suggesting that the ecosphere was wafer thin and the Earth only situated within it by the merest of flukes. The most modern research, however, has swung the other way; it now seems that the ecosphere may extend farther from the Sun than hitherto thought.

One of the conundrums that has dogged planetary scientists is the so-called "Faint Young Sun Paradox." As far back as we can look in the Earth's geological record, we find evidence for the presence of liquid water. This implies a global average surface temperature maintained consistently above freezing, despite the changing luminosity of the Sun. Yet, the young Earth, illuminated by sunlight with only 70% its present brightness (0.7 S), should have been frozen and should have stayed frozen up until comparatively recently. The fact that this didn't happen indicates that there must have been some mechanism at work capable of keeping the Earth's surface warm even though the planet was receiving less energy; a self-regulatory mechanism rather akin to that of a warm-blooded animal, which can automatically keep its body temperature constant whether the day is sunny or cool.

In 1981 James Walker and coworkers at the University of Michigan proposed just such a mechanism, the *Carbonate-Silicate Cycle*, which is capable of linking the amount of sunlight received by a terrestrial planet with the greenhouse effect of its atmosphere. It hinges on the fact that carbon dioxide in the atmosphere of a planet with liquid water on its surface is not stable—it weathers silicate rocks, reacting with them chemically to produce carbonate minerals, such as calcite, the main constituent of limestone. Why then does the Earth's atmosphere contain CO_2? This is because carbonate minerals are not stable either, under conditions of high temperature and pressure. Since the Earth's crust is tectonically active (it moves about, overturning parts of itself over time scales of millions of years), then carbonate rocks can be deeply buried where they become heated and squeezed. This drives the carbon dioxide out of the mineral phase whereupon it escapes back into the atmosphere via volcanoes. The clever bit is that the weathering rate at the surface is sensitive to temperature. If the planet cools then the weathering rate falls. However, the rate of volcanic outgassing of CO_2 stays the same because of the delays inherent in the cycle and so the amount of CO_2 in the atmosphere increases. This strengthens the atmosphere's greenhouse effect, producing a warming trend to counteract the original cooling. Conversely, if the planet warms up for any reason surface weathering increases, CO_2 is drawn down out of the

atmosphere, reducing the greenhouse effect and producing a cooling. What we in fact have is a planetary engine which operates automatically to maintain temperatures a few tens of degrees above the freezing point of water—conditions ideally suited for life!

The Faint Young Sun Paradox for the Earth may thus be explained. Surface temperatures have been maintained constant over our planet's history by a controlled decline of the atmospheric partial pressure of CO_2 from an initial value of about 1 bar to the 0.0003 bar of today—a change that would have kept pace with the brightening of the Sun.

However, this is not all of the explanatory power of the carbonate-silicate cycle; it also enables us to explain the history of Mars and to estimate the position of the outer edge of the ecosphere. Mars was not always the frozen desert it is today. Images returned by space probes have revealed areas of the planet cut by what look like dried up river beds; there are desiccated lake beds too, and some even claim to be able to point out the fossil shore lines of an empty ocean. These structures mostly occur on the most ancient of Martin terrain, that dating from the first billion years of the planet's history. Thus it seems that Mars experienced an early warm and wet epoch, a time when water ran and pooled on its surface, a time when Mars was a biocompatible planet, irrespective of whether life actually evolved there. How can we reconcile a faint young Sun with a warm Mars? Well, if early Mars had an atmosphere of about 5 bars pressure of carbon dioxide, with maybe other greenhouse gases too, then surface temperatures could have been at or a little above freezing. It is thought that this atmosphere could have been maintained by an active carbonate-silicate cycle, CO_2 being resupplied by intense volcanism powered by the internal heat of a young, recently formed, world. Why then is Mars still not like this? Why instead did the atmosphere dwindle, the seas dry up, and the planet's temperature plummet to 60 below? After all, the Sun is now hotter than it once was.

The answer is that Mars is *small*, smaller and less massive than the Earth and therefore having a larger surface to volume ratio. The little world lost its internal heat much more rapidly. Its crust thickened until it could no longer bury and decompose its carbonates. The carbonate-silicate cycle was cut. From that point on, biocompatible Mars was doomed. Its air reacted permanently with the surface; even after all of Mars's water froze, this process continued gradually to leave the planet with the tenuous atmospheric remnant we see today. Mars died, *even though it was situated within the ecosphere*. Yes! The fact that Mars was once biocompatible suggests that the outer boundary extends beyond the Martian orbit. A planet at about 1.8 AU from the present day Sun receives about as much radiation as a young Mars, about 0.3 **S**, and so we can speculate that any terrestrial planet with *active volcanism and tectonics*, capable of sustaining an *active carbonate-silicate cycle*, could remain biocompatible out to this distance or a little farther.

Now let's look closer to the Sun for the inner edge of the ecosphere. Computer models of the Earth's climate suggest that were our planet's illuminance to be increased to 1.1 **S** the oceans would start to evaporate. Large quantities of water vapor would start to accumulate in the atmosphere, a sufficient mass to keep a lid on a sort of planetary pressure cooker which would keep the oceans from disappearing entirely. Although water vapor is a powerful greenhouse gas, the increase in atmospheric pressure would prevent the boiling point of water, which itself increases with pressure, from being overtaken by rising surface temperatures. The Earth would be in a climatic regime known as the *wet greenhouse* with a 2 bar atmosphere of half nitrogen and half water vapor overlying scalding oceans at about 100°C. Increasing our planet's illuminance to 1.4 **S** would cause the pressure cooker to blow, the oceans would evaporate entirely, and the surface would dry out, reducing the ease with which volcanically produced carbon dioxide could weather back into the surface. Here we have a situation called the *runaway greenhouse*, a state in which we currently find the planet Venus. However, the Venusian atmosphere is now very dry. If, as seems likely, Venus once had a similar amount of water to the Earth then where has it all gone? Both greenhouse states initially result in an atmosphere which is so wet that, unlike on Earth, large quantities of water vapor can rise up to the edge of space. Here ultraviolet radiation in sunlight can dissociate water molecules into hydrogen and oxygen. Hydrogen being a very light gas escapes to space; some of the oxygen goes too, while the rest reacts with surface rocks. It has been calculated that an amount of water equivalent to an entire terrestrial ocean can be lost in this way in about 500 million years.

If these conclusions are correct, then at about 1.1 **S**, equivalent to a distance from the Sun of 0.95 AU, the wet greenhouse becomes established—a state incompatible with life of almost any sort. We have reached the inner edge of the ecosphere.

Since the Sun was significantly less luminous when it was young, might Venus have once been within the ecosphere? The answer is no, the minimum illuminance Venus might have received was about 1.38 **S**, so that it was gripped by a greenhouse climate from the start. However, it may have started off in the wet greenhouse before evolving a few hundred million years later to a full runaway. Thus during the earliest history of the Solar System, there may have been *three* terrestrial planets with oceans, *two* of which were within the ecosphere and at least one of which gave rise to life.

EASILY TERRAFORMABLE AND HABITABLE PLANETS

To complete our discussion of the three categories of planet we are interested in, we must briefly talk about ETPs and HPs. The former may be approached by asking the question, "Will it be easy to terraform Mars and Venus?" (Remember that the word

"easy" in this context is defined as being within the wherewithal of a space colony/starship, the size of a city state or small nation.) Well, the answer is a fairly firm *no* and if you have taken in the discussion in the last section it should be clear why.

Mars has lost its ability to recycle CO_2, with the result that its ancient atmosphere has become literally petrified into the rocks of its surface. Recreating an atmosphere thick enough to make Mars biocompatible again would be a huge undertaking. It could be done, but not as previously thought by simply warming the planet with orbiting mirrors. The gases would need to be shocked out of the crust by buried explosions or impacts—replacing the internal heat that the planet has lost—or even imported from elsewhere in the Solar System (see my article in the January 1991 *Analog*). This could perhaps be achieved by a mature civilization but not by the inhabitants of one ship lately arrived from a long interstellar journey.

For Venus we will have to replace an ocean's worth of water and the large mass of its CO_2 atmosphere must be eliminated. The old idea that all of this could be achieved by dumping a few photosynthetic algae into the planet's cloud deck, waiting a few years and then *bingo!* we have a habitable planet is, of course, bunkum. Any realistic proposal for terraforming Venus (see the reference list) inevitably requires a massive project well beyond the capabilities of a few hundred thousand interstellar travelers.

However, as we have seen, conditions on these two worlds may have been much less hostile during the first billion years of their respective histories. *In fact, both planets at that time would have been much easier to terraform than at present.* Mars was already biocompatible and could have been made more so by raising its illuminance. This would have increased the weathering rate at its surface, reducing the mass of carbon dioxide in the atmosphere. This process could have been speeded further by implanting photosynthetic life on Mars capable of using solar energy to use up still more CO_2 to increase its own biomass, releasing oxygen in the process. While Venus was in the wet greenhouse stage, a reduction in its illuminance to below 1.1 **S** would have caused most of the water in the atmosphere to rain out, resulting in a relatively rapid transition from greenhouse to more Earth-like conditions.

Now the modification of a planet's illuminance is likely to be one of the simplest and cheapest planetary engineering techniques. Construction of large orbiting sunshades or mirrors from hyperthin aluminium solar sail material would not be too difficult, especially to a civilization used to obtaining and processing space resources. This is the sort of terraforming that one can imagine interstellar travelers getting to grips with straight away. Thus, in the context of the model of the ecosphere discussed above, we can define *the set of easily terraformable planets to consist of all biocompatible planets, plus planets in the wet greenhouse state that have re-*

tained a substantial fraction of their water.

Now we just have to put the icing on our definition of a habitable planet. Of course, the fact that the Earth is habitable is the one data point we are certain of; however, this has not always been the case. In fact for most of the history of our planet, you or I could not have survived exposure to the then environment unprotected. We would have suffocated, gasping for the 21% oxygen we are used to from air that contained less than 1%. It is thought that oxygen levels in the atmosphere only approached present levels about 600 million years ago at the beginning of the Cambrian period, when the Earth experienced a rapid and dramatic proliferation of complex lifeforms—the so-called "Cambrian Explosion." Before that stretches the long eons of the Precambrian, the age of anaerobic life—bacteria, algae etc.—floating in the photic zones of the seas or living in the slime on the ocean floor. The Earth in the Precambrian was not therefore a habitable planet, but was of course biocompatible. Such a world would be even easier to terraform than a young Mars or Venus.

Since our model of the ecosphere is based on the carbonate-silicate cycle, which links the level of planetary illuminance with the chemical makeup of its atmosphere, we can take a leap of faith and choose the illuminance of the Earth at the beginning of the Cambrian (0.94 **S**) as the threshold at which a planet with Earth-like parameters can be considered habitable. Thus, *the set of habitable planets is assumed to be those biocompatible planets with an illuminance of* > 0.94 *S.*

WE NEED TO SUMMARIZE!

If you don't know much about planetology, then some of you may be feeling a little punch drunk by now. A summary of the model just described is definitely needed, something preferably which sums up the whole picture in one diagram. Have a look at Figure 1. On the vertical axis we have a scale of illuminance. All biocompatible planets are contained within the ecosphere that lies between 0.25 **S** and 1.1 **S** and is divided into three zones: *Juvenile Martian*, where planets could be similar to the early Mars; *Juvenile Terran*, where planets would be similar to the Precambrian Earth, the *Habitable*, which we have already defined. The horizontal axis is a scale of planetary volcanic/tectonic activity which you needn't worry about other than to note that the central dividing line where the scale reads zero is the point at which planets cool to the extent that they cannot sustain a closed carbonate-silicate cycle. Since both solar luminosity and volcanic activity vary with time, the position of a planet on the diagram changes, tracing out an evolutionary track. Such tracks are shown on the diagram for the Earth, Mars, and Venus, each one being marked at intervals of a billion years.

Now, what does Figure 1 tell us? Early in the history of the Solar System, both the Earth and Mars were within the ecosphere and were warm and wet. Venus may have been in the wet greenhouse region, with oceans on its surface

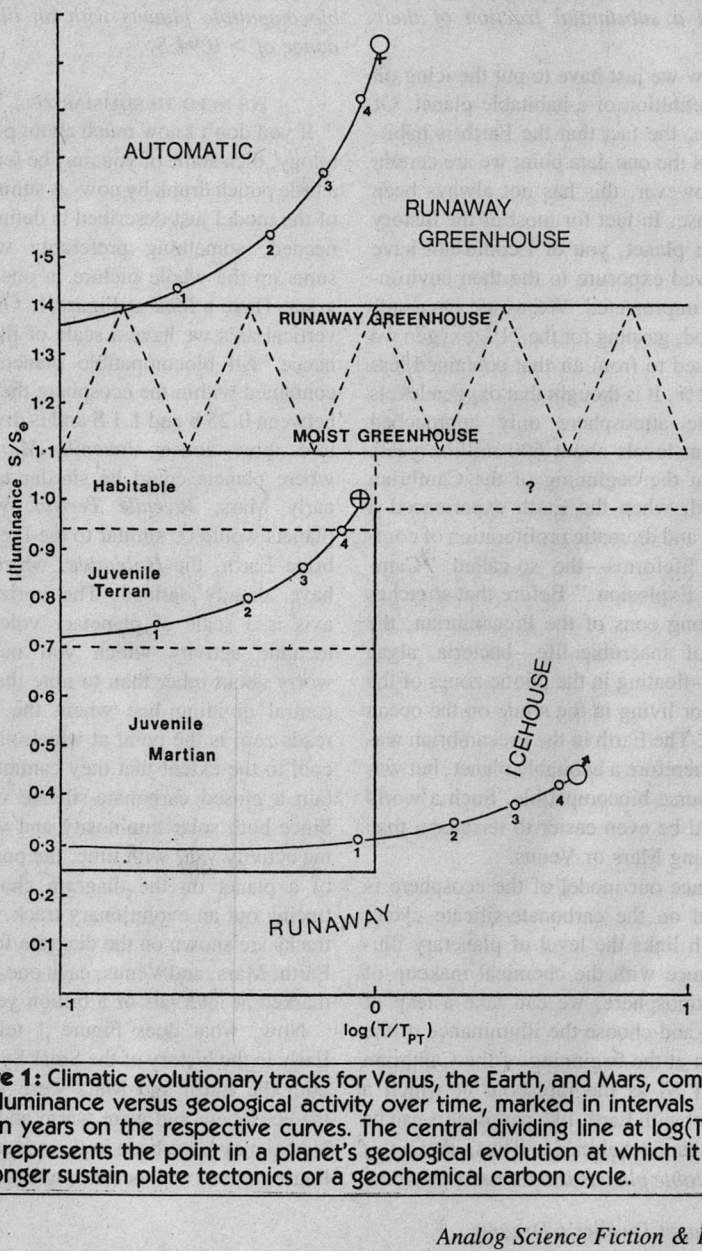


Figure 1: Climatic evolutionary tracks for Venus, the Earth, and Mars, comparing illuminance versus geological activity over time, marked in intervals of 1 billion years on the respective curves. The central dividing line at $\log(T/T_{PT}) = 0$ represents the point in a planet's geological evolution at which it can no longer sustain plate tectonics or a geochemical carbon cycle.

under a sweltering water vapor atmosphere. Shortly afterwards, the seas of Venus evaporated permanently, the loss of water to space from the upper atmosphere desiccating the planet for good. At one billion years or thereabouts, Mars leaves the ecosphere for the "runaway ice house," being no longer able to recycle its carbon dioxide atmosphere and to prevent the onset of a permanent ice age. Only the Earth remains biocompatible. After four billion years it becomes habitable, and 600 million years later we appear to ask the questions about how it all happened in the first place.

Now we have a model robust enough to allow us to speculate in a reasonably sensible way concerning the situation about other stars. Figure 1 looks quite hopeful. After all, at one time the Solar System contained *three* easily terraformable planets, instead of one. The habitable zone within the ecosphere, which is the approximate volume most other studies concentrate on, is seen to be just a small part of a much bigger *potentially* habitable zone.

EXPLORING AN EMPIRE OF STARS

In order to estimate the abundance of ETPs in our part of the galaxy, I embedded this model of the ecosphere within a broader astronomical framework. It became the centerpiece of a Monte Carlo computer simulation capable of generating random and unique planetary systems about stars of varying age and mass. The computer plays a kind of planet building game, following a large number of steps and shaking dice each time. It starts with the creation of the star itself, followed by the formation of its planetary system and terminating with an evaluation of the climatic evolution of its terrestrial planets. The general strategy of the program is shown in Figure 2. The ultimate aim of the calculations is to determine the surface temperature range of a terrestrial planet to see if it qualifies as one of the three types of world, defined above, which interstellar travelers might search for. The rules of the game cannot, of course, be based solely on rigorous theory as we have nowhere near a full understanding of planetology and have yet to detect an extra-solar planetary system. However, the laws of physics, empirical relations derived from observation, and current theory are blended together within the algorithms of the program such that the computer produces physically realistic, "sensible," although not necessarily stereotypical, planetary systems (see Figure 3).

I'm not going to cover the technical aspects of the simulation here; those of you who are interested and want more details can obtain it from the references listed at the end of this article. Suffice it to say that since the mass distribution and spatial density of stars in the solar neighborhood is approximately known, then the model can be used to simulate a sphere of space filled with as many stars as desired. The answers we are looking for are obtained by analysis of all the planetary systems generated.

How many stars do you want to look at? We'll need a good sample to get decent statistics. How about 100,000

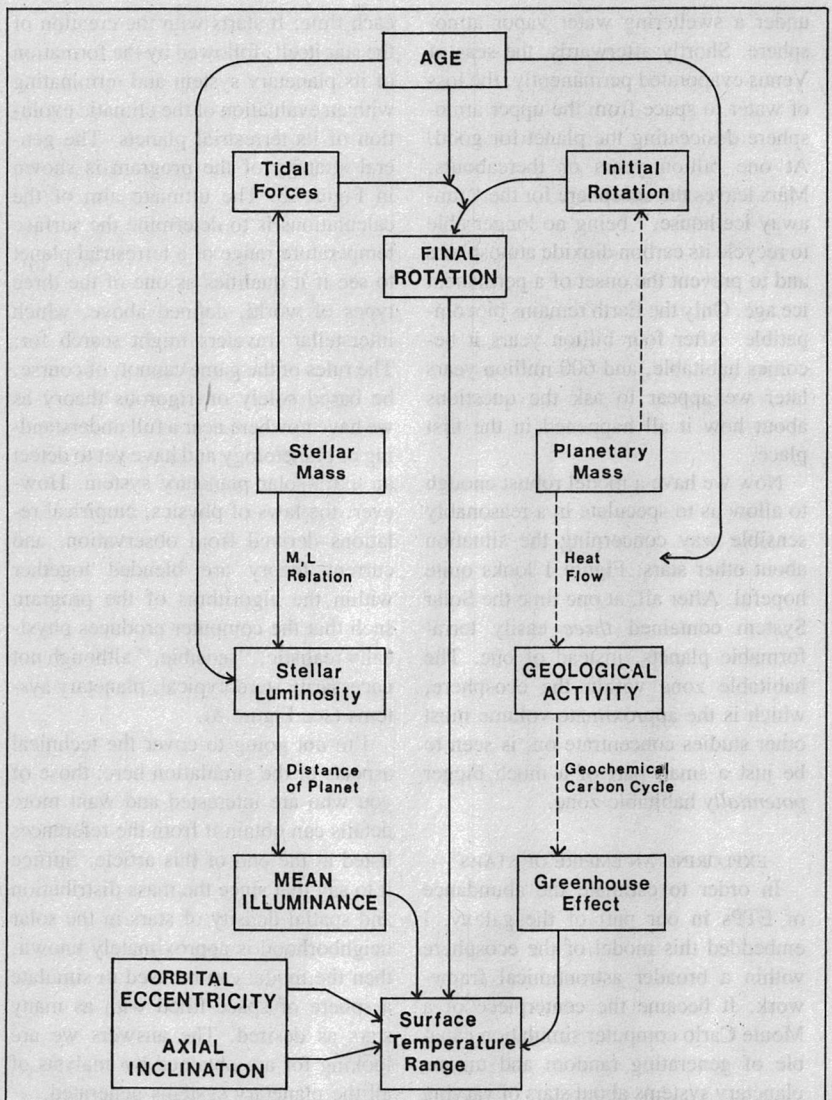


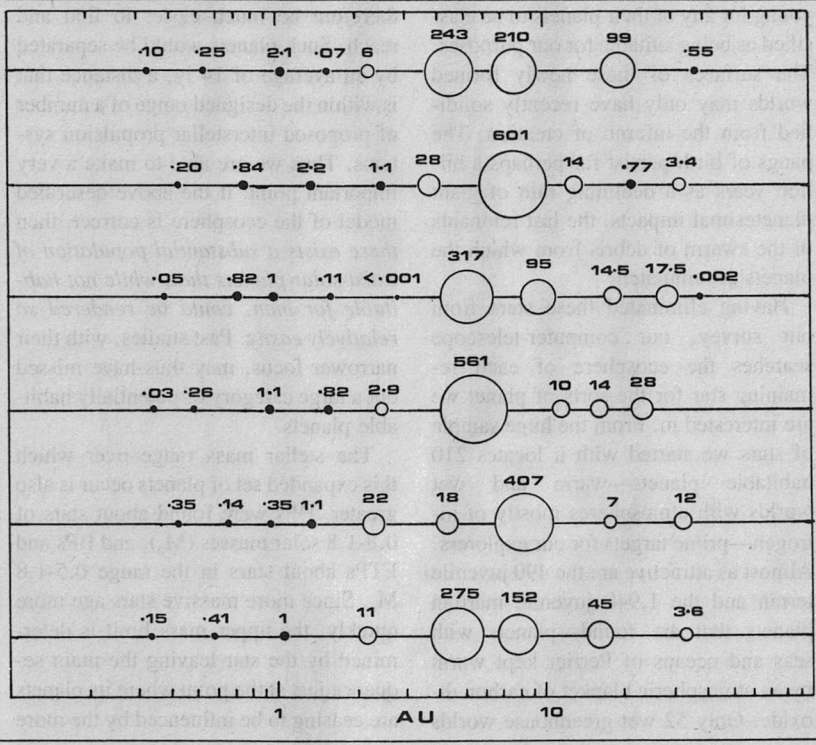
Figure 2: Stellar and planetary parameters that ultimately determine the range of planetary surface temperature. Dashed arrows represent speculative linkages.

stars for starters? That would be sufficient to keep the human race occupied for a few millenia; in fact, at about one millionth of the total stellar population of the Galaxy, it would be quite a respectable empire. OK, 100,000 stars it is then. Let's explore!

At the number density of stars in the Sun's region of the Galaxy, about 1 star per 300 cubic light-years, 100,000 of them are contained within an enormous spherical region about 380 light-years (ly) across. Most of our empire therefore is cold, empty, interstellar space. Let an actual run of the computer be our telescope, exploring each star system one by one. What does it find when its survey is completed?

For a start, not all stars are solitary like our Sun. In fact, most of them occur in pairs or triplets, orbiting each other in a variety of fashions, some close together, others separated by great distances. Of all the stars formed in our

Figure 3: Planetary systems generated by the simulation, in this case about a primary star of 1 $M_{\odot}$. The masses of planets are given in Earth units and the horizontal axis is a logarithmic scale of distance from the primary, in AU. The Solar System is included third from top for comparison.



region, about 55,000 exist within multiple systems. It may be that gravitational perturbations within such systems may prevent planets from forming and so first we shall examine single stars only. A significant fraction of the older and more massive of these stars will have evolved off the main sequence, passing through a period as a red giant, ending up as a white dwarf. No previously habitable planets about such stars will have survived; millions of years of being roasted to red heat followed by an eternity of the encroaching cold of interstellar space will have left them unfit for any sort of life. Other stars may be too young for any of their planets to be classified as being suitable for our purposes. The surfaces of these newly formed worlds may only have recently solidified from the inferno of creation. The pangs of birth persist for perhaps a billion years as a declining rain of giant planetesimal impacts, the last remnants of the swarm of debris from which the planets accumulated.

Having eliminated these stars from our survey, our computer-telescope searches the ecosphere of each remaining star for the sorts of planet we are interested in. From the huge sample of stars we started with it locates 210 habitable planets—warm and wet worlds with atmospheres mostly of nitrogen—prime targets for our explorers. Almost as attractive are the 490 juvenile terran and the 1,940 juvenile martian planets that are found—planets with seas and oceans of Perrier kept warm by an atmospheric blanket of carbon dioxide. Only 52 wet greenhouse worlds are found that retain enough water to be easily terraformed, nonetheless these would be welcome additions to the list of potential sites for settlement.

Our final tally therefore is 210 HPs, 2,640 BPs and 2,692 ETPs. Thus, about 1 in 476 stars possesses a habitable planet, a result generally in line with the more optimistic of the estimates produced by previous studies. You would have to travel an average of 32 ly to reach a star system containing such a world. However 1 in 37 stars possess an easily terraformable planet, *a ratio thirteen times higher than for habitable planets*. Stars possessing ETPs would therefore be much easier to find and reach. Such planets would be separated by an average of 14 ly, a distance that is within the designed range of a number of proposed interstellar propulsion systems. Thus we are able to make a very important point: if the above described model of the ecosphere is correct, then *there exists a substantial population of extra-solar planets that, while not habitable for man, could be rendered so relatively easily*. Past studies, with their narrower focus, may thus have missed out a large category of potentially habitable planets.

The stellar mass range over which this expanded set of planets occur is also greater. HPs were found about stars of 0.8-1.8 solar masses (M_o), and BPs and ETPs about stars in the range 0.5-1.8 M_o. Since more massive stars age more quickly, the upper mass limit is determined by the star leaving the main sequence just at the point where its planets are ceasing to be influenced by the more

violent aftereffects of formation. Since less massive stars are proportionately a lot less luminous, there reaches a point where the ecosphere is situated so close to the star that any planets in this zone suffer excessive tidal forces. This rapidly slows down the planet's rotation period so that its day equals its year, one hemisphere being roasted in an eternal daytime and the other plunged into everlasting night. HPs thus occur about a more restricted range of stars since they inhabit the warmer inner region of the ecosphere which is strongly influenced by tides. ETPs similar to early Mars can survive about stars of much lower mass since they orbit farther away. However, below 0.5 M_o all of the ecosphere lies within the tidal danger zone and conventional ETPs are not possible.

We cannot yet rule out the possibility that planets can form in multiple star systems, orbiting each component separately, or revolving about both. If this is the case then, ruling out the small proportion of multiple stars which are situated in such a way that stable planetary orbits within their ecospheres are impossible, we find that about 1 in 226 stars might possess habitable planets and an enormous 1 in 18 stars an ETP. What a change from previous gloomy predictions! Some of the Sun's nearest neighbors may be orbited by planets just waiting for life from Earth.

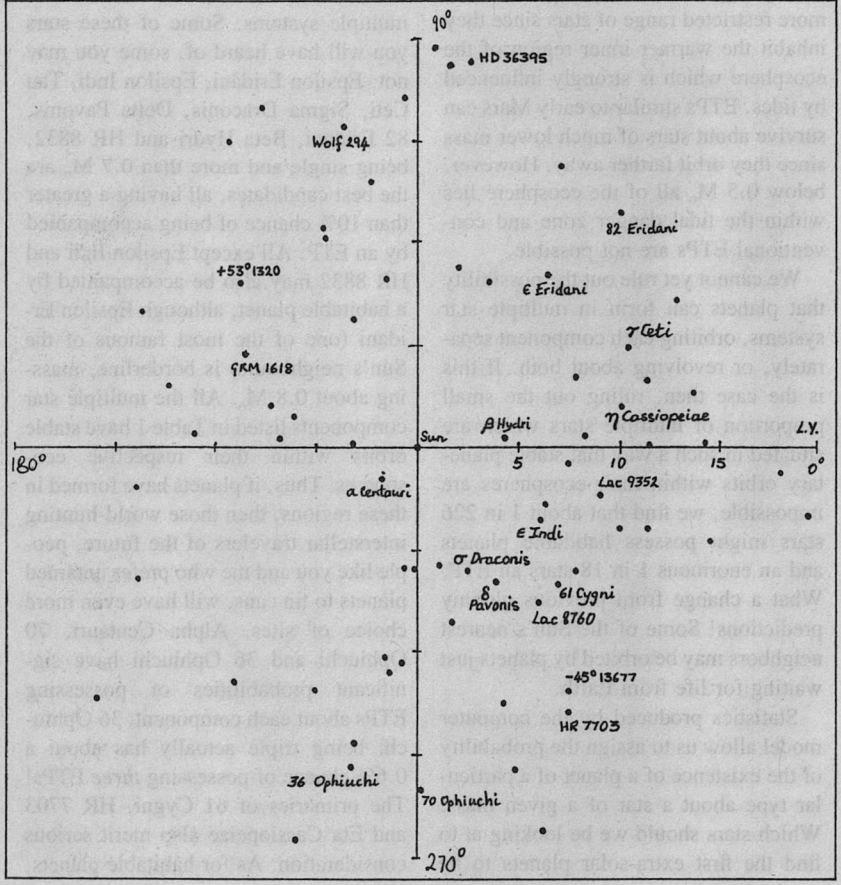
Statistics produced by the computer model allow us to assign the probability of the existence of a planet of a particular type about a star of a given mass. Which stars should we be looking at to find the first extra-solar planets to be settled by our descendants? To answer this, let's shrink the scale of our view from hundreds of light-years to a mere 22 ly from home, a volume that contains just 100 known stars in 75 star systems (see the map in Figure 4). Table 1 lists the stars within this distance which have a non-zero probability of possessing an easily terraformable or habitable planet. Perhaps surprisingly, there are 14 candidates, 28 if we include members of multiple systems. Some of these stars you will have heard of, some you may not. Epsilon Eridani, Epsilon Indi, Tau Ceti, Sigma Draconis, Delta Pavonis, 82 Eridani, Beta Hydri and HR 8832, being single and more than 0.7 M_o are the best candidates, all having a greater than 10% chance of being accompanied by an ETP. All except Epsilon Indi and HR 8832 may also be accompanied by a habitable planet, although Epsilon Eridani (one of the most famous of the Sun's neighbours) is borderline, massing about 0.8 M_o. All the multiple star components listed in Table 1 have stable orbits within their respective ecospheres. Thus, if planets have formed in these regions, then those world-hunting interstellar travelers of the future, people like you and me who prefer untamed planets to tin cans, will have even more choice of sites. Alpha Centauri, 70 Ophiuchi and 36 Ophiuchi have significant probabilities of possessing ETPs about each component; 36 Ophiuchi being triple actually has about a 0.6% chance of possessing *three* ETPs! The primaries of 61 Cygni, HR 7703 and Eta Cassiopeiae also merit serious consideration. As for habitable planets,

the model predicts that the star with the highest chance of having such a world is Alpha Centauri A—a sun that is right on our cosmic doorstep!

COLONIZATION STRATEGY

With the possible presence of easily terraformable worlds on our cosmic doorstep, our next question is how they might be explored, visited, and made into a new planetary home. The standard scenario of interstellar travel and settlement goes something like this: a starship is launched at a point of light

Figure 4: A two dimensional map of stars within 22 ly of the Sun looking down on the plane of the celestial equator. A distance scale in light-years is marked on the positive x-axis. Named stars all have a non-zero probability of possessing an ETP.



in the sky, about which almost nothing is known, in the hope that when it reaches its destination decades later, the target system proves to be suitable for settlement. We get the same message from both scientists and science fiction authors alike. For instance, the British Interplanetary Society's proposed *Daedalus* probe, designed to be able to perform a flyby mission to Barnard's Star in 50 years, would be capable of detecting giant planets a few hundred days, and terrestrial planets just fifty days, from closest approach. In *The*

TABLE 1.

Star Systems Within 22 Light-Years Which Might Possess Suitable Planets For Colonization.

Star	Distance	Spectral Type	Mass/Solar Units	P_{HP}(%)	P_{ETP}(%)
α Centauri A	4.38	G2V	1.1	7.8*	44*
α Centauri B	4.38	K6V	0.89	4.4*	38*
ϵ Eridani	10.69	K2V	0.8	0.6	34
61 Cygni A	11.17	K5V	0.59	0	5.8*
61 Cygni B	11.17	K7V	0.50	0	0.3*
ϵ Indi	11.21	K5V	0.71	0	18
Lac 9352	11.69	M2	0.47	0	<0.3
τ Ceti	11.95	G8V	0.82	1.5	35
Lac 8760	12.54	M1V	0.54	0	1.5
Grm 1618	15.03	K7	0.56	0	2.5
70 Ophiuchi A	16.73	K1	0.89	4.4*	38
70 Ophiuchi B	16.73	K6	0.68	0	16*
36 Ophiuchi A	17.73	K0V	0.77	0	28*
36 Ophiuchi B	17.73	K1V	0.76	0	27*
36 Ophiuchi C	17.73	K5V	0.63	0	9.0*
HR 7703 A	18.43	K3V	0.76	0	27*
σ Draconis	18.53	K0V	0.82	1.5	35
δ Pavonis	18.64	G5	0.98	5.1	39
η Cassiopeiae A	19.19	G0V	0.85	3.9	38*
η Cassiopeiae B	19.19	M0	0.52	0	0.7*
HD 36395	19.19	M1V	0.51	0	0.5
Wolf 294	19.41	M4	0.49	0	<0.3
+ 53° 1320 A	19.65	M0	0.52	0	0.6*
+ 53° 1320 B	19.65	M0	0.51	0	0.5*
− 45° 13677	20.6	M0	0.48	0	<0.3
82 Eridani	20.9	G5	0.91	4.4	38
β Hydri	21.3	G1	1.23	7.5	35
HR 8832	21.4	K3	0.74	0	23

Notes: P_{HP} = % probability of the occurrence of a habitable planet, P_{ETP} = % probability of the occurrence of an easily terraformable planet. Probabilities marked * only apply if planets form and have stable orbits in binary star systems.

Mote in God's Eye by Larry Niven and Jerry Pournelle, Admiral Kutuzov's flotilla jumps the 35 light-year trip to the Mote knowing nothing about what lies ahead, leaving all the exploration to be done after arrival. The implicit assumption common to both these scenarios, and a host of similar ones, is that missions to other stars will be dispatched in near total ignorance of what is to be found at the end of the journey. Since it is an assumption that is rarely stated it is rarely questioned. It is in fact completely wrong.

Any civilization wealthy and advanced enough to construct starships will have long before built large aperture telescopes in space. We're not talking about the Hubble Space Telescope here, which would have been hard put to detect an extra-solar planet even without its dodgy mirror, but instruments much more ambitious. Extra-solar planetary systems within our region of the Galaxy will one day be extensively explored from right here in the Solar System! One can imagine large arrays of telescopes on the Moon acting together as an interferometer achieving resolutions many orders of magnitude better than present astronomers' highest hopes. An array several *kilometers* across could detect terrestrial planets over vast distances and could even resolve coarse details of the discs nearest to them. Thus, contrary to the view commonly held, *interstellar travelers will know quite a lot about their future destination even before they have left home.*

One way to transport large populations over interstellar distances is to send them via worldship, a space colony modified by essentially attaching a propulsion system and a power plant. British scientists Alan Bond and Tony Martin have produced one of the most recent worldship designs, the vessel having enormous impact fusion motors capable of imparting a cruise velocity of 0.5% the speed of light. It could transport a population of 100,000 people, their ecosystems, industries, towns and countryside, their entire scaled-down world in fact, to another star 14 ly away in about 2,800 years. However, since easily terraformable planets may be quite common and detectable from the Solar System, then a detailed colonization strategy could be planned from the outset. Smaller and faster unmanned vessels containing an automated factory and sophisticated robots might be dispatched first to commence terraforming before the arrival of the settlers. Unburdened with the need to carry fragile ecosystems these ships might be launched with ten times the velocity of the worldship arriving in the target system about 2,500 years in advance. Once the necessary industrial infrastructure has been constructed, terraforming could begin by positioning mirrors or shades in orbit about the planet to change its illuminance and by introducing forms of life, such as algae and bacteria which can start to generate atmospheric oxygen, if a suitable partial pressure is not already present. About 0.05% of the Earth's total illuminance is used by the biosphere for the purposes of photosynthesis. In the absence of processes that

remove oxygen, 0.2 bars worth would be produced in about 6,000 years. Thus we are talking about a time scale of millennia to convert the atmosphere of an ETP to a state where it is breathable. Since the colonists will arrive two and a half millennia after the robot precursor ships, terraforming would already be at an advanced stage. A habitable planet would be awaiting them at the end of their long journey.

POSTSCRIPT

Thus, those reactionary planet lovers among you should not despair! If interstellar travel ever becomes a reality, then searching for suitable planets to settle will not be like looking for a needle in a haystack. If the modern view of the ecosphere and planetary evolution is correct then there could be as many as *3 billion* planetary colonization sites in the Galaxy. Ultimately, once a circumstellar civilization becomes more established, the terraforming of much more stubborn planets, such as extra-solar versions of Mars and Venus, would be feasible. This would increase the number of worlds occupied by a galactic civilization to perhaps over *100 billion*.

There's a future for us planet dwellers yet!■

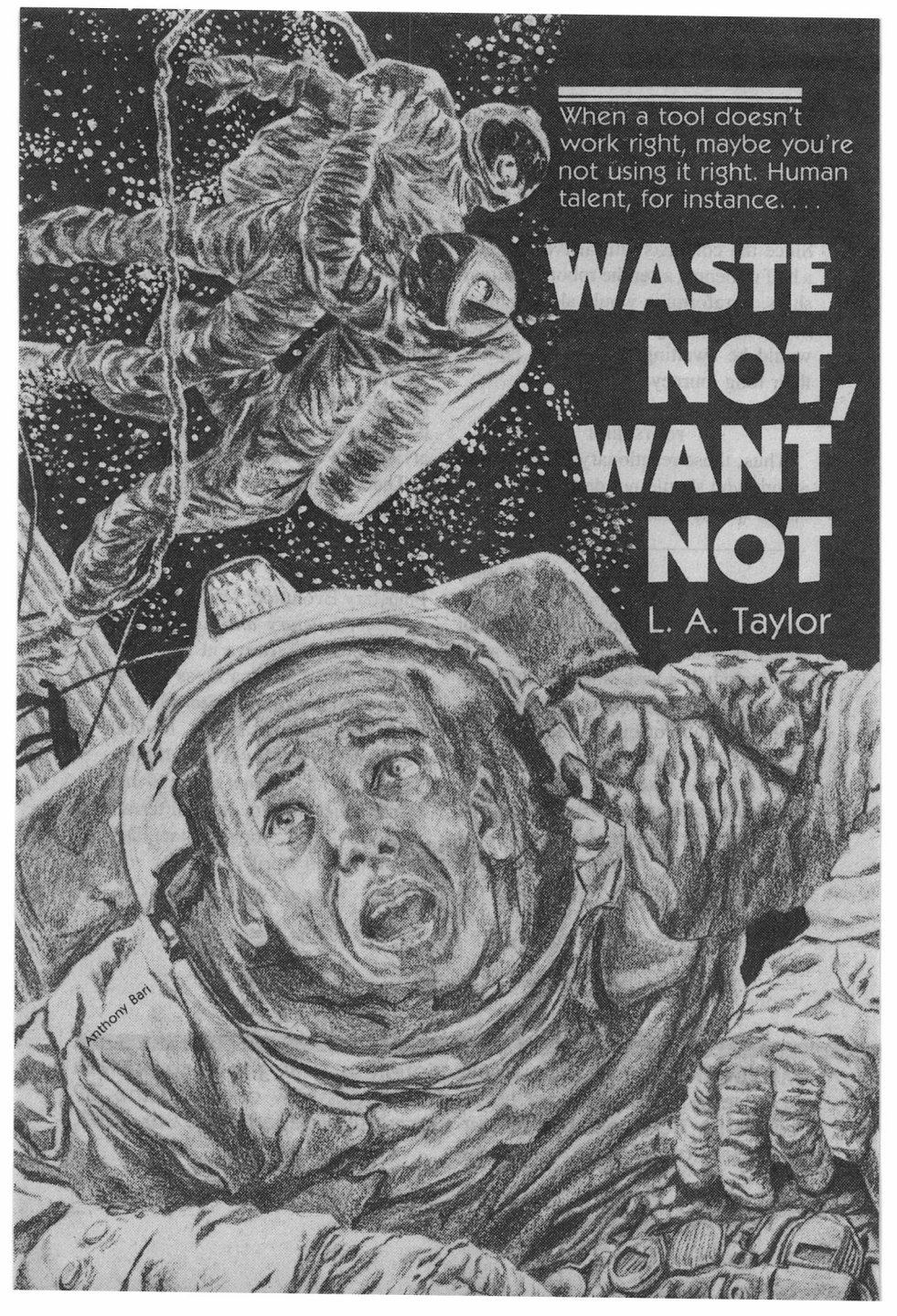
REFERENCES

Inevitably, in an article this length I have had to abbreviate and even cut out much of what could have been said. Planetology is a vast subject with essential contributions from all scientific disciplines. Much of our so-called knowledge is still speculative and so you have been asked to take a lot on trust. Anybody interested in more detail might do well to check out the following references:

Planetary Evolution: *Origin and Evolution of Planetary and Satellite Atmospheres*, S. K. Atreya et al. (Editors), University of Arizona Press (1989).

Interstellar Travel: *The Starflight Handbook*, E. Mallove and G. Matloff, J. Wiley & Sons, New York (1989).

Terraforming: *Journal of the British Interplanetary Society*, special terraforming issues, M. J. Fogg (Editor), December 1989 and April 1991.


When a tool doesn't work right, maybe you're not using it right. Human talent, for instance. . . .
WASTE NOT, WANT NOT
L. A. Taylor
Anthony Bari

Just outside the orbit of Naran, a stray piece of space junk escaped the deflectors and plowed a long gash into the hull of the Link Services cruiser *Protector*, First Officer Firk Brenne commanding.

Alarms whooped through the ship. Bells rang to warn of seal-off doors closing, although most reopened within minutes as the damaged area was isolated. The alarms stopped one by one.

"Attention," shipcoms called. "Attention. Hull penetration at cargo bay twelve has been sealed off. Resume normal activity. The following pledges will suit up and report to the main lock for repair duty at thirteen-thirty hours."

Pledge Taol Jalsse paused on the companionway from the mess hall to crew quarters, listened for his own name, and heard it. Twenty minutes to get to the main lock. Weightless, he pushed himself down the remaining steps and clawed his way along the handholds to his suit locker. The locker next to his was shut. Farther along the row, a couple of other pledges had just arrived and were struggling into their suit liners. Jalsse glanced at them. Hadn't he heard his friend Pankse's name, too? Could Mik have reported already?

No. A yellow space suit still hung in Mik's locker. About to frown, then remembering that service discipline required that his face be blank, Jalsse slammed the door. He reached into his own locker for his suit liner and pulled it over his uniform, yanking one rucked-up trouser leg down to smooth out the folds. Mik had not yet appeared, although two or three other locker doors had opened and Jalsse was sure he'd heard his name on the detail list. His suit slung over one shoulder, he ducked into the crew dorm for a quick pee.

As he'd feared, one of the hammocks in the top row bulged with the shape of a man completely wrapped in his bedding. "Mik!" Jalsse tugged at the hammock strings. "We're detailed. Didn't you hear shipcoms?"

"Can't do it," a muffled voice groaned.

"Yes, you can, damn it," Jalsse insisted. "Go suit up." He headed for the urinals. On his way out, with his suit already sealed and his helmet under his arm, he saw the hammock lining molded even tighter around Mik's body and gasped with exasperation.

Taol and Mik, Mik and Taol; either way, a pair of north-coast rowdies. Jalsse's father kept a shop. Just across the street Yako Pankse ran a repair center. Their sons had played together before they could talk; gone to school together; chased girls together; made the neighborhood miserable together; and at sixteen, to the considerable relief of everyone who knew them, they had pledged Link Services together.

Three years of Academy followed: each young man was surprised to find a talent for study in himself. Graduating close to the top of the class had assured them both of cruiser berths. Assigned straight to the *Protector*, they were now within a ten-day of completing their first mission, a five standard-year cruise to the Sul system and back to their home system of Shulla.

Jalsse had been carrying Mik Pankse all the way—or that was how it felt at the moment. In fact, he reminded himself, both of Mik's previous episodes of black funk had been brief, minor and

easily covered up. Both had been caused by Mik's completely unexpected, unreasoning fear of open space. Sure, he'd been trained. They'd all been trained. But simulators were never quite the same as the real thing, no matter how much time you spent in them, no matter how convinced you thought you were that the thing under you was a ship and the things over you were stars.

"Get out there and suit up, damn it," Jalsse said, punching Mik's shoulder. "We've got orders."

"I can't."

"You *can*. We're almost home. You want them to make you kneel to the head-knife *now?*" Mik didn't move.

Jalsse, a big man, trapped his helmet and gloves under the safety web of a nearby hammock and set his feet to drag Mik out of his liner. His friend's face appeared: ashen, his lips blue. Bad one.

"Taol, I can't work outship. Not even on tether. Not after last time." Last time Mik had thrown up in his suit. Lor, what a mess! Well, at least once he had bulkheads around him Mik had been able to clean it up himself. Now he looked away. "I'll take my chances."

"You are *coming* with *me*." The door of the dorm slid aside. Jalsse looked up as another pledge went past the end of the row of hammocks toward the urinals. Pankse's eyes followed the man.

"I'll try," he said faintly. Praise fate for weightlessness, Jalsse thought as Mik freed himself from his hammock, or he'd surely fall flat on his face! He retrieved his helmet and gloves and pushed Mik ahead of him to the lockers. Most of the detail was just finished suiting up. "Taol, I can't do it," Mik whispered.

Jalsse reached past him to open the locker. "Lor, Mik, you're twenty-three man-years old. Get a hold of yourself."

"Shut up." Pankse began to pull the suit liner on.

"Keep your eyes on the ship and you'll be all right," Jalsse said irritably. He shook out the yellow suit and held it ready. "Just don't look at the damn stars." Mik didn't answer. "Got that?"

"You want a punch in the mouth?"

"No, thanks. Hurry up. We're late."

"So go ahead." Pankse reached into the locker for helmet and gloves.

"Not without you." Jalsse stayed behind his friend as they headed for the main air lock, ready to shove him onward if he lagged. When they came up to the group the Junior in charge of the work detail was counting heads. Junior Officer Goreld, the second-shift radioman. Jalsse stared back with the stony blank gaze of the officer he hoped to be someday as the man's glance lingered over him and Mik Pankse.

"Kind of you to join us, gentlemen," Goreld said. "Pledges Jalsse and Pankse, isn't it?"

"Sir," Jalsse acknowledged. Mik said nothing. Jalsse kept a close eye on him as long-duty life-support packs were issued: on their last outship detail, half a man-year ago, Mik had fumbled his hook-up so badly he'd nearly cut off his oxygen.

Five men made up the crew, plus Goreld, whose rank symbol was stenciled on the sleeve of his suit. Jalsse replayed the shipcoms announcement in his mind. Surely there'd been more names than five? He'd have thought more like seven or eight. . . . Again,

he was behind Mik as they steered themselves into the main air lock. The inner hatch closed.

He has to go through with it now, Jalsse thought, without relief. The *lub-lub* of the air pumps changed pitch and disappeared. The outer hatch slid aside. Jalsse grabbed Mik by the helmet and pressed his faceplate to his friend's. "Don't look," he reminded him. The fierce glance he expected was instead one of pure fear; Mik's blue eyes seemed too wet. "Just keep your eyes on the job." Still only fear. *Lor, what now?* Jalsse wondered.

Goreld hung at the outer hatch, clipping on tethers. Still herding Mik, Jalsse was last—again. The radioman glanced at him, more sharply than he liked. "Nerves?" he mouthed. Jalsse kept his face as blank as an officer's and gave the tether a tug to check the fastening.

These were sliders, permanently looped to the work cables that zigzagged the length of the ship. As he left the lighted air lock, Jalsse switched on his headlamp. A moment later the beam of Goreld's lamp added his shadow to the confusion of light and dark on the surface of the hull ahead. The men pushed aft toward the holed cargo bay in single file. Just past the docked ground shuttle they had to switch to tethers attached to a different cable. Not a dangerous operation, but Jalsse again kept close watch on Mik Pankse, whose full lower lip now trembled. The hole in the *Protector* had been rolled away from the debris still traveling beside her, with the happy result that the damage now faced Shulla. They'd be working in sunlight. At least Mik would have a solid object in his peripheral vision; they might get through this yet.

Jalsse was risking his life. To the normal risks of his job he had added the risk of a trip to Headquarters to kneel to the knife, just by failing to report Mik Pankse's fear. He knew that. But if Mik had funked the job, if he'd ignored an order, he would have faced the headknife himself, and Jalsse resented the potential waste of a man with Mik Pankse's good qualities even more than he did his own danger. Besides, he'd known Mik longer than he could remember.

But friendship is not officially a possibility in Link Services, Jalsse thought, his belly cramping. Lor. One more tenday. Less. Seven lousy days. If they could just have gotten through seven more days, after better than three man-years, Mik would have been safe. Passing through Headquarters on his way to ground liberty, he could have applied for a transfer to—to what? Something. Where didn't a Linker with cruiser quals have to take an outship work shift, ever? Jalsse couldn't imagine.

The hole was long and narrow, with ragged edges, the chunk of sharp rock that had caused it stuck in the end of the slit. Jalsse saw now why they had assembled at the main lock, and not at one of the freight locks; the nearest was twice the length of his tether away, with no work cables from it to the damaged area. Double-length tethers might have reached from the freight lock, but were too likely to become entangled as they worked.

Behind him, Goreld unclipped his tether to work his way to the front of the group. "Transfer back, Jalsse," he

ordered.

Jalsse snagged the tether Goreld had dropped and exchanged it for his own. The Junior was already two men ahead of him, the pledge ahead of Mik reaching back for Mik's tether. The tether was still clipped to Mik's suit.

Why did they have to have a transfer at the very beginning? Jalsse jerked the tether off his friend's suit and put it into his hand. Pass it on, he pleaded silently, jogging Mik's elbow. For Erda's sake, pass it on!

The pledge ahead took the tether from Mik's hand. Jalsse clipped the one he had started with to Mik's suit and tugged hard on it. Mik turned a sickly-green face toward him. Ahead, Goreld was laying out a cable alongside the slit carved into the hull, getting ready to splice it to the tether guide so the repair crew could spread out.

Goreld began assigning stations, his voice in Jalsse's left ear a little tinny over the suit radio. This is going to be a long outship shift, Jalsse thought.

The edges of the damaged area would have to be smoothed before patches could be welded on. The men Jalsse had wondered about had been sent to the cargo bay before he and Mik had arrived at the main lock, and were to pass the thick sheets of plastisteel out through the hole in the hull and help to check the job for leaks with compressed air. We should have been faster, Jalsse thought. Mik could have handled the air cans, no problem, and I wouldn't be stuck with him.

Looking into the slit at his feet, Jalsse saw a ragged gouge through a meter of insulation with bright scored plastisteel at the bottom of it. He dropped his chin to his microphone switch. "Junior Officer Goreld?" he radioed. "Pledge Jalsse."

"Yes, Jalsse."

"This end of the hole doesn't go through, sir. We'll need to insulate before we can patch."

"Acknowledged." Goreld worked his way back along the line, not bothering with the tether shift this time. He looked into the hole, nodded, said to Jalsse, "Hold me down a minute," and pressed a button on his left arm console to radio a message into the ship on another channel.

Somebody down the line muttered something about the insulation being manufactured on Shan and shipped the light-year they had just traveled. Jalsse glanced at Mik, squatting like the rest of them, but hanging onto the work cable as if he thought the *Protector* might try to scrape him off against something. Little more could be done until the insulation arrived: that part of the damage couldn't as easily be reached from below, so the foam would go in before the patch went on. A hole had to be left for materials to be passed out by the men grumbling in the cargo bay.

They had covered the rest of the gash and were waiting. For a full hour, Mik had crouched too close to Jalsse, helping to push a slab of plastisteel into place if it happened to touch his gloves, or occasionally waving his laser welder at a seam without triggering it. Jalsse did his best to keep up with Mik's share of the work as well as his own, cursing silently. If he had not known Mik all his life, if he hadn't seen how well Mik worked anywhere but under the fat,

blazing stars—

Mik's hand laser started to drift away. Jalsse grabbed at it and missed. Mik was staring out into space.

Jalsse pushed off the hull, snatched the laser, and hauled himself back down the tether. Goreld was watching. He jammed the butt of the laser into Mik's belly, just hard enough to double him up. Eyes forced back to the ship, Mik grasped the laser.

"Thanks, Taol," he whispered into his radio. Shut up, Jalsse thought fiercely. Just shut up. Isn't it bad enough? Do you have to *tell* everybody?

"Where's that insulation?" somebody asked.

Goreld keyed his radio. "Five minutes," he said, after a conversation no one else heard. "Everybody up and stretch."

Jalsse slid the top of a boot under the work cable and stood. Down the line, Goreld was actually bending to touch his toes. Something tiny glittered in the dark sky off to his left. Jalsse watched for a moment: a scrap of blown-out foam, or a sliver of metal? Maybe even a distant ship. Without something to give him scale, he couldn't tell the size, the speed, or the distance. Yet something about the thing suggested it was small and close. His eye traced the forward trajectory.

"Goreld! Duck!" he said crisply. "Object at ten o'clock!"

Instead of ducking, Goreld straightened and began to turn, looking not at the object but for the man who had forgotten to call him by rank.

"Behind you, sir!"

Too late. Standing, Goreld had intercepted the object's path. It struck his shoulder. He seemed almost to stagger.

Jalsse was already off tether and moving toward him, grabbing arms, shoulders, life-packs, anything to keep from flying into space. For an instant he thought it was all right, that the object had bounced off Goreld's suit, maybe breaking or bruising his shoulder. Then he saw the spray of mist out of a pierced suit, heard a cough over the radio as the mist turned pink.

He slapped a glove over the puncture and held on tight, legs wound around Goreld for purchase. Hoping someone was monitoring, he said, "Bridge. Answer, please."

No reply. Under his grasp, the radioman's life-pack pumped air into the half-deflated suit, Jalsse could only hope in time. Ten seconds. He hadn't been airless ten whole seconds, had he?

Goreld coughed, with a gurgle that raised the hair on the back of Jalsse's neck.

"Bridge!"

"One," he thought he heard someone say. Still pressing his right hand over the hole in Goreld's suit, he brought his left arm up against Goreld's flailing hand. The radioman hit the end channel button.

"Bridge," Jalsse repeated. "Answer, please."

"Bridge," came a laconic reply.

"Pledge Taol Jalsse with the repair crew. We have a medical emergency. Junior Officer Goreld's suit has been breached and he is injured."

"Can you bring him to the main air lock?"

Jalsse looked forward. Between him and the lock were his dropped tether,

Mik crouched in fear against the hull with both hands locked to the work cable, the tether transfer at the shuttle. Two hands needed, everywhere. "No, sir, I don't think so," he said.

"This is Brenne," said a new voice. "Pledge? What's the problem?"

The First himself, as if he didn't have enough trouble. "Distance, First, and keeping my glove over the puncture. Could I take him to freight lock three?"

"Your tether won't reach, Pledge."

"I don't have one, First. I dropped it to reach Gor—to reach Junior Officer Goreld."

Goreld pressed his faceplate against Jalsse's. "Heater," he said.

"Heater?" Jalsse repeated. "Did you say heater?"

"Malfun. Heat . . . "

"Jalsse? What—"

"Goreld's trying to talk to me, First."

"What's he saying?"

"He says his heater's malfunctioning, but his life-pack's not damaged. He must be in shock. I think a piece of debris got his lung."

"I see. We're sending medics to freight lock three, Pledge. Do your best."

"Acknowledged," Jalsse remembered to say.

The other four men were looking at him. They hadn't heard the exchange with the First, and by now Goreld was surely too weak to change his radio channel for him. He pushed his faceplate against the Junior's. "Goreld?"

The man's eyes opened and closed. "Mother?" he asked dreamily. A bloody bubble came out of his nose.

Lor, lor, lor, Jalsse thought. Nothing he could reach with his left arm was pointed enough to push a button. Still clutching Goreld with both legs and hand, he motioned to the man nearest him to give him his tether. The man spread his hands for query.

Jalsse had a better idea. He beckoned. The Pledge was one of the two women in his duty unit, he saw with surprise as she strained her tether to reach him. He pressed his faceplace against hers. "I'm trying to get him to freight three, Vara," he said. "But I'll need more tether. Go cut loose the one I was using and bring it here."

"Got it."

"Be quick," he added, as Goreld began to writhe in pain: his suit pressure had dropped far enough to bubble his blood.

Vara went around the two men between her and Jalsse's abandoned line, pushing at them to keep the tethers untangled, and looked back at him. She pointed to the loop around the guide. He signaled yes, with raised left hand, and she cut it loose with her hand laser. Hurry, Jalsse pleaded silently as Vara worked her way back. Hurry. He reached out and pulled her close to press his faceplate to hers. "Clip that to my belt," he said. "Then splice it to Goreld's, end to end. Don't let us drift away."

"Don't worry," she said.

"Good idea," the radio remarked. Jalsse glanced toward Mik where he clung to the cable, now shaking so violently his suit shimmered in the hard sunlight. Wonderful, he thought. I'm broadcasting every word. But what if I need the bridge again? Better keep the channel. Better keep transmit on, for

that matter. He felt a twitch as Vara unclipped Goreld's tether.

She retreated a couple of meters and sliced the ends of the tethers neatly with the laser as Jalsse watched. Her partner, seeing or told what she was doing, held them side by side and melted them together with a short beam. Good, Jalsse thought. But test the join. She looked at him. He made pulling motions with his left fist. Vara stared, uncomprehending. Afraid he would loosen the slim bond of ice between his right glove and Goreld's suit, he repeated the motion and saw her nod. She picked up the spliced tether and yanked. It held.

With all his wriggling around, he had floated well away from the ship. Glove clamped over Goreld's shoulder, legs twined around the man to keep him close, Jalsse couldn't pull himself back down. He signaled to Vara, who looked up at him a moment and then hauled on the tether. The tug almost jerked his hand away from the puncture so precariously sealed. For the first time on an outship job, Jalsse's heart began hammering.

He touched down. Boots hooked under the cable, Vara pushed him over until he had hull contact most of the length of his body. Now he could try for freight lock three. The outer hatch had opened while Vara worked at the tethers, its dark interior inviting him in. Jalsse began worming along the hull, clasping the radioman in a parody of affection, doing his best not to push off the surface. "Cold," Goreld said once, heard through their touching faceplates. The open hatch yawned ten meters away. Jalsse had never seen such a long ten meters in his life.

What if Mik had had to do this?

Jalsse recalled Mik teetering along the edge of a roof, meters above the ground, laughing at him because he wouldn't follow. Far more dangerous than crawling across a hull in deep space, secured by a tether that could hold five men, let alone one. They'd been what, eight or nine years old? Mik's mother had stood on the ground, looking up, too scared even to scream at him. Though she'd certainly found plenty to say when he got to the other end of the roof and shinnied down the rain guide.

Maybe when it looks like you can fall into half the universe it's different for some men, Jalsse thought. Logic gives way and the daredevil dies, taking with it the courage a normally cautious man can find. But the daredevil ought to be dead. Open space had no room for carelessness. Jalsse looked into Goreld's face. His eyes were shut. His nose bubbled feebly. Hurry, Jalsse told himself. Hurry. Carefully.

I could so easily let Goreld die.

Jalsse stopped moving. Did *I* think that? he wondered. Why would I let a man die?

Because he knows about Mik. Because he *must* have heard Mik thank me, so he knows I know, too. And if he recovers he will surely report what he knows. About both of us.

The cold of the hull seemed to radiate into Jalsse's suit. He began moving again. And after Goreld? he asked himself. Who next? What kind of ship is it where crew can't count on each other? Where one man is doing a sort of slow mutiny, without ever meaning to do anything of the kind?

He reached the hatch.

The tether stretched behind him. The hatch couldn't close over it. Contort as he would, Jalsse couldn't reach the clip and keep his glove from slipping off the hole in Goreld's suit. Had he come this far for nothing?

"Bridge," he said. "This is Pledge Jalsse."

"Yes, Jalsse."

"I'm in freight three, but I can't release my tether, and I can't reach my radio controls. Can you tell the work crew to cut me loose?"

"Acknowledged." He watched as one of the crew—Vara?—moved to the tether and severed it. Then, his life pack hooked against the underside of the hatch, he hauled the tether in fifteen centimeters at a pull and shut the hatch over him.

His legs were cramping. His right arm ached. Was it still clamped tight enough? Jalsse looked at Goreld in the reflected light of his headlamp: eyes half shut. Drained looking. He couldn't see whether the beads in the man's air flow indicator were jumping. He couldn't activate the lock. Someone had thought of that; a faint pocking noise deepened slowly into the throb of air pumps and stopped. The inner hatch opened and three medics scrambled through. He'd made it.

"Good job, Pledge," the First said into his left ear. "The medics tell me you're in. Take the rest of this watch off."

And leave Mik stuck out on the hull. After what happened to Goreld, it would just about take a welder to loosen Mik's hands from that cable. Let anyone else bring him in, and Pledge Mik Pankse's career was over.

"Begging your pardon, First," Jalsse said. "I can easily climb through the remaining opening in cargo bay twelve and finish the job as detailed."

"If that's what you want, Pledge, please do. Goreld reported that the exterior repairs were going well, except for the delay with the insulation. Do you think you could see them finished?"

Me? Jalsse thought. Me? "Yes, First, I believe I could."

"Go do it."

Helping Jalsse peel Mik's suit off, Vara wrinkled her nose at the wet liner and made a flicking motion with her fingers. "Excuse me, gentlemen," she said. She raked Pankse with a glance of disgust and raised her eyebrows at Jalsse. "See you later, Taol," she added, and departed. Mik didn't seem to notice. Later?

Ground liberty was seven days away. Jalsse paused to watch Vara's lithe swing around a handhold into the nearest companionway, contemplating fresh prospects.

"You shouldn't have left me." Mik was still shaking.

"You're all right, aren't you?" Jalsse started rummaging in Mik's personal locker. "Lor, Mik, don't you have a clean uniform?"

"I was alone out there."

"With three other Linkers. Stuff it, can't you?" This will be just like the last two times, only worse, he thought. Somehow he'd have to help Mik put himself back together, and for what? To fall apart the next time he pulled an outship detail? Next year? Tomorrow?

The *Link Services Handbook* told him

what he should do. Trot up to Firk Brenne and tell him Mik was scared spitless. Tell him Mik couldn't do his share of the work. In other words, report Pledge Mik Pankse unfit for the Service. But what a waste! Just for one weakness, so rarely evoked, so easily avoided? When he could do everything else as well as anybody, better than most? Maybe, if he kept pushing, Mik would get his nerve back?

Jalsse sighed. All he could do was try. "Here's a jersey," he said, handing it backward to Pankse. "Pants . . . Lor, Mik, what a pack rat you are! Where do you hide your socks and underwear?"

He was eating the next midday meal when shipcoms announced his name: report to the First's quarters as soon as convenient. Jalsse looked up at the speaker and back across the table, to see Mik gone pale. "You won't tell him, will you, Taol?" Mik asked quietly.

Jalsse shook his head.

"Thanks." Mik reached for his sipping-mug of coffee.

"You've got to beat this, Mik."

"I know it."

"Maybe there's some trick to it. Maybe the meds offi—"

"Are you crazy? They'd have me back in Nevàston working for my old man before you could say 'safe spacing.' " Mik drank half the coffee and put his finger over the end of the mouthpiece. "Don't you go asking for me."

Jalsse hadn't thought of that. "Of course not."

"None of this 'a friend of mine wonders' stuff."

"They'd think it was me," Jalsse pointed out.

"Damn right. You want to sell spices the rest of your life, like your father?"

Jalsse shook his head and looked at the clock. "I'd better go."

"Remember."

"I remember everything," Jalsse said. "That's the whole trouble."

He unlatched his seat belt and kicked off toward the companionway without looking at Mik. Rising along the handrail, he tried to calm himself with the *Control, Officer!* the higher ranks used. He'd had some of that training at Academy. Needs practice, he thought, and remembered the trick of inhaling deeply, slowly, through his nose, to calm himself. He used it.

Jalsse knew where the First's quarters were, although he'd never been called there before. Usually, the purpose of such a summons was discipline. Maybe he knows about Mik, Jalsse thought. Maybe Goreld radioed to him, before he was hurt. Maybe—

He brought his feet to the designated floor in front of the First's door, surprised to notice a hint of acceleration effect. The *Protector* must be on approach to Headquarters already. He tapped twice.

"Enter," Brenne called. Jalsse slid the door aside.

"Ah, Jalsse. Come in and shut the door, please." The First was at his desk, in the end of his quarters that he used as an office. Jalsse brought himself to attention as best he could in his nearly weightless state.

"At ease, Pledge," Brenne said. "Sit down."

"Thank you, First." Jalsse pulled himself down to the chair bolted to the

designated floor in front of Brenne's desk and clasped the belt.

Brenne cocked his head at him, a signal that this would not be a formal conversation, although his face remained devoid of expression. "Good work yesterday, Jalsse," he said. "I think you would like to know that Junior Officer Goreld will very probably recover, although I am sorry to say he may have suffered enough lung damage to be permanently grounded."

"I'm glad to hear that, sir. That he'll recover, I mean."

"You showed good initiative, Pledge," Brenne said. "As I have come to expect of you."

"Thank you, sir." Jalsse hoped the First hadn't noticed his shocked swallow; he'd had no idea Brenne had formed any expectations of him at all.

"Your communications, however, were not quite up to the standard of a work crew supervisor. I'm not criticizing you, you understand. It's not normally a job for anyone ranking below a Junior. But I would like to hear your evaluations of your fellow Pledges —any outstanding performances. Good or bad."

"Generally speaking, they're all good workers, First," Jalsse said. "As I'm sure you know."

Brenne nodded. Jalsse's eyes were drawn to his rank badge, pinned to the high, folded collar of his jersey; a golden sunburst with a circle around it. Brenne's dark hair was grey over his ears. How long had it taken to earn that badge? Jalsse wondered.

"All of them, Pledge?"

Jalsse found his tongue empty of words.

"What do you think, Pledge?" The First narrowed his eyes, sending a chill through Jalsse's belly. "Would you trust your life to Pledge Pankse?"

His mouth opened with a click. "Under many circumstances, I would, and have, sir, yes."

"If, say, he had to go outship? As he did yesterday?"

Lor, he does know, Jalsse thought. Who told him? Goreld? Vara? His neck felt severed already; between null-grav and nerves, he thought his head might float away. He wanted to lie. But if other lives came to depend on what he said now? Could he ride herd on Mik for the rest of his career? He took a surreptitious breath. "I always try to depend on myself, First."

"Nicely phrased, Pledge." The First waited, but Jalsse knew this game: he called it see-who-can-wait-the-longest. He'd learned it in baby school, played it with teacher after teacher for the next thirteen years. And won, every time.

After a minute or two, Brenne nodded. "Would Pankse serve us better in another line of work, do you think, Jalsse?" he asked. "In, shall we say, a less psychologically demanding role?"

"I don't know what you mean, First."

First Office Brenne's mouth quirked slightly. "He's a good friend of yours, isn't he? See if you can persuade him to request a transfer to administration." Administration! *That's* where! He knows a way out, Jalsse realized. He's decided to show us—

"We can use all the men with deep space experience we can spare on Headquarters," Brenne commented. "Especially men as intelligent as Mik Pankse.

With luck, they can keep the bureaucrats from perpetrating some of their wilder imbecilities.''

''Perhaps so, sir,'' Jalsse said.

''You know it, Pledge.'' The First's mouth quirked again. ''Can't hurt to have someone on Headquarters in your debt, either, as I'm sure you can see. Some men have found that situation extraordinarily useful.''

Politics. The endless jostling for advantage some men seemed to relish almost above life. No less intense among Linkers than elsewhere, for all their regulation blank expressions. Jalsse met First Officer Brenne's eyes. ''That aspect is unimportant to me, First.''

''I thought as much, or I would act differently.'' Brenne again regarded him with the narrow-eyed calculation of a few moments before. ''You, Jalsse, are cut of a different material than is your friend. Have you ever considered applying for command-line status?''

Jalsse noticed his heart beating, as if it had hung immobile in his chest for the past five minutes. ''Command line?'' Somehow he managed to approximate the flat intonation of an officer. ''Yes, First, I would appreciate that opportunity.''

''Report to the bridge on your next watch, Jalsse. We'll see if we can make a radioman of you.''

''Thank you, sir.''

''Don't thank me, Pledge. You'll have to earn it.'' Brenne gazed at him for a moment. ''I have every expectation that you will make the best of this chance, Jalsse. You have the brain. You have the guts. Most important, to my way of thinking, you have the heart. But you will have to learn never to tolerate a man who cannot do his job, no matter how close a friend he may be. It's too dangerous. Too many other lives may be at stake.'' The First paused. ''Nevertheless, *Handbook* procedures are not invariably the best. As you see, there are other ways of doing things at times.'' *Lor,* Jalsse thought, awed by this trust. *He's risking his own head, talking like that!*

Brenne acknowledged that unspoken thought with a quick glance. ''But unless you are yourself a First, it would be best to consult with the man who is before you decide to depart from regulations,'' he added.

Would I have the same courage? Jalsse wondered. *Could I trust my judgment of a man that far?*

But I have, he thought. I have. ''Understood, First. Thank you.''

Brenne nodded. ''Dismissed.''

Jalsse shut the door behind him and paused just outside, grasping a handhold. Radioman! Bridge crew! The first step toward command. Imagine, Taol Vans Natanle Jalsse, the son of a spice merchant, in command of a ship like the *Protector*! Someday, he promised himself. Someday. He drifted toward the crew's quarters, handhold by handhold, planning how to start his talk with Mik.

It won't be easy, Jalsse thought. He paused for a deep breath to quell a rising sadness. Not easy at all. ■

Special Feature

ON THE INEFFICIENCY OF BEAUTY CONTESTS, & A SUGGESTION FOR THEIR MODERNIZATION

David Lance Goines

Rather than the subjective, whimsical evaluations that so often lead to dud Symbols of American Womanhood,[1] the modern beauty pageant should take a hint from the ancient Greeks and that straightforward measure of feminine pulchritude represented by Helen of Troy, daughter of Zeus and Leda, whose face ". . . launched a thousand ships, and burnt the topless towers of Ilium."[2] Here we have a useful, dispassionate, *scientific* measure of beauty: a *"helen."* One helen is sufficient good looks to launch one thousand ships, and to cause the destruction by fire of an entire city. The objective standards of *Ship Launching* and *Arson* may now be used to analyze feminine beauty.

SHIP LAUNCHING

Just what is meant by "launched a thousand ships"? What kind of ships are we talking about here? How can we compare modern ships to ancient?

The ships that carried the Wrath of Achilles to Troy had single banks of oars arranged symmetrically on either side, manned by up to 50 rowers. Such a vessel was called in Greek a *penteconter* and might have been 100 feet in

[1] e.g. Vanessa Williams, Bess Myerson, Phyllis George, Ann Simington, *inter alia*

[2] Christopher Marlowe (1564-1593), *The Tragical History of Doctor Faustus*, scene xiv

length and about one-tenth that in the beam, having a displacement[3] of about 20 tons.[4]

One thousand such ships makes 20,000 tons. By this measure, the woman who breaks a bottle of champagne over the prow of a ship of 20,000 tons displacement and so launches it, becomes the equal to Menelaus's wandering spouse. At least so far as maritime affairs are concerned.

If an average-sized woman were to do no more than launch herself—by getting into the bathtub, say—she would automatically get credit for about 3/1000ths of a ship launching. Larger women would do a little better.

If ships launched were the sole measure of beauty, Eleanor Roosevelt and Mamie Eisenhower would emerge, without peer, as the most desirable of women. Marilyn Monroe would not even be in the running. The pyromaniacal inclinations of the toothsome Mamie and Eleanor were, however, imperceptible. They didn't even smoke.

ARSON

Arson as a measure of allure merits separate consideration. The capital of the tiny Trojan realm was the three villages of Dardania, Troy and Ilium merged into a single fortress on the mound of Hissarlik. The "topless towers of Ilium" may well have been a fair-sized walled city of perhaps as many as 12 acres, though it is more likely that it was a fortified palace not much larger than a ballroom.

That the Troy of c. 1200 B.C. had a substantial population can be inferred from the offspring of the king alone. Priam was a mighty man who, in addition to the handsome Paris, sired on his two wives Arisba and Hecuba[5] 49 sons and 12 daughters.

By comparison, in 1871 Mrs. O'Leary's home town was a city of some 300,000 souls and the land area devastated by her careless cow was 3⅓ square miles: 17,450 buildings were destroyed, 100,000 people were rendered homeless and 250 lives were lost. A simple appraisal of torched acreage shows Mrs. O'Leary to be 44 times more beautiful than Helen.

In terms of speed, the Greeks needed 10 years to defeat the Trojans and destroy their city; Chicago burned in only 27 hours. By this measure Mrs.

[3]Warships are measured by displacement only. Merchant vessels are measured by displacement, gross tonnage and deadweight tonnage (dwt). Gross tonnage is a volume measurement; each cargo gross ton represents 100 cubic feet of enclosed space. Deadweight tonnage is the carrying capacity of a ship in long tons (2,240 pounds).

[4]J.G. Landels, *Engineering in the Ancient World,* University of California Press, 1981

[5]Mother of 19 of Priam's sons, including Paris, Hector and Polydorus, and the doomed prophetess Cassandra.

O'Leary is 3,244 times more beautiful than Helen.

There is no record, however, of Mrs. O'Leary causing any ships to be launched, though surely she must have bathed from time to time. By the measure of 3/1000ths of a ship per ablution, a wash every Saturday night would give her the equivalent of one ship launching every six and a half years. To equal the lubricious Helen, Mrs. O'Leary would need to bathe once a week for 6,500 years.

THE BEAUTIES COMPARED

Although Mrs. O'Leary edges out the fair Helen in the arson category, Helen's ship launchings add up faster than Mrs. O'Leary's baths. When Paris carried off his prize, Helen was married to Menelaus. Menelaus was the brother of the powerful king Agamemnon, who went around to the princes of the country drumming up a war of revenge against the Trojans. He himself furnished 100 ships, and was chosen commander-in-chief of the combined forces. The assembled fleet at the port of Aulis in Boeotia awaited only a favorable wind. But Agamemnon had offended the goddess Artemis by slaying a hind sacred to her and by boasting himself a better hunter. As punishment, a total absence of wind prevented the fleet from departing, and the army was visited by plague. The seer Calchas announced that the anger of the goddess could only be appeased by the sacrifice of Agamemnon's daughter Iphigenia. This accomplished, the fleet set sail, though not without some hard feelings on the part of Clytemnestra, Iphigenia's mother. All this took about a year. *This* time factor makes Helen 6,500 times more beautiful than Mrs. O'Leary.

THE WINNER

Comparing the values (Mrs. O'Leary's arson factor of 3,288 against Helen's ship launching factor of 6,500) gives us Helen of Troy, selected by the goddess Aphrodite as the most beautiful woman in the world and still the champ, by a factor of just about two to one. Even after all these years, Helen remains twice as beautiful as her closest contender.

Not every woman is hot enough to burn down a city. But taking up smoking, or cooking the evening meal *will* add up. Combined with regular bathing, every woman can be remembered as more beautiful. The table below will be of assistance:

TABLE OF HELENS AND EQUIVALENTS

HELENS	EQUIVALENT
Attohelen (ah) 10^{-18} helens:	Light up a Lucky While Strolling past a Shipyard

Femtohelen (fh) 10^{-15} helens:	Burn a Dinner Candle and Spit a Toothpick into a Water Glass
Picohelen (ph) 10^{-12} helens:	Barbecue a Couple of Steaks and Toss an Inner Tube Into the Pool
Nanohelen (nh) 10^{-9} helens:	Send the Old Man on a Canoe Trip and Build a Good Roaring Blaze in the Fireplace
Microhelen (μh) 10^{-6} helens:	Christen a Motor Boat and Start a Grass Fire
Millihelen (mh) 10^{-3} helens:	Launch One Homeric Warship and Burn Down a House
Centihelen (ch) 10^{-2} helens:	Incinerate a City Block and Launch Christopher Columbus's Entire Fleet: The "Niña" (40 tons), the "Pinta" (50 tons) and the "Santa Maria" (100 tons)
Decihelen (dh) 10^{-1} helens:	Torch the Central Business District of Oakland, California, and Launch the Clipper Ship "Flying Cloud" (1783 tons)
Helen (h):	Raze One City & Launch the WWI US Battleship "Delaware" (20,000 tons)
Dekahelen (dah) 10 helens:	Oversee the Incendiary Bombing of Ten Cities and Launch the Aircraft Carriers *Theodore Roosevelt* (91,487 tons) and *Dwight D. Eisenhower* (91,487 tons)
Hectohelen (hh) 10^{2} helens:	Instigate a Major Modern Conflict and Launch the Oil Platform "Stratfjord B" (with ballast, 899,360 tons), the Supertanker *Seawise Giant* (624,038 deadweight tonnage); the Oil/Ore Carrier *World Gala* (282,460 dwt tonnage) and the Bulk-Ore Tanker *Hoei Maru* (208,000 dwt tonnage)

Kilohelen (kh) 10^3 helens:	Launch the Equivalent of One Million Greek Warships and Spark a Nuclear Confrontation
Megahelen (Mh) 10^6 helens:	Launch the Equivalent of One Billion Greek Warships and Blow Up the World
Gigahelen (Gh) 10^9 helens:	Launch the Equivalent of One Trillion Greek Warships & Destroy the Solar System
Terahelen (Th) 10^{12} helens:	Launch the Equivalent of One Thousand Trillion Greek Warships and Make Serious Inroads on the Welfare of the Galaxy

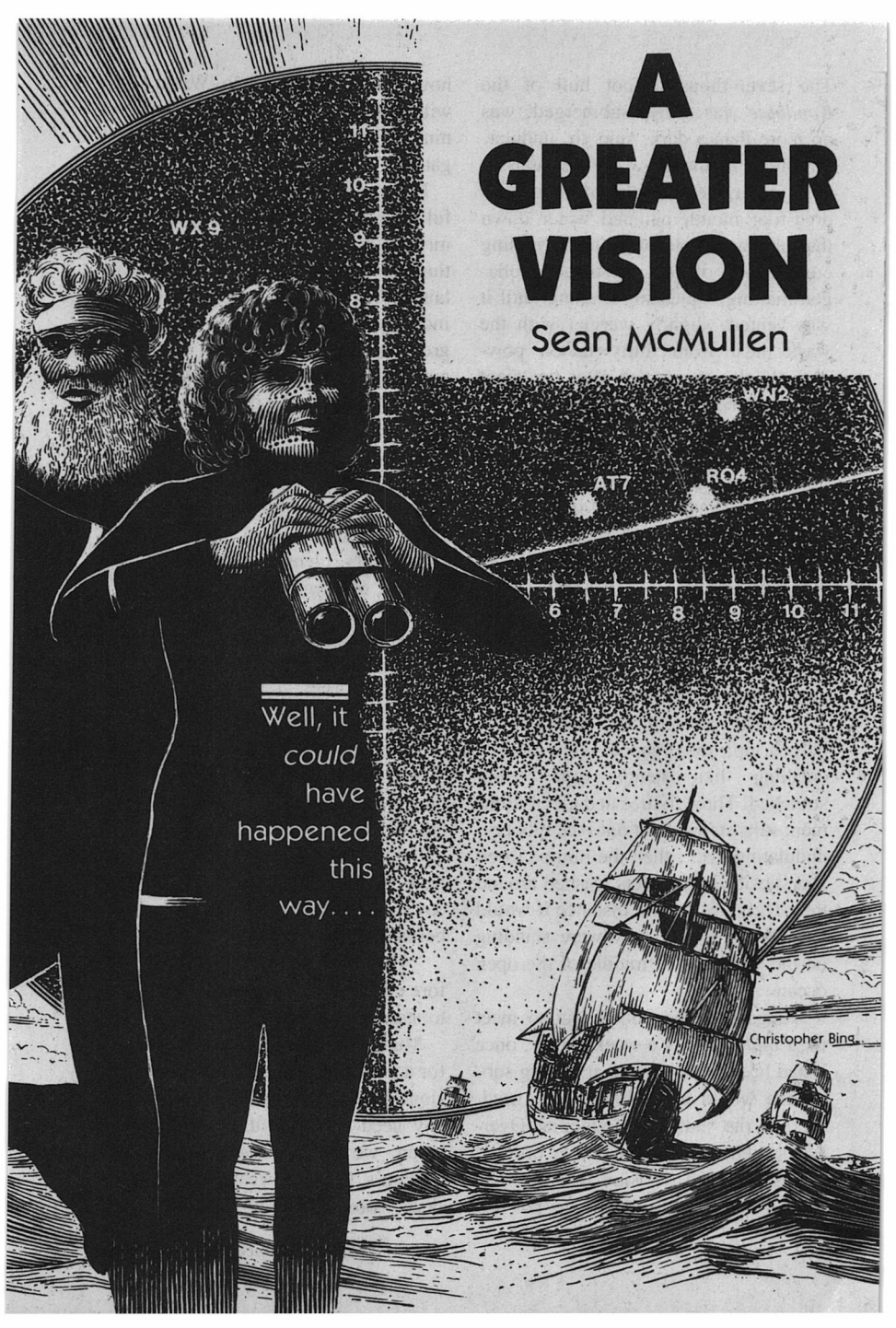
It is to be hoped that beauty exceeding the Hectohelen class evades even the most ambitious.

Now, doesn't this make the selection of a homecoming queen, Miss Fresno, Miss California, Miss USA, Miss World and, capping them all, Miss Universe, just a little more orderly? More exciting, too.

NB: When computing *negahelens*, or sufficient *ugliness* to sink a thousand ships and extinguish an urban conflagration, merely convert. ■

●Two sides? There are a hundred sides to every question, until you know the answer. Then there's only one.

William Hengist in *That Hideous Strength* by C.S. Lewis


A GREATER VISION
Sean McMullen
WX 9
11
10
9
8
WN2
AT7
RO4
6
7
8
9
10
11
Well, it could have happened this way....
Christopher Bing.

The seven-thousand-foot hull of the *Kondolae* was nearly submerged, was no more than a dark, smooth, undulating shoal in the glow before sunrise. With great, gentle gulps its two hundred-foot mouth pumped water down the tubular muscle of its hull, rippling contractions of polymer-braced collagen matting, squeezing it along until it was vented, slightly warmer with the waste heat from thirty fusion powerplants. It was named after the giant hunter of the Dreamtime who had been transformed into a whale.

The *Kondolae* was a long way north of its Antarctic harvesting area, where it could dilate the ridge along its back into a tube two thousand feet across to swallow icebergs for the meltworks in the south of Australis. It had been assigned to special duties for ten years now, awaiting the incident that would transform it from a powered ice barge into a shaper of history.

A small area of the deck slowly bulged up, then gaped open with a creaking like hemp rope being stretched. Three figures in dark environment suits stepped out onto the rubbery, undulating deck, then the hump closed and subsided. Wavelets washed around their feet, and from a distance it would have seemed as if they were standing on the water in the middle of the open ocean.

Nunga had been flown out to meet the *Kondolae* only a week earlier, once it had become obvious that the big submarine would really have to be used. He had the status of Counciliar Overseer, and he would be in charge of operations once the decision to strike had been made. That decision was not his, however. It belonged to Wirana, the wild card among the vessel's crew of nine hundred. She was the tactical navigator.

Nunga was in his late forties, and was full of the drive and aggression so common in those newly installed in positions of power. Mudati had been a captain for two decades. Nunga dyed a few individual strands of his black beard grey, to give an impression of age and authority. Mudati's hair and beard flared from the collar of his environment suit like a white halo.

"When will dilation start?" asked Nunga. "The breeze is gentle, it's perfect weather for the fog generators to raise a screen."

"There's plenty of time," replied Wirana, deferential but firm.

"We don't have time. We have between five and eight days, depending on the wind and the use that our quarry makes of it. This vessel takes a full day to dilate to maximum diameter."

"Premature dilation would be unwise," Mudati advised. "It would slow our progress and strain the powerplants."

"But if we strike at once we'll not have to move for more than a single day under full dilation. Tomorrow, just before dawn. That would be ideal."

"There are still six hundred miles before contact," Wirana said, then turned to stare out to sea.

Mudati considered the two opinions for a moment, then announced his decision. "I'm not convinced that there's any need to strike at all. I remember when we were shadowing Fernam Dulmo's fleet six years ago. The Elders's observer used the same argu-

ments that you do, but the threat came to nothing."

Nunga folded his arms and scowled, his back to the dawn.

"Dulmo was just a cypher. This is different."

"The answer is no—for now. Wirana, when do you think we might strike?"

"Perhaps in four nights, but no earlier."

"Four nights!" exclaimed Nunga.

"Nothing less."

Nunga trod the hatch stud, and the hatchway bulged clear of the water then stretched open. He stamped down the steps without taking his leave of either the captain or navigator. Mudati and Wirana were now alone under the brightening sky.

"He'll be onto the satellite link to complain about me just as soon as he reaches his cell," said Wirana.

Mudati stood beside her then pointed up at Jupiter.

"This is your last quarter with us before you go there," he stated rather than asked. Wirana nodded.

"I'll be shuttled to lunar orbit about midsummer, to spend a few months of accustomisation aboard the *Wondibingi* before we leave for Jupiter."

"You should do well. In your two years' trial aboard this vessel you have been a model officer, well suited to long voyages in isolation. How long is the Jupiter voyage?"

"Nine years, all up. I'll be forty-four when I return."

"Ten years at the Academiem, three years on the Lunar Orbit Assembler, three on the Moon, two years of isolation experience with us—your whole life has been a buildup to Jupiter."

Wirana looked up at Jupiter, gleaming brightly not far from Mars. "It's a chance to be first, to walk on the frontier. That's enough to gamble a life upon."

"How would you feel if it was canceled?"

She looked down at the water swirling about their feet. "I know what you are leading to, Captain."

"Well then, explain. Why are you going out of your way to antagonize Nunga?"

"If he flings himself under my feet, he'll be stepped on."

"That's no answer. He's been mentioning you in his reports."

"He does not understand the frontier," she said slowly, looking now at the distant sails of the nao and its two attendant caravels. "Admiral Colombo and his crews have performed nothing short of a miracle to get as far as this, yet Nunga . . . you heard what he said, he called him the quarry, as if he was hunting a crocodile. People like to turn their enemies into *things* before they destroy them. That's what Nunga is doing."

"But nobody is going to be destroyed."

"Not bodies, not even souls, but something far more vital." She kicked at the swirling water. "I'm sorry, I should not be talking like this. It's not your fault. I feel . . . so isolated, like those men on the ships. I wish that they could have their discovery."

"And what would follow? Dozens more ships, hundreds, thousands, and on every ship hundreds of ravening freebooters in search of easy gold, slaves and conquest."

"Conquest of what? Civilizations that practice human sacrifice?"

"Which the ancestors of these men were practicing only two thousand years earlier. If it comes to that, need I remind you of what is going on in Europe at this very moment in the name of their religion? Their religion ignores the land, they degrade the soil, drive species to extinction and torture their own kind. Not one of those ships has a soil chamber on board."

"So what happened in Australis after we arrived? Where is our megafauna? What happened to our coniferous forests?"

"But we learned, Wirana. Now it's our duty to teach but we're not ready, we need time and resources to turn their whole society around. Our planners never dreamed that they would develop so fast."

They had been through it all before, and it was not even a matter of convincing Wirana. They stood together, looking out after the little ships, waves washing over their feet with the undulations of the submarine's muscles. Colombo was on the frontier, somewhere that Wirana would be soon, yet she had to name the time to take his frontier away from him. She despised herself for it.

Mudati raised his binoculars and stared at the ships for a while. "Most of their journey is behind them now. Their ships are bearing up well, and the weather's good. They're rigged for speed. The birds flying about them should suggest that land is close, and its direction."

"I know, and there's been weed and flotsam in the water for days now. He must be certain of landfall, he'll not give up."

"If you're sure of that, why not advise me to begin dilation at once and get it over with?"

"Why not? To . . . allow him a little longer on his frontier, perhaps. I don't know."

The caravel *Nina* was ahead, being faster than the other two ships. Suddenly there was a puff of smoke, followed by a dull blast.

"They've seen us—" Wirana began, but Mudati held up his hand.

"No, that lombard was only fired as a signal. See there, a standard being unfurled at the *Nina*'s masthead. A sign that land has been sighted."

"Impossible. They're still days away from the nearest island."

"True, but Admiral Colombo has undoubtedly offered a reward for the first man to sight land. I'm surprised that there have not been more false alarms already."

The *Nina* began to trim sail, to let the other ships catch up. Other signal flags were being hoisted now.

"I asked you and Nunga to come out here to try to bring you closer to the men on those ships," Wirana said as Mudati turned back to the hatchway. "I wanted Nunga to stop turning them into things. Is there anything wrong in that?"

"No. Are you coming below now?"

"In a minute or two."

She spent the time alone on the frontier that was not hers, watching the distant ships and looking up at Jupiter from time to time. Nobody questioned the need to strike, and as the tactical navigator it was up to her to name the mo-

ment. An atrocity awaited her signal. At last the edge of the Sun's disk blazed into view on the horizon, and Wirana descended into the submarine.

Seafaring was an old tradition with Mudati's people. Sixty thousand years earlier they had built humanity's first rafts and crossed the waterways of the East Indies to discover and settle Australis. They had never lost their technological lead, even though their society had been looking inward for a very long time. Twenty thousand years before the Ziggurat was built at Ur, an Aboriginal philosopher had built the first steam engine. During the last ice age another had analyzed ore from what had been called sickness country, and within a few centuries the refined uranium from that ore was used to drive their first nuclear-powered trains and ships.

All the while the rest of the world made halting progress from nomadic hunting to Neolithic farming, then the first cities were raised on the land of the middle east. As the Phoenician ships of Pharaoh Nechos II circumnavigated Africa, the first Aboriginal rocket thundered into space from the east coast of Australis.

In general the Aboriginals studied and monitored the rest of humanity with detached interest. Beyond Australis the progress of technology and civilization had been much slower, but over the last three thousand years some new and frightening trends had been observed. Civilizations rose and fell in mere centuries, reaching unheard of levels of sophistication during their brief flowerings. Computer models predicted that there was a point at which the headlong leaps in progress would become self-sustaining, and would race past the painstaking progress of the Australis people in mere centuries. All that was needed was a new frontier.

The *Kondolae* surfaced again at dusk, two miles in the wake of Cristoforo Colombo's fleet. The sea was smooth, with a light breeze. Wirana was in the chart cell when Nunga came in to check the status of the ships. He always verified her figures himself.

"Ideal sailing weather," Wirana remarked, trying to be pleasant. Nunga just grunted. "Moonrise in a few hours, and clear skies."

For some moments he examined a trail of winking lights on the electronic wall chart, then picked up a monitor frame and studied it carefully.

"They've altered course twenty-four degrees, they're steering straight for the closest islands. How could he have known?"

"From the flight of the birds," replied Wirana, weary of his visits by now.

"How would you know? You use computers and satellites to navigate."

"But I studied the history of navigation for this assignment. If I was navigating for Colombo's fleet I'd take the present course."

"He's good," said Nunga grudgingly. "If anyone can do it, Colombo can."

Wirana folded her arms and stared into the glowing screens, each with a different representation of the little ships and their status. She sensed a softening in Nunga, and almost without thinking she tried to build on it.

"Exploration is a precarious business," she said. "I feel sorry for all those men, so far into the unknown on those frail, tiny ships while we're down here, eating marinated crocodile steaks and drinking macadamia mash brandy."

Nunga scowled, and turned from the screen to stare her down.

"We have had our trials too. Narabinda lost half of his expedition in the cold, grey dust of the Moon while the Romans were having orgies and chariot races. My grandfather died when the tenth Mars probe crashed into the red deserts while Colombo was at his mother's breast. When the *Wondibingi* arrives at Jupiter *you* will be in danger too, from sulphur volcanoes and showers of radioactive particles. There's no reason to sympathize with the men on those ships. They may be very brave—"

"Death from the dangers of the frontier is honorable. Being smothered by the obscene lie that this ship is about to commit is something else. We're prostituting sixty thousand years of medical and technical progress."

Nunga scuffed the sand overlay of the decking, unsure of whether to persuade or attack.

"It simply has to be this way. What you refer to as an obscene lie is the only chance for our world. If we just make Colombo's fleet vanish, others will try. They have to be convinced that there is nothing out here. Otherwise they will race out of control before we can educate them to develop in harmony with the Land."

"But we're enslaving the soul of their people."

"If they are given a huge, rich frontier just now they could well overtake us within five hundred years."

"Impossible!"

"No, eminently possible. Consider their muskets, falconets, and lombards. Even though we had invented black powder rockets before the last ice age, these people invented guns before us. What weapon might they develop with nuclear power?"

"Why, none, it's not practical. The smallest possible nuclear bomb would wipe out a city. How could you have the capitulation welcome and the reconciliation festival after a battle if all your enemies are dead?"

"They don't have those traditions, they never have. They have no honor, no ethics, they'd stoop to tactics that we would never dream of using."

She did not agree, and she did not reply. The conversation was annoying her, and she wanted Nunga to leave.

"They will take about four days to reach land," she said. "What else do you want to know?"

"Nothing. That means we must strike now, while the ocean is still deep enough to conceal us."

"There's a good depth almost to the islands."

"Act now! They're nine-tenths of the way across, it's obvious that they will reach the islands. If they had sailed in a more southerly direction they would have reached land already. They'll do it, there's no doubt at all."

"I want to know that he *could* succeed, even if he does not. Until I know that I'll not recommend dilation to begin."

Nunga raised his eyes to the ribs of

the ceiling. "Of all the irrational, stupid—I'm going to report this to the Elders! Six hundred of my specialist medical elders are being kept waiting on your whims. It's costing a fortune."

"If I let a bureaucrat like you frighten me, I'd be unfit for the Jupiter flight."

"Jupiter? You'll not even return to the Moon, I'll see to it."

On the following day Admiral Colombo ordered his ships to steer west by north. The gigantic submarine and its own fleet of attendant submarettes also changed direction.

"He has doubts," reported Wirana at the quarter day review meeting. "Colombo has changed course to miss the closest islands."

"The mainland is still ten days away," agreed Mudati, "and the Gulf Stream will give him a strong northward vector. This may be the turning point, he may give up and turn east for home."

Nunga frowned but could do nothing but agree. Colombo could make his name immortal, but only if there was a strike. He was dependent on the Italian adventurer's whims, and he hated it.

The fleet was soon back on a west-south-west course, but the brief deviation had suggested that Admiral Colombo was uncertain. The main directive in Mudati's charter was the avoidance of intervention, so the mariners were to be given every chance to fail by themselves. The next day was a disaster, however. A good breeze took the ships a record distance for the voyage. Wirana nervously eyed the depth-sounder as the sea floor sloped up with the continental shelf. The *Kondolae* needed a depth of 2,000 feet to navigate safely when fully dilated and submerged.

Aboriginal history had its atrocities, but had generally been marked by steady, carefully thought out progress based on a love of their land. The *Kondolae* had taken decades to build, grow and shape, and was by now centuries old, typical of their approach to industry and technology. Mudati was the hereditary captain, the ninth so far. Their cities were numerous but not large, and they merged in with the landscape. Colombo could have sailed all the way around the Australis coast without noticing anything more than unusual rock formations, yet there was an advanced civilization there. It was a civilization with sixty thousand years of written history, and an advanced technology that had been blended into the land, rather than gouged out of it.

Early in the evening Nunga called a meeting of all senior officers in the navigation cell, and arranged a satellite hookup with the Counciliar Elders back in Australis. One wall screen displayed a transmission from the eye-cameras of a robotic albatross flying high over the ships. Their sails were trimmed for the strong wind, and they were moving fast.

"This is the greatest distance that they have sailed in one day for the whole voyage," thundered Nunga, partly for the benefit of the Counciliar Elders, whose heads were holographs behind transceiver screens. "We have to act now, we're probably too late already. The captain is in flagrant violation of the charter for this voyage, and Navigator Wirana should be dismissed at once for gross negligence."

He sat down on the red sand of the floor. Wirana stood up.

"The ships cannot possibly reach land tomorrow, but will definitely sight some island the following day," she said firmly, addressing the screens rather than Nunga.

"You admit it!" spluttered Nunga, but the captain motioned him to be silent.

"The *Nina's* lookouts will be able to see the trees of one of the islands around noon on what they call October 12th, if the present course is held." From the corner of her eye she saw Nunga's mouth begin to open, but she was ahead of him. "Thus tonight is the perfect time to begin dilation of the ice chamber. It will take a day to dilate and tomorrow evening will be the best time to strike."

For a moment Nunga was too shocked to respond. Victory at last, but victory too late. Captain Mudati allowed himself a little grin as he tapped a key to call the control node cell.

"Commence dilation at once, on my authority," he ordered.

Nunga got to his feet, fists clenched. "It's too late, they'll sight land before we are ready to strike. *One* change of course will throw our tactical navigator's calculations out. The whole *point* of this venture is to prevent them seeing land."

"Your experience, Captain?" asked an Elder.

"In that case we'll be forced to kill them in the conventional sense, and Navigator Wirana will have the deaths of ninety men on her conscience."

Wirana was shaken, but did not show it.

"Tomorrow night will be perfect," she continued, her voice level but her eyes blazing at Nunga. "There's no Moon until after midnight, the breeze will not be too strong—and we'll have proved beyond any possible doubt that they could have reached an island. Our charter is not to intervene unless the danger of landfall is beyond question."

"It was beyond question a week ago," Nunga snarled.

The ridge on the submarine's back began to expand into a second tube, open at both ends, but this one did not pump water. As it expanded the vessel sank lower to remain below the surface, and by morning the drive tube was six hundred feet below the surface while the carrier tube's roof was barely below the waves. The fusion powerplants were now straining to move the larger surface area through the water. A dozen submarettes that had been flanking the *Kondolae* now moved forward to form an arc upwind of the three ships. The seas were rougher than at any time during the voyage, as if anticipating the drama to come.

Wirana was in the navigation cell at sunset when Colombo changed course to sail west. The island of Guanahini was now dead ahead, and would be visible by moonlight an hour or two after midnight. Nunga was strangely composed when he heard the news.

"They must die," he said simply. "The opportunity has been missed, it's too late. They changed course, exactly as I warned."

"We will take six hours to surface," said Mudati, "and another half hour to strike. The limestone cliffs of the little

islands just south of Guanahani will be visible to their lookouts by then."

"But we can cover them in fog from the submarettes," Wirana pointed out. "If we start generating the fog bank now it will be shrouding them a couple of hours before we need it to shroud our own approach, yet it will cut off their view of the island."

"It's too late," muttered Nunga sullenly. "There's not enough depth to let us travel safely."

"I'll be the judge of that," said Mudati, suddenly tired of Nunga's petulance.

Ahead of schedule the submarettes began to raise a thick fog, which rapidly rolled out over the *Nina, Pinta*, and *Santa Maria*. The admiral quickly ordered the *Nina* to drop back, just as had been expected. The *Kondolae* was big enough to swallow whole icebergs, so big that surfacing was a major operation. Superconductor driven pump muscles flushed seawater from the ballast bladders low on the outer hull, and the submarine rose out of the water and powered along like a floating aircraft hangar with a 700-foot-high roof. At midnight it began to bear down on the patch of windblown fog.

Nobody on the ships realized that they had been swallowed—fog, seawater, and all. At a signal from Mudati the ends of the tube began to close with a vast rumbling of artificial muscles, capturing a foggy pond and three ships. Within the tube the wind died, and the *Kondolae's* own fog generators now took over from the submarettes, filling its vast interior with clammy billows. The trapped water quickly settled to a calm sheet.

Robot manipulators, designed to handle millions of tons of ice, gently swung out from the internal walls and reached for the huddling ships. They were programmed to grasp the hulls firmly from below, yet give the sensation of floating. The water remaining within the huge tube was now pumped out while mist was blown past them from below. To the Spanish sailors it seemed as if they were plunging through a nothingness of thick mist, and the air was cooling rapidly.

From an observation gallery high on the hull Wirana looked out over the rapidly dispersing fog to the moonlit cliffs and trees that had been snatched away from the Spaniards. Mudati was standing beside her.

"He got to within sight of them, yet he never knew," she said.

"Does that make you feel better?"

"History will record that he completed the voyage without knowing it, and all the world will know in centuries to come. That was the least that I could give my fellow explorer."

"So that was the reason for your delay."

"I gave the man immortality as an explorer. It might not make up for what Nunga is doing to him, but it's something."

"You may have lost immortality for yourself. There was a lot of truth in Nunga's reports on you. The Elders want no foolhardy adventurers on the Jupiter expedition."

"Exploration without risk does not exist. Crew the *Wondibingi* with sensible bureaucrats and they'd never risk leaving lunar orbit. I took a considered

risk, based on experience."

"Just between you and me, Wirana, a majority of Elders believes that too, but at the inquiry please stress that you delayed for so long because of the magnitude of the moral issues at stake. OK? Now, let's go down and meet Admiral Colombo."

"But he'll be dead!"

"Don't you even want to look upon the man that you fought for? Don't you want to see him in the flesh?"

"No more than I'd want him to see me on the toilet."

They had sailed over the edge of the world, they were falling and doomed. Some began to pray, some fought each other blindly, but this did not last long. It became hard to breathe, and within minutes there was not a man left conscious.

Bartolome de Torres awoke shivering, cold sand beneath his naked body, waves washing around his legs. He sat up, surveyed a beach strewn with naked white bodies, some stirring. There were seven or eight dozen of them. The sky was dark, but there was a glow on the horizon. He looked up. Jupiter and Mars were high, so it had to be morning. He was on land, land beyond what seemed to be the edge of the world. He was naked, not a ring, not a boot.

He rose to his knees and began to pray, giving thanks for the deliverance that he had prayed for so fervently in that terrible region of cold and dark. Others were awake now, some praying, some cursing, and suddenly someone cried out "Look, look, the rock!"

Bartolome turned to follow the pointing finger. Gilbraltar! An unmistakable form, there could be no two landmarks like it, yet . . . he glanced at the sky again. Mars and Jupiter were still close together, the Moon was a mere sliver. No more than five days could have passed since they had sailed off the edge of the world, yet they had been sailing west for more than a month!

He had died. He had been stabbed in the throat by a crazed shipmate. He felt his throat: a little sensitive, but no wound. Abruptly he cried out as he realized that his teeth were no longer hurting. For the first time in years his teeth were not hurting. Someone nearby cried out that his gout was gone. A miracle, a whole succession of miracles! The crews of all three ships had been brought back to life and cured of all ills.

They had evidently been discovered by seaweed gatherers before anyone had revived, for a squad of cavalry was approaching, following by a crowd on foot. Spanish armor, Spanish saddles, and they were hailing them in Spanish. He sat down heavily in the sand. They had been returned to Spain.

"We are all naked before God," said the man beside him, "and here we are naked."

"So have we been before God?" Bartolome asked. "I was dead, and now I live. My teeth have stopped hurting, too. A miracle, what else but a miracle?"

"A miracle. We have been saved. Brought back over the edge of the world, brought back to life, brought back to Spain. Give thanks to God and His Holy Mother, rejoice!"

"But why us? We are just sinners. I killed a man, I was under sentence of

death, then the King pardoned me to sail with the Admiral. Then we fell over the edge of the world and died. Did God pardon us to come back to Spain?''

''We were surely brought back for a purpose,'' suggested his neighbor.

A strong subliminal suggestion suddenly broke through into Bartolome's consciousness.

''God pardoned us our sins to witness the edge of the world!'' he concluded. ''A kind God would not let honest seamen die in vain, sailing into waters from where there can be no return. We were sent back to give a warning to all Christians. The world is bounded, the edge lies far out in the Atlantic.''

The men on the beach were naked but in good health, and in years to come it would be found that none of them could be infected with any disease. Those who avoided accidents would die well into their nineties, or even older. Soon blankets, cassocks, and cloaks were being handed out, any clothing that could be found in a hurry. Their rescuers were beginning to suspect that something strange and wonderful had happened.

Columbo was led through to a horse, wrapped in blankets and walking unsteadily. His eyes were wild and staring, those of a man whose great vision has been replaced by something greater.

''God raised us up, brought us back to life,'' he shouted to the onlookers like a prophet newly arrived from the wilderness.

''Mother Church will make us saints,'' said Bartolome.

''Saints are made by good works,'' admonished his neighbor. ''Come, we must begin the work that we were returned to do.''

He helped Bartolome to his feet, and together they walked up the beach as peasants dropped to their knees before them, imploring them to accept their own clothing. Anything that they wore now would become a holy relic.

''God brought us back from the edge of the world as a warning to sailors,'' cried Bartolome. ''Beware sailing too far west.''

''Christ be praised, Holy Mother of God, save us all,'' the crowd shouted back. ■

●All genius is distorted. Including my own. But so for that matter is all life; a mad and futile ferment of substances meant originally to occupy space without disturbing it. But alas, here we are in the thick of the disturbance, and the only way that has occurred to us to make it tolerable is to join in and raise all the hell our ingenuity may suggest.

Nero Wolfe in the *League of Frightened Men* by Rex Stout

The Alternate View

POLLUTING THE UNIVERSE

G. Harry Stine

Sometimes I'm asked if we will pollute space by moving our industrial activities out there. I've been thinking about this for a quarter of a century. So I forget that some people can't grasp how much room there is beyond the Earth. I often forget it myself. We humans aren't used to thinking in three-dimensional volumes. We're two-dimensional in our outlooks.

In addition, few human beings have much of a sense of perspective, not only in the three-linear dimensions but in the time dimension as well. Even in art, perspective is a recently developed capability of the human brain. We have to be taught perspective in art and drafting. We are taught history in the hope that the subject will give us some time perspective. Some people can learn. Others can't.

We also believe the rest of the world is just like what we see within a radius of 25 miles of where we are.

And a cubic mile is just about all we're intellectually comfortable working with.

To get a handle on what might be involved if we deliberately set out to pollute space, let's run some numbers. It's easy to do. I used a $9.95 Radio Shack hand calculator. Anyone can come up with these numbers, even using longhand arithmetic.

The entire biosphere of the Earth consists of the surface of the Earth times the ecosystem's depth. This is the average depth of the oceans (2.5 miles) plus the effective depth of the atmosphere, ozone layer included (15 miles). In comparison with the radius of the Earth, this is a very small number.

The area of the Earth is 196,938,800 square miles, according to the 1992 issue of *The World Almanac*.

Therefore, the volume of the Earth's biosphere is the surface area of the planet multiplied by the depth of its biosphere (17.5 miles). This tells us that the Earth's biosphere, our environment, contains 3,446,429,000—a little shy of 3.5 billion—cubic miles. Most people aren't used to dealing with numbers that big unless they work in Washington D.C.

Let's compare this number against something familiar and on a more human scale. The island of Manhattan is 14 miles long, 2.3 miles wide, and extends upward to the top of the World Trade Center, 1,330 feet, a quarter of a mile. Manhattan therefore occupies a volume of about 8 cubic miles.

The Earth's biosphere is 428,127,826 times the volume of the Manhattan Island environment.

This sounds like the city's budget for garbage (pollution) removal, but we're getting used to big government numbers. After all, it costs more than a billion tax dollars every time NASA flies

the space shuttle.

As we move out into space, the numbers get bigger. So let's start small.

The first space industrialization activities will take place in the Earth-Moon corner of the Universe. The Moon is 238,857 miles from the Earth. That's its average distance. The simple formula for the volume of a sphere taken from a junior high school math text allowed me to calculate the volume of the Earth-Moon environment. It's 57,082,439,000,000,000 cubic miles —some 57 quadrillion cubic miles.

This is 16.5 million times the size of the Earth's biosphere.

But we can easily reach out into the Solar System, too. We don't need star ships to do that. Any place in the Solar System can be reached with current rocket technology. And if you thought the Earth-Moon system was big, read on.

The Solar System has a radius of 4 billion miles, roughly the distance from the Sun to the planet Pluto. Using the same formula, I calculated the environment of the Solar System. It has so many cubic miles in it that we can't even describe the number.

It's 26 followed by 28 zeros.

That's 77 quintillion times the size of the Earth's biosphere. It's several sagans large. (A sagan is widely recognized in science as billions and billions of something.)

It took the human race about 150,000 years to pollute planet Earth to the point where our very best scientific instruments can now detect it. To believe that we can pollute the Earth-Moon system that's 16.5 million times bigger implies a faith in human rapaciousness and neglect that's beyond reasonable consideration. As a species, we may be mean, nasty, vicious, covetous, and aggressive, but we aren't stupid or we wouldn't have survived this long.

Another factor is the belief that human beings will pollute anything they touch. To render this planet uninhabitable would require a technology that's far beyond anything we have available today. This belief is based on a fear of the perceived capabilities of technology fed by a scientifically illiterate and sensationalistic news media reporting statements from people with an axe to grind and intended for a population that is technically competent but scientifically challenged (to use a current PC phrase).

We *might* be able to destroy the Earth's biosphere if we had a worldwide general thermonuclear war. But this is now a highly unlikely scenario. Even if it occurred, the potential consequences are highly debatable. I've run some numbers about that in my work with the Hudson Institute, NASA, and the Department of Energy. Furthermore, it's an academic study. No one has yet conducted the experiment, and no one wants to.

Therefore, to consider that we humans could pollute something 77 quintillion times as large as the Earth's biosphere—in which most of us are still living in good health along with other flora and fauna—implies technologies beyond anything we can even dream of today. Maybe "Star Trek: The One Hundredth Generation" might have such technologies available to them, but not much before that, if then.

We also fail to appreciate the big change that has taken place in industry.

As my friend Alvin Toffler points out, we're finished with the era of massive mass production. Smaller and faster is better. I agree.

And we're dealing with very big numbers when we talk about space even in our own backyard, the Earth-Moon system. If anyone thinks that a million is a small number and that it's easy to do something 16 million times more than what we're doing, I'd like to ask them for 1 million dollars for a cup of coffee, OK? ("Buddy, can you spare a billion?")

We also have to look at what pollution really is. The use of the word is running out of control.

Every living organism from the lowly amoeba to a human being discharges wastes into its immediate environment. This is a consequence of a principle that scientists and engineers are taught. It's called "The Second Law of Thermodynamics." This is a fancy term that means there has been, is, and always will be waste, scrap, and garbage. However, we're doing better in our constant battle against this. Creating a 500-page book manuscript used to mean 1,000 pages of waste paper. Computer word processors based on modern technology have reduced this. A 500-page manuscript is now accompanied by only about 100 pages of waste paper.

We are living organisms. We always create waste.

When any organism creates more waste than the immediate environment can recycle or reprocess, it's called "pollution."

When an organism produces waste materials that the environment *cannot* recycle, that's also pollution.

But pollution is a four-dimensional problem. It's time-phased. And it's localized. Some days you can't see across the street and the next morning you can see forever. Hardly a day goes by that I can't see at least 93 million miles, but the Sun shines in Arizona more often. This isn't the end of the Earth, but you can usually see it from here.

It's indeed possible to see and smell the localized pollution in large metropolitan urban areas. But 50 miles away it takes the best and most expensive scientific instruments to measure it.

This localized pollution is caused by too many people crowding together in too little space. When psychologists forcibly put animals into overcrowded environments, the animals go crazy. Only human beings do this to themselves voluntarily.

And we not only create pollution but hate, aggression, overweening selfishness, a power drive, covetousness, possessiveness, jealousy, turf battles, shortages, hoarding, and a rigid hierarchy based on physical coercion. Look at any large urban metropolitan area on the planet for proof of this. The predominant philosophy is, "Hey, I've got mine, Jack! Don't try to take it away! And give me some of yours or I'll take it!"

Human beings evolved as hunters. We need room around us. An indication of how humans *could* behave in an environment of ample room and adequate resources—that is, *rich* people in comparison to others—can be seen in the United States of America and Canada. Americans and Canadians rushed to the suburbs during this century for a very good reason.

The late novelist Louis L'Amour put this very well from another viewpoint: "The automobile is modern man's antidote to overpopulation."

Can or will human beings pollute space?

Not with any technology we can imagine in the imaginable future.

Not with a whole Solar System out there with lots of room. By the time we may have grown to the point where we might pose a pollution threat to the Solar System, we'll probably open up the whole Galaxy. Or we'll be operating with technology that is more efficient and doesn't produce as much waste, just as we have done with computer word processors. We don't even know what that technology will be today.

Perspective and an alternate view lead me to the logical, rational, reasonable conclusion that we'll go into space without worrying that we'll pollute it in the next few millennia. Space is so big that we couldn't possibly pollute it in more time than the human race has been around.

And the basic reason for moving industry into space is to take it from where it *does* pollute in a limited environment of only 3.5 billion cubic miles here on Earth and put it where it *cannot* because of the sheer volume out there. ■

CONTEST FOR SPACE

Because of the crucial importance of space to this nation and the danger that the space program now faces in Washington, the following organizations are sponsoring a letter-writing contest for adults and children: *Analog Science Fiction & Fact,* Challenger Center, *Final Frontier, Isaac Asimov's Science Fiction Magazine, NASA Tech Briefs,* National Space Society, *Omni,* Spacecause, and Spacepac.

Letters of two hundred words or less on any pro-space theme may be entered into the contest by sending a copy of the letter, your name, address, age, and phone number to Spacecause by *October 15, 1992.* Contest entries should be sent to Mark Hopkins, President, Spacecause, Dept. D, 3435 Ocean Park Blvd., Suite 201-S, Santa Monica, CA 90405.

A three-day adult session at the United States Space Camp in Huntsville, Alabama, will be awarded to the best letter from someone seventeen or older. The author of the best letter from a child or young adult will receive a week-long children's session. Transportation is not included. In addition, the one letter judged best overall will be published in the magazines of the sponsoring organizations listed above. These magazines have a combined circulation of more than one million.

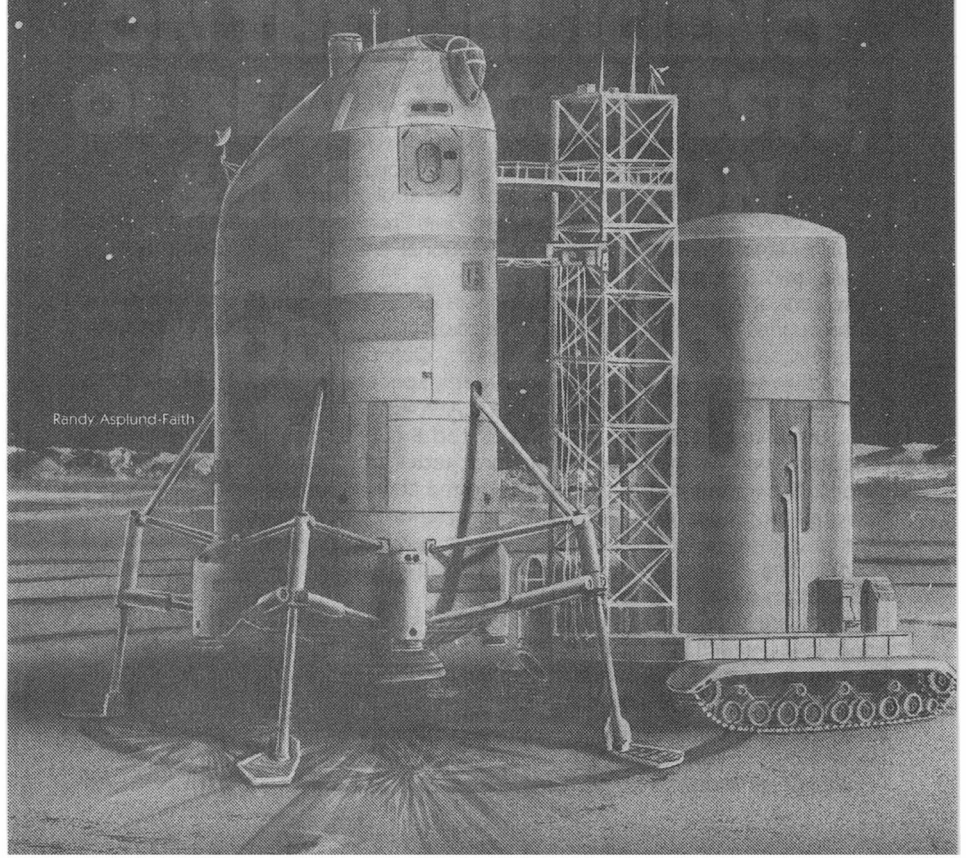
If you are interested in learning about taking effective action through letters and other means in support of the civilian space program, send Spacecause a contribution of $10 or more. You will be added to the Spacecause list for two years—that's only $5 per year!

(Part II of IV)

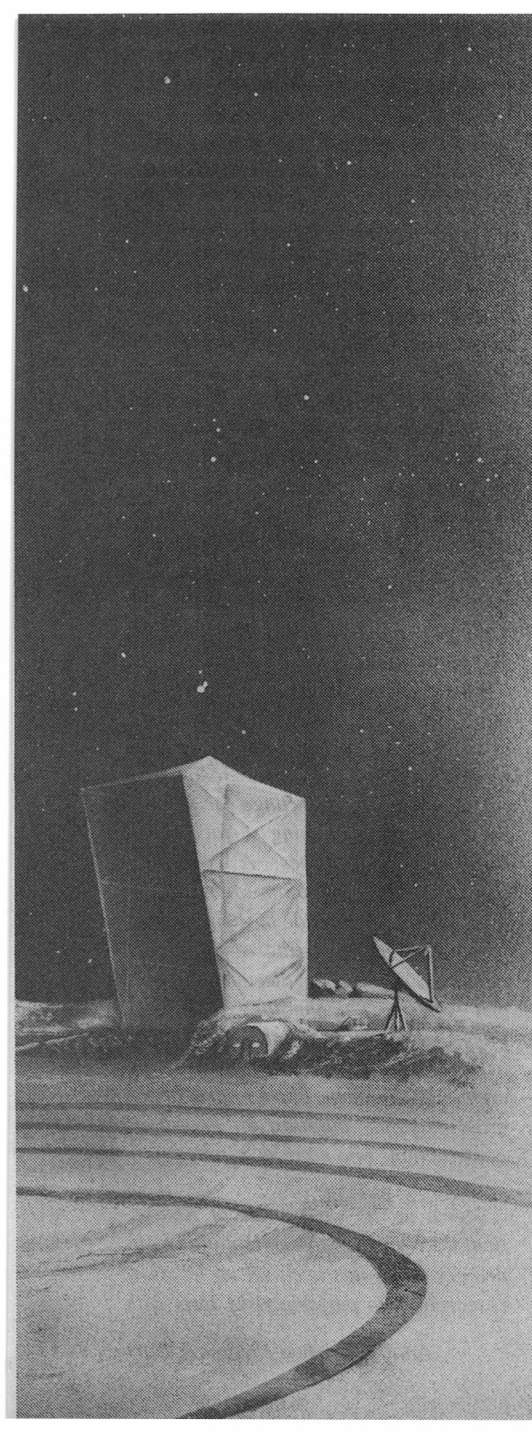
Kevin J. Anderson & Doug Beason

ASSEMBLERS OF INFINITY

Faced with a new phenomenon, you must attack it with all the knowledge you already have—which probably doesn't include all appropriate precautions!



Randy Asplund-Faith



SYNOPSIS

On the Moon, hotshot technician **Trevor Waite** *and his two assistants,* **Siegfried Lasserman** *and* **Becky Snow,** *pilot a hopper vehicle to the lunar farside. A very low frequency array designed to function autonomously in Daedalus crater has started to malfunction. The telepresent robot that usually checks out such anomalies has mysteriously broken down; for the first time in five years, someone has to travel in person to the far side of the Moon.*

Leaving Lasserman at the hopper controls, Waite and Snow deploy a rover vehicle to take them down into the crater. As they look out across Daedalus they are astounded to see a giant excavation project, a strange and bizarre construction being erected there—but they know this is impossible! The lunar base should have detected all sorts of seismic signals judging by the amount of Moon dirt being moved in this operation.

Down in the crater, Waite and Snow find no moonbuggy tire marks, no machinery, no signs of life—it is as if no one has ever set foot there, yet somehow this massive construction project is underway, silently assembling itself from the ground up. Walking around, Waite and Snow see giant gossamerlike frameworks, the foundations of something big, something no human has ever built.

Waite hears an urgent call over the suit radio from Lasserman. He looks back to the hopper, and is stunned to watch it dissolve *before his eyes. A moment later, Becky Snow dies beside him as her suit is ruptured, disintegrating as he watches helplessly.*

Then alarms start flashing in his own

suit. Waite has microleaks throughout the material, more than the self-sealing system can handle. He looks down and sees the outer layer of his suit evaporate. He shouts into his radio one last time, then his suit is breached.

Back at Moonbase Columbus on the other side of the Moon, **Jason Dvorak**—*architect and new commander of the base—is shown Waite's final transmissions. Jason has a wife and young twin children back on Earth; he has come to the Moon to tackle the grand challenge of expanding the moonbase into an actual autonomous colony, but it has cost him his marriage. He is not very happy on the Moon, but knows he would be less happy on Earth. He has no idea why he was unexpectedly promoted to be moonbase commander, why the former commander,* **Bernard Chu,** *was sent up to the L-2 waystation* Collins *to take over there.*

Working with the engineers **Lon Newellen** *and* **Cyndi Salito,** *Jason calls up maps of the Daedalus site and finds that the topography has greatly changed since the last lunar mapping photographs.*

Back on Earth, **Celeste McConnell**—*director of the United Space Agency in Washington, DC—mobilizes the moonbase to determine the origin of the mysterious Daedalus construction. Celeste is forty-two, trim, extremely sharp, and a good public servant. As an astronaut fifteen years ago she singlehandedly rescued most of the crew members on the space station* Grissom *when a satellite impact breached the habitat modules, and has been a national hero since. The disaster killed her husband.*

At the moment, she is working with Air Force General **Simon Pritchard,** *thirty-six, opportunistic, and very intelligent. His specialty is in running supercomputer combat simulations and consequence models. Pritchard is somewhat upset because he has been given "busy work" instead of something truly important.*

From Local Mission Control, Celeste and Pritchard watch as Jason Dvorak on the moonbase sends out a telepresence probe to the farside crater to take readings—but shortly after it lands within the eerie gossamer structure, the probe disintegrates. *The staff frantically tries to find out the reason—there's no radiation, no detectable energy surge that would destroy the probe.*

An infrared flyover of the Daedalus crater shows a "hot zone" in a circle about three kilometers in diameter surrounding the construction. Jason and the moonbase staff arrange for a sample-return mission using surface-penetrator geology probes. A contained sample is whisked off to Sim-Mars, an isolated lab on the far side of their crater.

During remote testing of this lunar regolith sample, they discover the culprit—alien nanotechnology machines, tiny engines a billionth of a meter across. The Daedalus site must be crawling with them, like a swarm of microscopic ants building an enormous construction, one atom at a time.

Down in the wastelands of Antarctica, the Nanotechnology Isolation Laboratory (NIL) has been set up to allow researchers to perform risky tests with

prototype nanotechnology machines. The NIL is staffed by the meticulous and well-respected old researcher, **Jordan Parvu,** *and his assistant,* **Erika Trace.** *Erika is young and attractive, a talented researcher in her own right, but Parvu thinks she is too buried in her work. She has no other close friends, no social activities. Why would she want to be with an old man in Antarctica, rather than with people her own age? He keeps trying to tell her to "get a life" but she does not want to stop working with her mentor.*

She and Parvu have received a new canister of nanomachine prototypes developed jointly by Stanford and MIT, which are being successfully tested in the NIL's heavily safeguarded "nanocore." Before the two researchers can celebrate, however, Parvu receives a direct communication from Celeste McConnell, explaining what they have discovered at Daedalus crater; with his background in nanotechnology, Parvu is the obvious choice to study the nanomachines discovered on the Moon.

Instead, Parvu claims to be too old and delegates Erika to go. This is actually a thinly disguised excuse to force Erika to "leave the nest." He thinks the alien nanomachine infestation is a perfect challenge for her. Angry at Parvu and not wanting to leave, Erika grudgingly allows herself to be picked up and taken to a special supply ship that takes her out to sea. Her next stop will be the Moon.

PART II

CHAPTER 7

To The Moon

Erika wasn't in orbit for more than three revolutions before her scramjet-boosted aerospace plane rendezvoused with the Lagrange shuttle-tug. Earth wheeled above her as if it were about to drop down on her head, making her dizzy as the vessels approached each other. Coming out of the black backdrop of space, the spindly shuttle-tug reminded her of a Tinker toy model she had once built. Her brother Dick had broken it.

Once docked, the crew handed her off to the Japanese-contracted tug. Everyone seemed rushed—from the moment she had left Star City, to launching in the aerospace plane that took her to low-Earth orbit. If she had gone the usual route, the trip to the Moon would have taken ten times as long. But the Agency was in a hurry to get her to work.

Combining aerospace technology and solar-electric tugs yielded an efficient and affordable option for frequent trips to the lunar surface. But this route also required a month-long spiraling trip from LEO to L-1, the Lagrange staging area to the Moon's surface. Director McConnell at the United Space Agency couldn't afford to wait that long. It had already taken Erika two weeks just to get the bare-bones preparations for her assignment.

So a specially fitted Japanese tug had been brought on duty at L-1 for just this purpose—to get Erika to the Moon in the shortest time possible. Outfitted with relatively inefficient but fast nuclear-thermal propulsion, the tug would haul Erika to L-1 within seventy-two hours.

Numbed by the whirlwind of events, Erika did nothing more than follow in-

structions, allowing herself to be handed from person to person, strapped into her couch, checked over for safety glitches. She had been too busy to feel terrified, but she knew it would hit her during the three-day journey in which she would have nothing to do. Grudgingly, she let her uneasiness about leaving Parvu fade to be replaced by a growing enthusiasm for the challenge.

All those training sessions in Star City still seemed a jumble to her—a mish-mash of safety demonstrations, spacesuit fittings, survival techniques, breathing exercises, anabolic procedures, lectures on zero-g and low-g hygiene. A crash course in survival instead of the full complement of astronaut-certification training. It had been like taking a drink out of a fire hose.

She longed for the peace and isolation of Antarctica, where Jordan Parvu now had the NIL all to himself. Was that how he wanted it? She didn't think so. No matter what, she was still going to need a lot of Parvu's assistance to figure out the nanomachine infestation. A good way to test whether long distance really was the next best thing to being there, she thought.

Erika spent the three days in transit studying tapes of the Daedalus events. Events—not deaths. She couldn't bring herself to keep thinking that someone had died just by getting too close to the gigantic construction. If she got too hung up on the people, the loss of life, she couldn't study it with the proper objectivity. She couldn't let herself feel a grudge against the little machines.

Waite, Lasserman, and Snow could not be living beings to her, not warm flesh with pasts, and lovers, and some sort of future in mind. Seeing the uproar on the newsnets hadn't helped much, interviews with people the three of them had left behind, hometown funerals, grade-school classrooms decorated with crayon-drawn posters portraying them as heroes.

No. They were simply data points —W, L, and S—complex organisms that had been disassembled, just as the regolith sample had been. Erika had always known that nanotechnology was dangerous, hence all of Parvu's incredible sterilization precautions back at the NIL. But these mysterious nanomachines went far beyond anything she and Parvu had attempted. Or imagined.

She felt like a butterfly collector who had always studied dead and mounted specimens, suddenly thrust into the middle of a dense and uncharted jungle.

Webbed into place in her cramped cabin, Erika called up her stored data on the portable computer. Staring at the virtual display, she slowed down every portion of the regolith disassembly process in the Sim-Mars vault. Frame by frame she observed the sequence, zeroing in each 3-D pixel as it disappeared from view.

She went over Waite's last transmission. She saw the moonbase control center images of the telepresent hopper being disassembled at the Daedalus construction site. There seemed so much to study, but it was not enough to keep her mind completely occupied. She understood Director McConnell's need to placate millions of uneasy inhabitants of Earth. When someone wanted an answer fast, the easiest way was to grab a local expert and keep the pressure on until a solution was found.

Erika had been dropped smack into the middle of the problem. She felt as if she had stepped on a big pile of horse manure.

Hour by hour she pored over the events. For three days. The other crew members, busy with their own tasks, left her alone. That suited Erika just fine.

She turned her thoughts again to Jordan Parvu. Why hadn't he wanted to come to the Moon? If he wanted to study functional nanotechnology so badly, why didn't he jump at the chance? She couldn't believe he didn't want to take the risk. After all, Antarctica was perhaps the most savage spot left on Earth. And the Sim-Mars isolation lab on the Moon certainly could be no less safe than the NIL.

No, there had to be something more to it. Jordan did not want to step into the spotlight, but to focus things on her. He did always speak about how much he wanted her to succeed.

She felt a warm lump in her throat and tears welling in her eyes. That was the real reason. She knew it to the core. Now she had lived up to his expectations. This was different from trying to meet her mother's demands—she wanted Jordan Parvu to beam with pride over her successes. But that didn't make the monumental pressure feel any less.

"Hello Dr. Trace, I'm Bernard Chu, commander of Moonbase—" The wiry, intense man seemed flustered, then smiled thinly. "Excuse me, I'm sorry. With so many things going on, I can't even remember my own title! I'm the Lagrange way station director—welcome to the Collins."

Erika shook the Asian man's hand. "Thank you. And please, call me Erika. 'Doctor' sounds too formal." Her soft South Carolina drawl usually made new acquaintances feel comfortable.

Chu nodded and, holding onto Erika's elbow, helped her float out of the chamber. Webbed netting held boxes, ropes, toilet paper, silvery packaging film, and a hundred other things she couldn't identify, nor could she determine any sort of organization scheme. Since she couldn't tell "up" from "down" in the weightlessness, storing material in the netting made sense.

"Since the shuttle-tug normally takes nearly a month to get here, everyone becomes accustomed to zero-g by the time they arrive," Chu said. "But you have not had time to adjust. Are you feeling all right? Space whoops?"

She did not want to be reminded about the queasiness. "I've managed to keep my food down for the past day."

Chu nodded. "No problem then. You'll be heading to the lunar surface within the hour. We have the shuttle outfitted and waiting, pilot ready to go. Celeste—ah, Director McConnell told us not to waste any time."

"An hour?" Erika blinked her eyes as sudden nervousness rushed up on her again.

"That's the nice thing about being at L-1—we're always in position for a lunar rendezvous. Captain Zed—I mean Zimmerman—is the shuttle pilot taking you down." Chu nodded to a lanky, square-jawed man floating upside down at the rear of the room.

Erika started to greet him, but Zimmerman interrupted her. "If I were you I'd take a shower," he said. "A quick one." Zimmerman pushed himself out of the chamber.

"He isn't very big on explaining things," Chu said. "He means for the dust."

"Dust?"

Chu set his mouth and got a faraway look on his face. Suddenly, Erika remembered that he had been the moonbase commander until a few weeks before. "Yes, the moondust gets into everything—even the water supplies, no matter how much they try to filter it. So if you want to feel clean for one last time, take a shower here before you go. Our water is limited, but for Celeste's special guest, we can spare some."

"No wonder nobody wants to stay down there for long," she said.

She looked up at Bernard Chu, expecting the man to nod in agreement; but he looked serious, as if something else were on his mind. "Yes, you must be right."

"Fifty kilometers above the ground. Check your straps one more time."

Zimmerman's voice startled her; he had broken the quietness only a few times during the transfer orbit from L-1 to the lunar descent. The trip from the Collins had been one continuous silence, with Zimmerman grunting answers to her questions until she had finally decided to be quiet.

On the interior wall of his craft, Bryan Zed had painted *GLORIA*—his wife's name. He had told Erika, using only about three sentences, how it was tradition to paint the name of one's spouse on the outside of a special aircraft—Glamorous Glennis, Enola Gay—but since he had no way to reach the

exterior hull of his shuttle, the cabin wall would have to do.

He displayed several images of Gloria on the flight deck next to a plaque given to him by his graduating class at astronaut training. They had awarded him "Mr. Personality," but it must have been some sort of joke. Erika wasn't sure if Bryan Zed realized that.

She fumbled at her straps, but they were already as tight as they could be. Erika felt her face flush with excitement and a bit of fear as she tried to see the televised view of their approach. Below, the lunar surface looked like flash-frozen meringue. Gray and black shapes filled the high-definition screen. Craters, tips of craggy mountains, and vast plains of hardened lava slipped past the screen as the shuttle descended. But the shadow of lunar night masked most of the details.

She spotted a lit-up array of half-buried cylinders in the distance, similar to the Mars training camp in Antarctica. All too quickly the view narrowed to a smoothed landing area.

"Five kilometers." Zimmerman was really on a roll. This must have been twice as many words as he had spoken since the journey down from L-1. Erika couldn't see his face as he concentrated on the landing, but he continued. "We usually deliver supply pods by remote piloting, but a human in the loop gives a much greater sense of security." He placed his hands over the override controls.

"I guess it must." Erika forced the words, then closed her eyes.

"Two kilometers—we're down to fifty meters a second."

The lunar shuttle vibrated as the stern engines ignited for a few seconds. The view screen showed nothing but a landing pad in the distance. Red concentric circles spread out from the middle of the zone. Set into the ground at a 90 degree angle, a string of strobe lights intersected the circles, bright on the dark plain.

"Looking good." To Erika's relief, Zimmerman didn't turn around, but he kept up the chatter. "If our angle was wrong, the strobes would look red because of prisms in the rim. We're right on path. Relax."

The ground swelled toward them. The shuttle began vibrating as the engines kicked on, this time to stay. The landing pad's strobe lights disappeared from the screen as dust boiled up, spoiling the view.

"Twenty . . . ten . . . five . . . bingo!" Zimmerman slapped at the controls just as the engines cut off. Erika had never imagined he could sound so delighted.

Erika felt dizzy as she sat up. "The Moon. One small step for mankind, and all that."

Zimmerman gave her a blank stare and turned back to the control panel to switch the view from the landing zone to the lunar horizon. The image jumped from an unbroken plain to the brilliant headlights of an approaching rover, glimmering off plumes of dust kicked up from the shuttle's landing. From the other side of the landing pad a gantry rolled up to Zimmerman's lander. As it approached and made contact, Erika heard a faint "thunk" as the gantry docked.

Erika pulled out her lunar EVA suit, ready to go through all the motions she

had rehearsed back in Star City. But Zimmerman made no move to secure his own suit. She hesitated. "Aren't you coming with us?"

"No," he said in his flat voice. She expected him to say something like 'Just the facts, Ma'am.' "Not in my purview. It's dangerous out there."

The light above the airlock switched from amber to green as she waited. Air hissed and Erika smelled the tang of ozone. As the airlock door unseated its seals and pushed open, she felt her hair fly up at the edges; a chill ran down her back as she heard the faint popping of sparks.

A spacesuited man with the name patch DVORAK stepped out of the chamber. The suit looked as if it had been freshly cleaned, which seemed strange since she had just seen him driving across the dusty lunar landscape.

A voice came over the control panel radio, not from the suit. "Erika Trace?"

Zimmerman nodded to the stranger. "Mr. Dvorak is the director of Moonbase Columbus. He's patched through the radio."

"Oh." Erika glanced at the spacesuit but spoke toward the transmitter on the control panel. "Uh, yes sir, Mr. Dvorak."

"Please, call me Jason unless it makes you uncomfortable." He moved his arms, but his voice coming from the other side of the chamber made her feel disoriented. "We can leave for Columbus once you've finished suiting up."

Erika turned and picked up her helmet. Bryan Zed led her to a cubbyhole across from the airlock. "You know the drill?"

"Yeah. I've practiced this enough."

"Have you? Let me help anyway. There's a big difference between stepping into hard vacuum versus a tub of water back on Earth. Difference in viscosity, for one."

For a moment, Erika felt a flash of defensive anger again, but from the way Zimmerman went about helping her, she realized that he would have acted the same way no matter who it had been. But Erika was so accustomed to doing things herself, working alone or with no one but Parvu for company, she knew she would have to make a conscious effort to fit in. Otherwise her time spent here would be even more miserable than she feared.

She stood in front of the cubbyhole that held the life-support pack and spent the next fifteen minutes letting Zimmerman secure her connections. Once he tightened the last zipper, he powered up her suit.

She felt a surge of hot liquid run through her suit's inner liner. "I can feel the heater." She jerked her neck to bump the chin control, trying to remember all the memorized checklists. "Everything seems OK. I'm ready for the helmet."

With the helmet on she could suddenly hear Dvorak's breathing over the suit radio. "Mr. Dvorak?"

"Ready?" He struggled up from a mesh net that had served as a chair for the enormous bulk of his suited form.

"As much as I'll ever be." Consciously, she made herself smile to look relaxed, but no one could see her through the helmet anyway.

"Let's do it." Dvorak turned his

faceless helmet to Zimmerman. "Thanks, Bryan."

Zimmerman grunted, back to his old ways.

"Let's go, Dr. Trace." Dvorak turned for the airlock.

Erika stepped across the shuttle deck and followed him, immediately surprised at the ease with which she could move. The augmented servos that functioned as the suit's muscles made everything simple. In the crash course she had taken back on Earth, the suit and life-support pack had weighed nearly a hundred pounds; even in the water simulation tank she had not gotten a true feel for what it was like to move around in low gravity.

She squeezed into the airlock and waited for the air to cycle out back into the shuttle's reserve tanks. Dvorak pushed against her suit and motioned with his hand.

"Try not to move too quickly, and keep your center of gravity over your feet. If you start to fall, it'll feel like you're drowning in a bowl of molasses and there's nothing you can do about it. So if you drop anything, either let it be or call for help—but don't bend over. That's an acquired skill."

She felt a little more relaxed with Dvorak's conversation. It was a pleasant change from Bryan Zed's impenetrability. She found herself putting a light tone in her voice. "Sounds like how to survive on the Moon in two easy lessons."

"That's about all you'll need to know for now. But the main thing is that if you've got any questions, don't be afraid to ask. Believe me, the only dumb question here is 'Why did she have to die?' "

Erika kept her mouth shut. If there really was anything to this nanotech threat that existed on the other side of the Moon, then she had a lot more to worry about than learning how to walk in low gravity.

The airlock opened, and Erika felt like Dorothy opening the farmhouse door in *The Wizard of Oz*. The view sprawled in front of her, the same as had appeared on the high-definition screen inside the lander.

They stepped out onto a gantry platform encircled by safety wires. Above, a shower of stars lit the distant crags in pearly relief. As the platform lowered them to the lunar surface, Erika felt no sensation of movement.

Dvorak helped her into the rover, which looked like someone had added balloon tires to the stripped-down chassis of a junked car. Behind them, the gantry withdrew from the landing pad.

Dvorak moved around to the other side, climbing in behind the controls. He powered on the headlights. "We've got about a ten-kilometer ride to the base, half an hour."

"When can I see the nanotech specimens?"

"We're preparing another sample-return mission as soon as you've been acclimated, Dr. Trace—"

"OK, please stop calling me Dr. Trace. It's Erika, all right?"

"Fine. But in return you have to promise never to call me Jase. Jason is fine, but I hate nicknames."

She found herself smiling behind the faceplate. "A deal. When will we get a new sample? I've been going a thousand miles an hour for the past two weeks

preparing for this. So as soon as you can get me to the lab and have the samples ready, the sooner I can do my job here." *And the sooner I can go home,* she thought.

As the rover rolled away from Zimmerman's lander, Erika braced herself with one hand. The constant-volume suit caused annoying problems—when she bent her legs, the air redistributed inside her suit, causing the suit to respond by pinching her. And her hands already hurt from the pressure of moving the gloves.

She caught a support strut as the rover bounced away from the compressed landing area. "Am I going to be stationed out at Sim-Mars? How far is that from Columbus Base?"

"Just over fifty kilometers, on the other side of the landing zone. We don't have all the specialized tools for you to use the lab telerobotically, so you'll have to go there in person."

"I never thought I'd get there before the Mars crew."

Dvorak sighed. "We didn't think it would be used so soon either."

Erika fell silent, losing herself in the stark, exotic scenery as they bounced along. The grayness of the entire nightside world looked foreboding. She had been on the surface for only a couple of hours and she already wished she could see some color, smell something other than the antiseptic inside her suit. How about the high desert of New Mexico, or the lush woods of South Carolina? Even the sharp snow of Antarctica and the stench of a crowded penguin rookery?

The silhouetted horizon seemed oddly near, as if she could throw a stone all the way to the edge. As the rover bumped along, she picked out a spot on the horizon and tried guessing how long it would take to reach it.

Approaching the moonbase, Dvorak pointed out the distant astronomical facilities, the enormous dangling box of the gamma-ray observatory, the sprawling radio telescope, the high-energy cosmic ray observatory, and the solar telescope. The broad proton-beam collector lay off to the left, ready to receive a burst from the Nevada Test Site on Earth.

She couldn't comprehend the effort it must have taken to assemble and distribute the massive equipment. By starlight, Erika could make out tracks in the regolith, indicating that more activity had occurred here. It made her think of the gigantic Daedalus construction.

Dvorak said, "We're almost there." She saw rounded mounds at the star-lit horizon. Erika suddenly felt good about being here.

Moonbase Columbus looked as if a giant had strewn empty beer cans on the ground, then kicked dirt over them. In the center of the base a regolith-covered hemispherical dome—the control center—towered over the buried modules. Other cylinders lay like spokes radiating from the dome. The remaining buildings sat above ground in a random arrangement with connections running from cylinder to cylinder.

Dvorak said, "The original base is the pretty-looking stuff in the center. Everything else is temporary storage for Phase II until we can dig below the original structure."

"An anthill on the Moon!" She suddenly giggled.

"Well, the dirt is for radiation protection from solar flares and galactic cosmic rays."

"Wow cosmic!" She laughed again. *Why was everything silly?* She felt punchy, wonderful. She hadn't felt so good in . . . a long time. She wondered what it would be like to dance in low gravity.

Dvorak abruptly turned to her. She couldn't see his face through the mirrored faceplate, but she could imagine the look he was giving her. She wanted to stick her tongue out at him, teach him a lesson, call him "Jase" over and over again until he got really upset. . . .

Dvorak's voice burst over her helmet radio. "Erika! Check your CO_2."

"See oh two? See you too. See you later!"

He leaned over to check the diagnostic readings on the front of her suit. "Decrease your oxygen supply."

Oxygen. Erika kicked up the reading on her chin display and glanced at the colored lights dancing on the front of her helmet. Most of the lights were green, but two flashed red. She seemed to remember something at Star City about this—

She felt pressure at the front of her suit. Dvorak had one hand on the wheel and the other groping at her chest. Wow, bodice-ripping romance on the Moon! "Hey!" She tried to knock his hand away.

The thought of necking in a parked lunar rover, while both of them wore bulky spacesuits sent her into a fit of laughter again, but suddenly she realized it didn't sound funny anymore. She frowned and glanced at her heads-up display. The red lights had turned to amber:

O_2 partial pressure—3 psi: decreasing
CO_2 partial pressure—2 psi: increasing

"Hey, I was hyperventilating!"

Dvorak grunted. "You might want to keep your voice alert on to catch that next time. Bitchin' Betsy, we call it. Zimmerman didn't have you switch it on."

Erika flipped up the suit options and keyed it in. "Thanks." She felt incredibly stupid. *Hyperventilating!* What a way to make a first impression—and with the moonbase commander yet.

"No problem. Happens to everyone." He turned the rover and headed toward what looked like a tent in a plowed-level area. "Well, a few people anyway."

As they approached, Erika made out four other rovers parked underneath the deeper shadow of a silvery awning. "Easiest garage in the world," Dvorak said. "Since there's no weather, all we have to do is keep the sunlight off them during the daytime."

Erika climbed down from the rover after he brought it to a stop. Dvorak led her to the moonbase airlock. "Step up and wait inside for me."

The inside of the chamber was lined with several air vents. The metal walls had a control panel embedded near each corner. The multilingual instruction placard described them as emergency manual backups, in case the control center links malfunctioned.

When they were both inside the lock, Dvorak said, "Stand back from the wall and raise your hands."

Erika took an uneven step backward and placed her hands over her head. She heard a rapid "whoosh" throughout her

helmet, then a sharp "snap."

"That's our dust buster. An electric charge polarizes the dust, pops it off your suit, and the air carries it out. Between that and the floor suction we manage to get most of it. But you'll find the grittiness will still drive you crazy."

The airlock slid open. An enormous man wearing only a powder-blue jumpsuit stood inside the entrance. He was so large that it looked as if he might not have been able to get into the airlock. He helped Erika take her helmet off, letting Dvorak handle his own undressing. With a burst of air from the inside, the first thing she noticed was the musty, humid smell that reminded her of a room packed full of people on a hot day.

"Erika Trace? I'm Lon Newellen. I'll be driving you right out to Sim-Mars, after you've taken a breather here." He started helping her with her suit fastenings.

"Thanks." Erika allowed the beefy man to disengage the life support unit from her back as she looked around. The habitat was a long cylinder packed with supplies. Boxes stamped FREEZE-DRIED on the side were stacked all through the room. Nets hung from the ceiling, bulging with additional boxes. At the end of the module, looking like the opposite end of a craggy tunnel, was an airlock.

Dvorak moved around in front of her; he tossed his helmet to the side. A middle-aged woman caught it and gave the base commander a thumbs up. Other people came to the doorway.

Newellen finished unfastening the unit from Erika's back. "That should give you a little more mobility. Feel free to take off the rest of the suit—we're in double-hulled chambers now. All the comforts of home." Erika thought of her austere NIL quarters and realized he wasn't far off.

Erika turned to Dvorak. Finally, she was able to put a face to the voice that had come over the radio: dark curly hair, brown eyes, narrow features. He looked to be in his mid-thirties. His lips curved upward in what seemed to be a perpetual shy smile.

"Welcome to Columbus, Erika." He nodded toward the middle-aged woman. "Dr. Salito is our mining expert; you can share her quarters whenever you're not out at the Sim-Mars lab."

"Call me Cyndi," said Salito, shaking Erika's hand. "We're anxious for you to solve all our problems at Daedalus."

"Sure." She felt overwhelmed already.

"We've got you scheduled to go out to Sim-Mars tomorrow," Dvorak said. "Big Daddy has a break in his duties then."

"When he says tomorrow, he means twenty-four hours," Newellen said. "Since the lunar day is fourteen Earth days long, 'tomorrow' would literally mean about ten days from now—"

"Thanks for explaining that, Lon," interrupted Salito. She took his arm and ushered him toward the airlock at the far end of the tunnel, shaking her head.

Dvorak waited for them to leave before breaking into a smile. "Big Daddy gets a little too helpful at times, but he means well."

"I thought you said you hated nicknames?" Erika said.

"On me, but not on anybody else. They're inevitable up here. After living with these people for months in close quarters, they become a little more than neighbors. The flip side of the coin is that you tend to forget how to interact with other people."

Erika nodded. She could identify with that after being isolated for months, seeing no one but Jordan, unless she counted the rare visits from the Mars trainees. It had been nice—peace and quiet with no one around to disturb her research. And the technical papers she had published could speak for themselves.

She started to push back her hair when she realized that she still had the rest of her spacesuit on. She held up the thick glove that enclosed her hand and laughed.

Dvorak looked at her curiously, then shrugged. "Go ahead and get out of that thing. I'll introduce you to the crew."

CHAPTER 8

Springfield, Virginia

Major General Simon Pritchard felt as if he had walked into a world he had left years before. Out of uniform on a Sunday, he sat at a table covered with a huge sheet of brown paper. From the outside, the crab house looked as if it should have sported a buzzing neon sign that said nothing but EAT; instead, this place called itself ERNIE'S CRAB HOUSE.

Celeste McConnell had asked him to meet her here.

The flecked Formica tabletop underneath the brown paper tablecloth had been popular in the fifties, out of date for a few decades, back in fashion again during the nostalgia of the eighties, and now looked old once more. The crab house itself seemed unconcerned with a changing world outside.

A waitress brought him a pitcher of beer and an empty mug. He looked startled since he had not ordered it, but he accepted the mug anyway. When she pulled out her green order pad—a paper order pad!—he held up his hand. "I'm waiting for someone." He glanced at his wristwatch. He was ten minutes early.

"OK. Give me a holler." Tables sprawled across the floor of the open crab house, offering no privacy at all. A jukebox by the door competed with a television set above the counter. He wondered what Celeste was up to. His old jeans and loose checkered shirt felt comfortable, and he fit in with the other customers. Off in the corner fifteen men had pulled tables together and played a game with the check totals to see who would pay the bill; they could have been blue-collar workers or White House staffers.

He sipped his beer. It had been a long time since he had been in a place like this. He did not belong anymore. This was too strange to him. He wished Celeste would hurry.

Simon Pritchard's father had been a tough *Go Union!* auto worker. His three older brothers—Dan, Allen, and Robert—were well-built, athletic, and their father's pride. Simon, the smartest and most persistent son, had managed to secure an appointment to the Air Force Academy in Colorado Springs, then embarked on a career strewn with accomplishments.

His father had died of lung cancer at

forty-three, before Simon had demonstrated his military success. Dan had become an auto mechanic, Allen an assembly line worker, Robert a grocery store manager. Simon's career left them in the dust, but he did not gloat about it. In fact, he rarely thought of them.

He had returned to Detroit to see his mother once. She was still a housewife, living modestly off her husband's pension and life insurance, doing absolutely nothing with herself. During Simon's visit, she talked about her garden, soap operas, and the neighbors, filling him with trivial details about other people Simon had gone to school with, about her grandchildren, about her other sons and their bowling leagues and hunting trips to Canada.

Simon had wanted to talk about the importance of his job, the way he was helping to shape the nation's future. When his mother had cooked a big family reunion dinner with his brothers and their families, Simon had found it one of the most drawn-out evenings of his life.

He blazed high with success, but he had lost his family in the process. They had nothing in common anymore. *Why did they stall when I went so far? Am I an anomaly, or are they?*

"I hope you're thinking about something important," Celeste McConnell said as she slid into the seat across from him. "That intent look in your eye is enough to start a fire."

Pritchard tried to recover himself by waving for the waitress. "Just thinking about this place. Brings up old memories. How did you ever find it?"

She shrugged and smiled at him. "Slumming." She poured herself a beer from the pitcher. "Actually, this place was pretty well known for awhile." She nodded to the wall where old pictures hung of former presidents, astronauts, and senators who had frequented the establishment.

Celeste had dressed in a loose teal blouse and clinging poly-jeans. She had pinned her dark brown hair back behind her ears in a style that made her look girlish, though she was at least six years older than he. She wore little makeup. The whole effect made her look much softer, less businesslike than the iron agency director . . . and very attractive.

"What are you staring at?" she asked, smiling.

He straightened and took a sip of beer, feeling his cheeks start to burn. "You look different, that's all."

That seemed to delight her. "And so do you, General. You don't look quite so stuffy and intimidating out of uniform."

"Intimidating?" Pritchard found the thought amusing. "I was thinking the same thing about you. I like this version much better."

"Ditto," she said. "The whole idea was to go where nobody would recognize us. God knows my face has shown up on the newsnets often enough in the last two weeks."

"Then why did we come here?" He looked around at the other customers, at the lack of privacy.

"Somebody's always watching my office. I wanted to make sure nobody saw the two of us together. That could put the wrong spin on everything. We have to be very careful about appearances right now."

Now she had his interest. He met her eyes, then turned away. "I thought you had changed your mind and were leaving me out of the picture. I've been out of the public eye—"

The waitress interrupted them as she took their order. She then went off as the men in the corner burst out laughing. Someone must have gotten stuck with the bill.

Celeste leaned across the table, clasping her hands together. She looked petite, delicate, and very strong. Her black-lacquer eyes were unreadable, but her voice was mellow and reasonable.

"We have more than just a mystery at the Daedalus crater, Simon. The sheer fact of the construction and its alien origin has stunned the public. We're not alone in the Universe anymore, and we don't know a damned thing about the new kids on the block. What is that construction? How fast is it going to be finished, and what will happen when it is? What if they're not friendly? Could this be an outside threat, an alien invasion?"

She stopped to look at his expression. "Don't look at me like that! I've already heard it in the editorials, and it's bound to pick up speed. I'm not sure it's so silly. The construction has already proven it can be dangerous—three people dead, two hoppers destroyed. What if this 'circle of death' around Daedalus keeps growing? What if those alien machines decide to disassemble the entire Moon? Turn it into a galactic parking lot or something?"

He nodded, serious now. "I've considered that myself, and you could very well be right—but it doesn't make sense that you're trying to keep me hidden in the closet. Shouldn't I be helping you make your case? With my rank and my background—"

Celeste held up her hand to silence him. She took a long sip of her beer, placed it back on the tabletop, wiped foam off her lips, then studied him again. "Simon, have you ever seen the old movie *Dr. Strangelove*?"

Pritchard smiled. "Yes. Just last year in fact."

It was one of his favorites; it had caused quite a stir when it had been rereleased as the first of the old classics that had not only been colorized but three-dimensional as well. Purists had boycotted the exhibitions and generated enough publicity that the rerelease had done ten times as well as it otherwise would have. Pritchard had gone by himself to see what all the fuss was about; the movie had lampooned all those military stereotypes.

"Then you must remember Colonel Jack D. Ripper, the man who wants to destroy everything that does not fit with his philosophy? And that general—Bloodworth? The gung-ho soldier who wants all the big military toys."

Pritchard snorted. "I still know some people like that. But the world is better off forgetting absurd stereotypes."

Celeste grinned sharply. "But they won't! We think we're beyond that now, and the military just needs to keep watch over Third World hot-spots. But as soon as a two-star general like yourself starts warning about alien invasions and campaigning to gear up the weapons complex, exactly what image do you think is going to pop into the public's mind?"

Pritchard had encountered that sort of

thinking all through his career. On the one hand, he had risen remarkably fast, being in the right place at the right time over and over again. As a colonel, he had led the Air Force into co-sponsorship with the United Space Agency and had been surprised by the storm of protests even among highly educated scientists about tainting pure research with connections to "warmongers."

Pritchard had always felt that the military's new role should be focused outward, leading the way in colonizing the solar system—like the military of old, who were the real pioneers of the American West, going out on expeditions like Lewis and Clark, braving the dangers of a hostile environment and paving the way for the second wave of civilians.

With extremely expensive and high-tech weapon systems dropped out of the budget, the armed forces had contented themselves with advanced conventional weapons, fine-tuning their accuracy and effectiveness. Treaties watched over by the International Verification Initiative had dismantled most of the nuclear weapons, leaving only a handful of warheads in secure installations—mostly as a deterrent against certain Third World countries who were ignoring the non-proliferation sanctions to build up their own stockpiles.

After the European Economic Community had effectively wiped out political borders, leaving only cultural differences of more interest to tourists than army commanders . . . after the fragmented Communist powers became preoccupied with internal problems—what was left? Who did they need to keep on guard against—except the lunatics? "I see your point," he said.

"I want you to work closely with me, but you must keep a low profile. I believe you and I have the same agenda, and together we can make it happen." She paused. "As coconspirators. This whole thing can launch our future in space, make colonization and expansion more than a PR show or a few experimental exercises."

Now Pritchard knew what Celeste had been up to all along. It was something he had suspected, but not nailed down until now. "I have that dream myself."

His comment seemed to startle her. "I'd be interested in hearing your dreams," she said, but her words were mumbled, and her eyes looked far away. . . .

Eleven years before, on board the Grissom, Celeste had awakened from a dream with the gut-terror of falling and falling and falling—the way she often awakened in zero-g. Her husband Clark told her she would get used to sleeping on the space station, but after two months Celeste still could not stop the disorientation.

This had been more than just a dream, more than just a nightmare. One of those dreams that compared to ordinary nightmares the way migraines compared to ordinary headaches. This one had been even clearer than the others, more definite.

Explosions—
Freezing—
Tearing metal—
Screams—
Death . . . .

She saw herself floating to one of the modules. Module 4. The protruding

module with the medical lab. Only there would it be safe. She had to get to it.

Swimming away from the rapidly fading images, she remembered with razor clarity seeing the glowing green chronometer on the wall panel. She remembered what time the disaster would happen. *Disaster*. The word itself meant an unfavorable alignment of planets or stars. *How ironic*. Celeste blinked now and saw she had only twenty-three minutes left.

Twenty-three minutes until calamity would strike. And Module 4 would be the only safe place on the entire Grissom station—but how to get everyone there? How could she save them all? She knew none of the details, only that something would happen. *It would happen!* She couldn't tell anyone how she knew. They would laugh at her. She would laugh at it herself—if her dreams hadn't proven to be true so many times before.

She was alone in their sleeping quarters. Clark would be on duty in the command module with Rico Portola. She had never told even her husband about the dreams—and he would not understand now. She had only twenty minutes.

How could she divert the tragedy if she did not know what to warn them about? She had to get all eight members into a single module, and in only a few minutes.

She remembered the other times that the dreams had come to her . . . the car wreck . . . her brother drowning. Celeste finally hit the wall intercom, turning up the volume. "All station members. Attention! All station members, that's you, too, Clark and Rico! I'm calling an emergency meeting in Module 4. Right now, everybody."

She did not answer when a few of the members sharing her same sleep period answered with befuddled questions. Clark came on the line, demanding to know what she was doing.

"Just come down! Right now. This is very important."

She had no idea what excuse she would use once they got together. If the disaster did not happen, how could she explain? She might be disciplined, maybe sent back Earthside. *But if nothing did happen, wouldn't that be a small enough price to pay?*

Before exiting the sleeping quarters she shared with Clark, she called up the personnel roster on the wall infopad. Maybe she would get lucky—eight crew members, extended families, birthdays, anniversaries. She scrolled down the dates, keeping one eye flicked to the dull green numerals of the chronometer on the wall. Fifteen minutes left.

She found a corresponding date. Good! She scanned the name, committed it to memory and grabbed for the door frame to pull herself through.

Clark's voice came over the intercom on narrow-band to their quarters only. "Celeste, what the hell is going on? We can't leave the control center right now. Rico's found something—space debris, we think, but it has an anomalous return signal. It's going to come close. I need to stay and monitor it."

Even floating in zero-g, Celeste felt her knees turn to jelly. "Clark, that's it! I think it's going to hit the Grissom!"

She heard him snort over the speaker. "Naw, it's got a tiny cross-section and

a really screwy orbit—it'll miss us for sure. Probably somebody's screwdriver from an EVA twenty years ago. Not on any of our charts, though, so we need to track it and let Mission Control enter it into their database."

"Clark, swear to me that you'll come to Module 4. Right now. You and Rico! I'm not kidding."

After a long pause, he answered her cautiously, his Texas drawl stretching the words. "All right, hon. We'll be down. Promise."

She pulled herself into the narrow corridor and pushed off from the bulkhead to get to the intermodule airlock. Eleven minutes. She worked her way through the airlock, into the next module, then shot into the vertical lock overhead. The closed door said "4" in bright blue.

Dr. Bernard Chu, a thin and intense young biochemist, joined her as he hurried to the emergency meeting. She couldn't see the chronometer. She hustled Chu into the medical lab. Everyone had arrived—except for her husband and his partner.

The gathered crew members looked at her, one blinking sleep from her eyes, another looking angry, and two showing fear. Only seven minutes remained. The module was cramped with their bodies. Drifting without enough handholds or seat straps, the six people kept bumping into each other, murmuring about the emergency meeting.

If Celeste was going to have a cover story when all this was over, she had to state her excuse now. It was a lame reason, even stupid. But she could never survive a board of inquiry if she said simply that she had experienced a premonition.

"I suppose you're wondering what this is about?" She looked at all of them. "Well, it's all because of Bernard Chu."

Chu blinked in astonishment. "Me?" The others flashed a glance at him, immediately pegging the biochemist as the cause for the turmoil. "What have I done?"

But Celeste stared at the chronometer, at the hatch. *Come on, Clark!* "We are cut off from Earth here, and we must make every effort to keep our ties. I called us here together to celebrate the birthday of Bernard's son Shelby. He is eight years old today." She smiled at Chu, who blinked in astonishment. She saw tears spring to the man's eyes.

Several of the other crew members grumbled in annoyed surprise. Someone clapped. A voice said, "Big fucking deal."

Celeste hit the intercom on the wall again. "Clark, where are you!"

One minute left. Clark was always late. With his long legs and big frame, many had called him a remarkable contrast to petite Celeste and her intense scurry. The newsnets had called them a "darling couple."

"Still up here," he answered. His voice sounded distracted. "There's something funny about his debris. Can't get a good reading. Never seen anything like it."

Despair burned like acid in her throat. The last number on the chronometer changed. No more time. "Shut the hatch!" she yelled at Chu, who sat nearest to the module airlock. Startled, Chu moved to close it.

Over the intercom, they all heard

Rico Portola's voice calling to Clark. "Look out the port, Clark! I can see it!"

"Holy *shit!*"

It was the last thing Celeste ever heard Clark McConnell say.

The entire station rang with a sound like a church bell thrown from a tenth-story window. The impact tossed the six of them about in the cramped module. Two men ended up with broken limbs; four people, including Celeste, had bloodied noses.

Chu managed to shut the airlock hatch in time.

The lights flickered and went out, replaced by red emergency lights powering up from solar cells mounted on the skin of each module. Screams and shouts filled the tiny medical lab. Celeste found herself huddled against the wall near the arbitrary ceiling, whispering her husband's name over and over again as tears bit the edges of her eyes before floating free. *Why hadn't he listened to her?*

Only static came from the intercom linked to the command module. . . .

Later, after the whole story had come out, Celeste learned that the Grissom had been struck by a stealth satellite made of radar-absorbing material specifically designed to have a minuscule sensor profile. The satellite, as big as a bulldozer, had sheared off the command center and one other module entirely, and had strewn debris that ripped into the other three modules. Most of the life-support systems had been taken out, and the survivors had little air and no food. It would be four days before a rescue mission could be prepped and deployed from Earth.

When it became clear how awful the disaster was, Celeste worked with Bernard Chu to sedate everyone, lowering their metabolism. That had been the only way they could survive.

And they had lived through it, just barely. By the time the Assured Reserve Vehicle arrived, most of the air had turned bad; their groggy bodies were near starvation. Even with such an enormous disaster, only two people had died: Rico Portola and Clark McConnell.

Celeste's quick thinking had saved six of the eight on Grissom. Some considered it blind luck that she happened to get them all in the same place at the same time, the only haven on the entire station, for a silly birthday party.

Seven years ago, it had made her a hero and paved the way for her career in the Agency; first as chief of the Astronaut Office, then the associate administrator for Exploration, until finally being nominated as first director of the unified international Space Agency, autonomous and responsible only to the U.N. . . .

"Aren't you going to eat?" Simon Pritchard said, interrupting her thoughts. He pounded a crab claw with a wooden mallet. She wondered how long she had been silent. The waitress had brought them a platter of steaming Maryland crabs.

"I hope you're thinking about something important," Pritchard said with a grin, then repeated her own words. "That intent look in your eye is enough to start a fire!"

She took a small sip of beer. "I was just dreaming," she whispered.

* * *

CHAPTER 9

Moonbase Columbus

"Are you sure you're not going to need an assistant out there?" Dvorak said. "Newellen is a telerobotic specialist."

"Yeah," Cyndi Salito interrupted, "since nobody can work with him, he's got to do everything by remote control."

"Oh, shut up!" Newellen said.

Erika shook her head. After a full night's sleep, she felt rested for the first time in a week. "I'm more comfortable working by myself, really. With hazardous stuff like those nanomachines, you don't want me to be nervous. And besides, let's minimize the number of folks at risk."

"If you insist," Dvorak said. "Director McConnell wants us to give you every bit of help we can."

"She's got nanocritters in her pants," Newellen grumbled.

Nanocritters! She liked the term. Erika hid a smile by turning to load her gear inside the pressurized rover. The airlock opened directly into one of the supply habitats, making the packing much easier than hauling equipment outside.

Erika threw a bundle of vacuum tape into a pile accumulating at the rear of the rover-van. In the low gravity, the bundle sailed through the air. Already she had packed more things than all the personal possessions she had carried away from the NIL.

The rover-van resembled an Earth-bound Winnebago RV, larger than the stripped-down rover Erika had ridden in from Zimmerman's shuttle. She half expected the outside to be plastered with stickers that read "HOWDY! MERLE AND BILLY JOE EBERT SAY HELLO FROM ALEXANDRIA, LOUISIANA!"

According to Big Daddy Newellen, the rover-van could travel five hundred kilometers from Columbus and stay outside for two weeks, if necessary. It was equipped with a telerobotic control panel for interfacing with geological-survey rovers, and was entirely self-contained. The best part was that with the pressurized cabin she would not need to stay suited all the time.

She wiped sweaty hands on her jumpsuit and glanced back at Dvorak. He lounged against the airlock, watching her. She couldn't tell if he was smiling, or if his face always wore that puckish grin. "Could you throw me that next box?" she said.

Dvorak bent and picked it up, turning it over on its side. "Chlorine?" He tossed it to her. It tumbled in the low gravity.

She snagged it and set it with the rest of the supplies. "Those, ahem, 'nanocritters' might be organically based, and a caustic solution could be useful. I don't want the specimens to come into contact with any of my germs either. Who knows what kind of information they can pull out of even a virus DNA? Other than those first three people who died, these things have never come into contact with anything alive. Let's keep it that way."

Dvorak set his mouth, but didn't seem to know what to say.

Erika dropped her hands to her side. "I've seen the tapes, Mr. Dvorak. I know you're thinking about how dangerous it is. But you've got to realize that I've spent most of my professional

life working with nanotechnology." She headed for the airlock. "So let's get me started, all right?"

"That's what I wanted to hear." Dvorak brushed himself off. Somehow, the fine and gritty moondust managed to creep into everything. "I'll let the Agency know you'll be on your way. Take whatever time you need to study the neutralized samples still inside the vault. We can arrange to launch another javelin to snatch a sample of regolith from the hot zone."

"Thanks. And keep doing a daily IR flyover, to make sure nothing changes drastically." She fidgeted. It was time to get going and be alone again; back at work, back where she belonged.

"OK, but using IR as a diagnostic is pretty much worthless now while the site is in full daylight. The temperature difference is a lot more apparent at night." Dvorak held out a hand. "We'll do our best. Good luck. Keep in contact."

"I will."

Dvorak turned to Newellen, standing just inside the airlock. "And have fun. Don't let Big Daddy push you around."

Erika backed into the Winnebago and found a seat amidst the stacked supplies. Her spacesuit hung by the airlock, dwarfed by Newellen's frame as he sealed the door.

He grinned at her. "I feel like I'm going on a vacation."

With apprehension, Jason Dvorak watched the rover-van's airlock hiss shut, not sure if he was doing the right thing to allow Erika Trace to go off on her own to face the thing that had killed three of his crew.

But Erika was a grown woman, a professional, hand-picked by Director McConnell as the most qualified person on Earth to investigate the Daedalus specimens.

It didn't help that she reminded him of how his wife Margaret had looked ten years ago. But Margaret always seemed helpless and out of her element. Erika didn't have that problem.

Jason thought of what Bernard Chu would have done in that situation. Was it really a good idea to let Erika go off alone? He should not be thinking of Erika first. He should be worried about the inherent risk in bringing more live nanomachine specimens so close to the moonbase.

"What is it?" Erika squeezed to the front of the Winnebago. She stared down at the screen, not out the front windshield.

Guided by doppler radar and a heuristic homing sensor, the rover-van guided itself to Sim-Mars. Lon Newellen sat back and watched the vehicle pick its way across the lunar landscape as he munched out of a bag of food. He pointed a dehydrated apple to the high-definition TV screen inset in the control panel. "It's a week's worth of IR flyover images. I can pull up a slow-dissolve montage of the last week's readings if you want."

"Go ahead." As she watched the glowing red circle around the Daedalus construction, seeing views from day to day, she saw the intensities fluctuate around some portions of the great structure, but nothing moved beyond the three-kilometer diameter. When the two-week-long lunar day spilled solar

heat across the area, the resolution of infrared changes dropped drastically.

Far ahead, unseen in the lunar night, sat Sim-Mars, built in preparation for the final simulated Mars mission. No one could ever have guessed it would be used to study alien technology before the training mission ever got there.

Newellen spoke around a mouthful of dried apple chips, "Personally, I don't trust that x-ray shower. I mean, not with my life. There's just no way to make sure that compact toroid thing produces enough radiation to kill whatever might have contaminated the lab. Besides, these nanocritters have survived who-knows-how-many years in open space with all the radiation you can imagine. I mean, how can the measly little puff we give them be all that bad?" He started to put another shriveled apple into his mouth when he turned to look at her. She held her mouth tight and didn't say a word.

Newellen shrugged and tossed the fruit up in the air. It twirled in the low gravity and sank toward his mouth in slow motion. He stationed himself under it and gulped it down. "But it doesn't matter what I think, does it? You're the one going in there. By yourself."

"Yeah," said Erika. "I know."

The Winnebago docked to Sim-Mars. Once he had idled the rover-van's engines to a quiet hum, Newellen didn't let Erika open the airlock until he had satisfied himself that the isolated lab module had ample air and lighting.

Erika hesitated before entering. Everything in there should have been sterilized. Remote diagnostics ran purity tests of the lab's atmosphere; readouts on a TV monitor showed that the simulated Mars base was ready for humans.

"Don't expect me to carry you over the threshold, Erika. That's not my forte, even in low gravity."

Erika forced a smile for him, then drew in a breath as she entered. The air smelled the same as everywhere else she had been on the Moon—stale with a hint of soot and machine oil.

If all of the nanotech specimens had not been killed after all, she probably wouldn't have time to find out. She'd disappear just like Waite, dissolve into nothingness. . . .

She pushed the thought from her mind, and realized that she was being foolish. She knew that if the Farside sample had contaminated the lab, Sim-Mars would have been changed beyond recognition, with every scrap of metal and plastic dismantled.

She turned to Newellen. "Thanks for the lift, uh, Big Daddy."

He shrugged. "Wish I could stay and help you. I'll be camping out about ten klicks away if you need me."

Before her lay her most dangerous and exciting times, her greatest responsibility. Erika strode forward, unmindful of the airlock closing behind her.

Erika flexed the milliwaldoes, reaching into the bowels of the sterilized vault. She watched the high-def holographic tank in front of her as the tiny multi-digited extensions moved with her. Although the milliwaldoes were a thousand times smaller than her hand, they duplicated her movements exactly. And she did not need to risk contaminating a single cell of her real hands in an

environment containing the alien "nanocritters."

Her head already ached. She had been working for five hours with the "dead" sample brought over by the first geological javelin probe, the one that had been studied via telepresence from Moonbase Columbus. Unfortunately, the bombarding high-energy x-rays had obliterated nearly all traces of the nanomachines, leaving only hunks of microscopic slag, ruined pieces of the tiny destroyers, a few intact dead shells. She had gathered more information just from looking at the long-distance videoloops.

No, she needed a fresh sample. *A live one.*

She contacted Columbus without hesitation. Jason Dvorak agreed to get her one right away, then dispatched another javelin probe to the Farside.

While she waited for the live samples, Erika inspected the apparatus available to her at Sim-Mars. Nearly every conceivable instrument for extraterrestrial analysis was crowded into the lab area, to be used by the Mars astronauts for their exhaustive studies of the fourth planet. Though some people had become skeptics in the past half century after Viking had landed on Mars, an important portion of the Mars mission activities was to search for evidence of microorganisms in the harsh environment.

Using the dead nanocritters as test specimens, she observed them with transmission electron microscopes, then scanning electron microscopes using secondary electrons, backscattered electrons, characteristic x-rays, low-loss electrons. She had good results with Auger/ESCA electron spectroscopy, then even better with a scanning x-ray microscope. By altering the energy level of the bombarding x-rays, she had fine-tuned her method by the time the quad-armed robot rolled out of its retrieval dock outside of Sim-Mars to accept the second package from the Farside probe. . . .

Now, her milliwaldoes hung fifty microns above the new regolith chunk. The entire analytical apparatus was housed in a depleted-uranium-lined vault in the next room, while the vault itself was shielded with lead. Running the stereo image along a pair of twisted fiberoptic lines into virtual goggles, Erika worked under the sensation of actually watching from a spot just above the waldoes, a world on an incredibly small scale.

A voice came from the speaker set in the control panel. Stationed ten kilometers away from the isolation lab—rescue distance, Dvorak had called it—Lon Newellen sounded as if he was in the next room. "We're still having trouble with the video link, Erika. Are you sure you've got all the channels enabled?"

Erika threw a glance behind her at the tri-video camera. It was positioned to stare over her shoulder during the entire sample analysis. A green light blinked RECORD, but two rows down an LCD array read TRANSMIT PARITY ERROR: RESET. Erika smiled to herself. "Uh, doesn't look like anything is wrong here, Big Daddy. It says it's recording."

"How about resetting the parity switch?"

Erika reached toward the disabled switch but stopped short of touching it;

when the recording was reviewed later, no one would be able to tell if she had depressed the switch or not. "It doesn't seem to work."

Newellen remained quiet for a moment. "I could come on over and fix it for you—"

"Look, I've got to keep working," Erika said with an edge to her voice. "No telling how much time I have. This is a new facility, remember? It's bound to have some glitches. Don't worry. I'll call as soon as I have anything."

"Oh, all right." He was probably bored with twiddling his thumbs and not getting any picture.

Submitting to the cameras recording her every move was bad enough, though necessary for the permanent record of the nanotech analysis. But Erika could never work with half a dozen people watching over her shoulder, backseat driving in realtime. She would make her own decisions and set her own pace.

"Voice contact will have to do for the first sequence of tests," said Dvorak's voice over the lab speakers.

"Starting the magnification now, from low and working my way up to high." Erika had already moved the milliwaldoes up to the surface of the sample. The view jumped in magnification as the polarized-light microscrope kicked in. Computer-enhanced, the image looked weird as false-color coding added to the three-dimensional topography.

She spoke out loud for the benefit of the others, which suited her fine—she normally talked to herself or Parvu in the laboratory. "I can't see anything unusual at this magnification. The surface of the sample looks viscous, though, like it's liquid. Maybe just Brownian motion. Maybe not."

She checked a diagnostic on the bottom left corner of her virtual goggles. "A good bunch of heat radiating out of it, though. A lot more than you'd expect from an ambient rock. The sample isn't radioactive, and I can't detect any chemical process. Probably waste heat generated by the nanocritters."

There, she had adopted Newellen's terminology for the microscopic devices. No doubt it would stick once the newsnets picked it up.

"Higher magnification?" Dvorak asked over the link.

Erika kept her voice stiff. "I'm still doing an overall analysis of this chunk. Let me call the shots, OK Jase?" She used his nickname on purpose.

"Sorry. I'll stay quiet."

She ran through the standard macroexamination, testing the regolith's mechanical properties, heat conductivity, pliability, brittleness. She brushed the edge with the tip of the milliwaldo, hoping to scrape the surface of the specimen. It seemed to flow away from the tip of the tiny pincers.

She returned the milliwaldoes to their home base, a section of thinly-sliced ceramic. Just off to the right of her field of view were the images of larger "precision waldoes"—devices ten times as large, for fine macroscopic work on samples.

To the left of the thin ceramic film appeared a dot barely visible in the holotank. She slowly moved her hands on the virtual controls toward the dot; as she approached, she kicked up the magnification by an order of magnitude.

Smears of chromatic aberration

blurred out the details, but she resolved the dot into a cluster of still tinier waldoes, able to manipulate objects a millionth of a meter in size. She left her huge-seeming milliwaldo hanging and slaved a pair of microwaldoes to follow the now-massive ones she still controlled.

"OK," she said into the speakers. "I'm bringing the micro along to the spot on the sample with the highest heat readings." She guided the milli back toward the heat source, bringing with it a tiny set of microwaldoes. "Let's have a look."

Once over the spot, she guided the giant milliwaldo to position the micro correctly. Switching controls, she flexed the microwaldo's digits. The view clicked down three more orders of magnitude; everything seemed to rush toward her in the holotank as she now viewed the regolith sample from a viewpoint a thousand times smaller than before, through the eyes of Auger/ESCA microscopy.

"Whoa!" She drew in a breath at the sight.

Stationed just above the regolith sample, the microwaldo's sensors sent back a stereoscopic view: multifaceted objects scurried around the sample like ants on a stirred-up anthill. She had seen the remote images from the first sample, but now the nanocritters seemed to be right in front of her eyes, in a handful of shapes and sizes.

She was protected only by a wall of lead and depleted-uranium shielding that the nanomachines could probably disassemble any time they wanted to. Images of Can't Wait Waite and Becky Snow with their suits bubbling and dissolving passed before her, but she blinked them away and pushed her face closer to the holotank to make out more details.

After coupling with the scanning x-ray microscope, she was already at the maximum resolution of the remote lab. No one had ever expected to need to look at material structure on the scale of a billionth of a meter. At that magnification, a simple virus would have looked the size of a house.

And the aliens had been able to put together complicated machines a hundred times smaller.

The nanocritters looked unlike anything else she had ever seen, as far removed from the clumsy nanotech prototypes in the NIL as a rowboat was from a rocketship. Parvu's prototypes had been lumps of machinery jumbled together until the pieces happened to fall into place. These intricate machines looked as if they had been sculpted, designed with an artistic flair in five or six distinct varieties, every subsystem assembled with the precision a model builder used to make a sailing ship inside a bottle. It was incredible.

"Hey, Erika? You still there?" It was Lon Newellen. "Should I come in for a rescue?"

"No. Hang on a minute." She brought her hands down toward the holographic surface in front of her eyes. The microwaldoes mimicked her movements.

Erika could sense her heart beating faster as she got caught up in the excitement. "These critters are so small I'm having trouble even getting a lock on their morphology." She spoke faster as excitement set in, and her Southern

drawl deepened. "How can they even function? They're really nothing more than molecules, set in patterns I've never seen before. What's their energy source? I'd guess breaking down chemical bonds inside the raw materials around them. Need more tests, though. Are you all still listening?"

"Wish we could see a picture!" Dvorak said.

Oh, all right! she relented. She pulled her hands from the waldoes and left them stationary. "Let me try emergency repair procedure number two." Blocking the view of the camera with her shoulder, she reset the parity, allowing transmission to commence. Then she made a great show of smacking the control panel with the palm of her hand. "There, does it work now?"

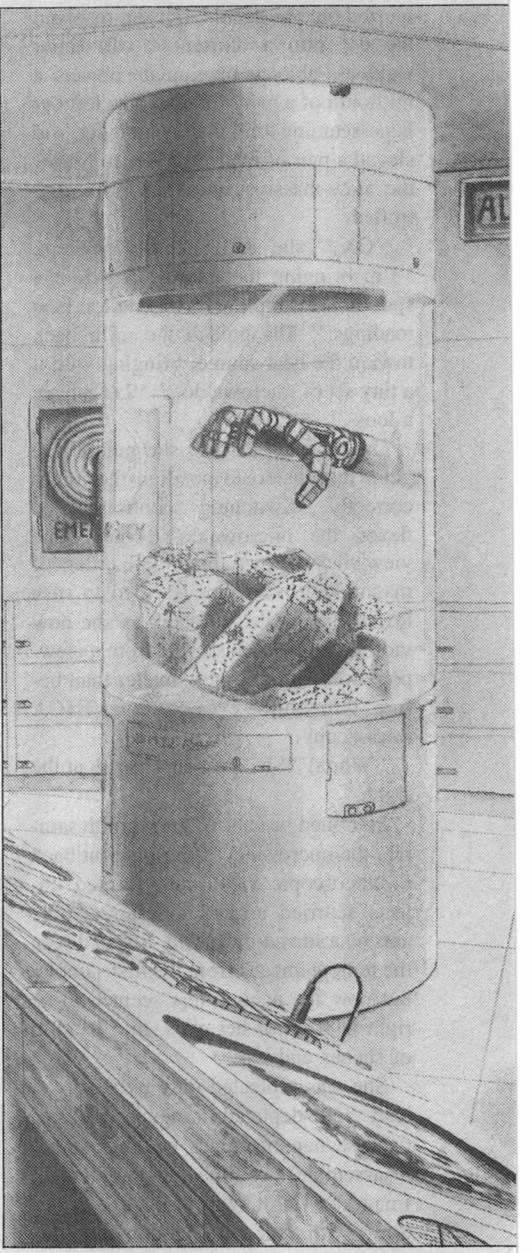
"We've got visuals!" Newellen said from the rover-van.

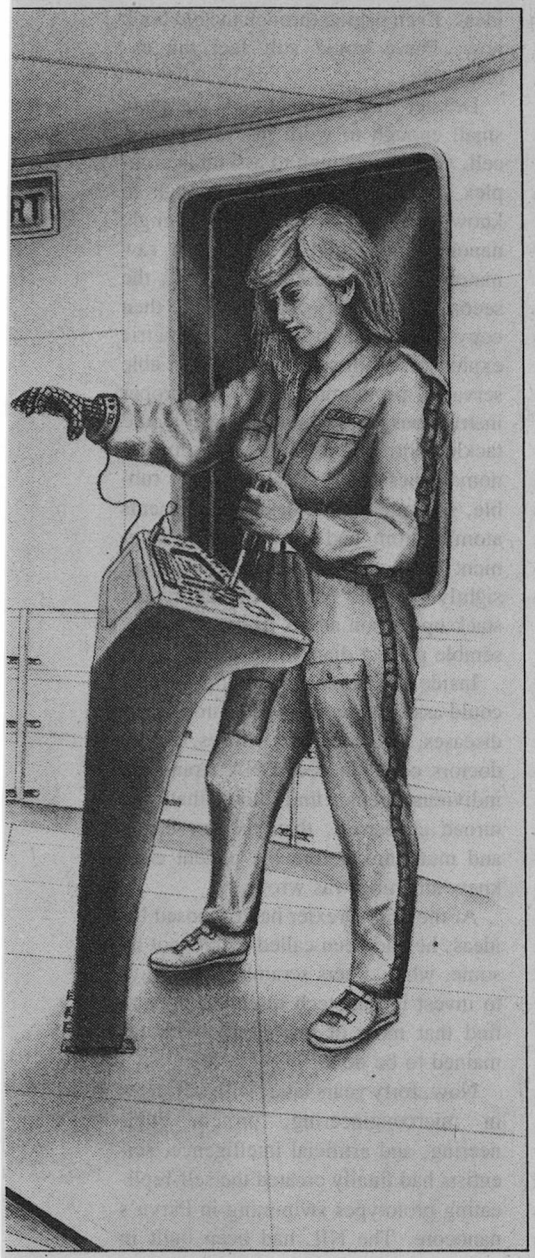
"Good, now let me keep working."

Moving across the panel, Erika encoded a molecular-dynamics program. The code shot off to an array of parallel processors embedded in the matrix of a solid-state cube; the program would perform a perturbative decomposition of the molecular orbits to reconstruct the devices she had seen.

"Seems to be four or five different sorts of devices—some are assembling raw regolith, others are processing it, a third kind is scuttling back and forth between all the others. Is this a coordinator? A supervisor? A reprogrammer?

"There's one type that seems to sit back and do nothing. It's got a completely different shape. Scattered among all the specimens, I see bigger islands, like nanocritter shopping malls. Central controlling stations? Boy,





there's a lot of hypothesizing going on here."

"Erika, have you figured out how long those things will take to chew up the whole sample and start climbing the walls in the vault?" It was Big Daddy, still talking from his ten-kilometer distance.

Dvorak broke in before she could answer. "Make sure you don't take any chances. We need to destroy the sample before a single one of those things gets out. Director McConnell's people caution four hours max per sample, then it gets sterilized."

Erika glanced at her screen. "Reproduction rate is below critical threshold. Maybe their self-replicating phase is over. Or, it's more likely that they need a handful of diverse elements to build more copies of themselves, and they ran out of 'ingredients' in that little lump of Moon dirt. That could be why this sample hasn't disassembled yet—they haven't got anywhere to go."

Dvorak said what she had been thinking. "Unless they decide to look for greener pastures outside the containment."

Erika swallowed. "If that happens, I'm not gonna have much time to get out of here."

CHAPTER 10

Antarctica: Nanotechnology Isolation Laboratory

Alone in the Nanotech Isolation Laboratory, Jordan Parvu felt like the last customer in a store closing for the night. The lights were dim, the doors secured.

Outside, the wind had set in again, pounding against the wall even through layers of insulation. Erika Trace's quar-

ters were empty. She had removed her paraphernalia from the bathroom cubicle, and Parvu realized that he missed Erika's clutter.

He had forced the moonbase assignment upon her because he knew it would take a major impetus to get Erika to forge her own path instead of following in his footsteps. She was too good to keep working brilliantly in his shadow. Still, Parvu yearned to discuss automata theory with her, as they had done for years.

She had arrived on the Moon three days before. Parvu received the rushed data summaries Erika transmitted to the Earth-side researchers, asking for input and suggestions. Though she had not talked to him directly, he was fascinated by her conjectures, how she had classified the extraterrestrial automata into Disassemblers, Assemblers, Programmers, Controllers, and Unknowns. She had done a great deal of work in a short time.

Now inside his quarters, Parvu watched videoloops showing his grandchildren at play, waving to him, smearing themselves with chocolate ice cream at a birthday party. In the silent room, his reflection in the wall's cosmetic mirror looked wistful.

He thought of all the things he hoped to accomplish, how well the prototypes in the nanocore were progressing. He had in his hands the possibility to change the world. . . .

Researchers had been working on nanotechnology for four decades, spurred on by K. Eric Drexler's extrapolations in the 1980s. Drexler had shaken the scientific world with his amazing and frighteningly plausible ideas. Even paging through the old book now, Parvu could still feel the excitement.

Drexler had conjectured automata small enough to work inside a human cell, versatile enough to assemble complex structures—and smart enough to know what they were doing. A single nanomachine could use whatever raw materials it needed to copy itself; the second-generation copy would then copy itself, and so on, in a geometric explosion. With so many tiny and able servants, programmed with the proper instructions, the human race could tackle enormous jobs. A swarm of nanomachines could attack a pile of rubble, separate out the desirable elements atom by atom, and sort them into convenient bins, with no waste and no unsightly mess. Nanomachines could stack up carbon atoms from coal to assemble perfect diamonds.

Inside the human body, tiny scouts could assist white corpuscles in fighting diseases, bacteria, and viruses. Nanodoctors could inspect DNA strands in individual cells, find those that had turned cancerous, then fix any errors and mutations before the patient even knew anything was wrong.

At the time Drexler had proposed his ideas, he had been called a crackpot by some, while others scrambled for ways to invest in nanotech research, only to find that most of the groundwork remained to be done.

Now, forty years later, with advances in microengineering, protein engineering, and artificial intelligence, scientists had finally created the self-replicating prototypes swimming in Parvu's nanocore. The NIL had been built in

Antartica by the United Space Agency with tight enough safeguards that such research could actually be done.

Drexler himself had been quick to point out the perils of nanotechnology. A rampant self-replicating machine could create enough descendants to turn the Earth into a ball of gray goo in a matter of days. During college, Parvu had worked in a place that raised white lab rats for research; despite tough controls, rats still got loose from their cages. And a single nanomachine was a hundred million times smaller than a rat.

Even if all controls remained in place and nanotechnology was developed without mishap, Parvu tried to imagine the upheaval society would go through if people suddenly had the answer to all pollution, cures to all diseases . . . perhaps even immortality. Since nano-assemblers could make glittering things of value out of any garbage heap, material wealth would mean nothing.

Knowing human nature, how could mankind survive?

But the aliens had somehow overcome those difficulties . . . or had they? Was that why they had sent samples here, as a test? To do their dirty work on a far-away rock to check out the large-scale construction ability of their automata before turning them loose closer to home?

The teleconference chime startled him out of his thoughts and he perked up. Parvu switched off the pictures of his family and fumbled for the screen. When he finally found the RECEIVE button, the screen shimmered and Erika Trace stared at him.

During the two-second delay before she could compose herself, her face brightened visibly when she saw him acknowledge the transmission. Then she looked nervous again, haggard.

She wore a powder-blue jumpsuit; her blond hair was tied back in a pony-tail. Her eyes had become weary, with a bit of the innocence polished away. He had put her through much in the past few weeks, but she didn't look bad, just different, stronger.

"Erika! I am delighted to hear from you! Are you well?"

"I'm fine Jordan. Sorry I didn't call you sooner. It's been a nightmare with all the Daedalus nanotechnology . . . there's so much to learn. And everybody thinks I know all the answers!"

Parvu stared at the screen, unable to keep himself from grinning. He wanted to ask how her training had been, or her flight to the Moon, or if he could do anything to help. He still had some of the caviar left, though he had already fed the crackers to the three rats during a lonely moment.

Erika looked away from him—with the transmission lag, it never worked to try and hold someone else's gaze. "I just called to . . . I need to run this over. I'm too close to it. I've got the details, but no framework. It doesn't make any sense. I just need another perspective to help nail down the interaction between the nanocritters."

"Ah." Parvu nodded, then sat down in a comfortable chair across from the screen. "Minor questions, then. I thought you were interested in something important. Very well, let us start from first principles." Parvu ticked off the thoughts on his fingertips. "If an alien race were capable of sending any-

thing to another star system, why would they choose to deliver microscopic automata? If they merely wished to contact us, they could have sent a radio signal."

Two seconds later, Erika interrupted, raising her hand. "That assumes they think anybody's listening and anybody can respond. What if they sent their automata just as probes? As investigators to see what they would find?"

"Again, I must ask the question—why these automata? Why not send a full-scale probe, if you are going such a great distance? And if they are merely probes, why are they erecting such a huge structure on the Moon? What is it for?"

Erika shrugged, answering the first half of his comment. "Well, maybe nanotechnology is the way they think. Say their society is based on nanotechnology—they wouldn't consider sending massive objects when they can send little probes programmed to build what they want when they get here. But if they're from another star system, then why do they need to build this construction project so fast?"

"Speed!" Parvu stopped, as if a light bulb had winked on over his head. "Of course, speed! Or is it velocity? I keep confusing the precise terminology."

"What do you mean?"

"Speed of travel! Consider—to send a probe from one star to another, it must carry an enormous amount of fuel. It must haul an entire spaceship structure with it, and it would still be difficult to reach an extremely high velocity. But—" He held up his thumb and index finger, squeezing them together. "A device only a billionth of a meter across is the size of a particle! Such a machine could be accelerated to all but a fraction of the speed of light. It carries a computer memory equivalent to the old CRAY supercomputer, and when it arrives it can self-replicate. Such a machine! Just think of it!"

Parvu felt his skin flushing, and he sat up straighter. "Suppose the aliens didn't mean to come here in particular, but simply sent out a stream of automata in all directions? Beamed out near the speed of light across the Universe, they are bound to encounter a solar system sooner or later. They can traverse the Galaxy more efficiently than if encumbered by propulsion systems and bulky spaceships."

Erika ran a fingertip along her lip. "Talk about 'go forth and multiply!' And so when one of these scouts happened to land on the Moon, it had programming to start replicating itself and building this . . . structure we can't figure out."

"Yes, indeed! Perhaps alien ships are following behind it, slower vessels plodding along behind their automata, whereas the scouts will get here and set up a—" Parvu shrugged and held his hands out as if to indicate an armload of possibilities. "A transmitting station? A ready-made base for themselves when they arrive? But for what? Just to study other planets, or as a prelude to an invasion?"

Erika looked alarmed at that. "The nanocritters at that site have already killed three people and dismantled part of the VLF array." She shook her head. "But if they shotgunned nanoscouts out across the stars, there wouldn't be any way to tell which one would hit pay dirt

beforehand. I can't believe they'd send ships out after them, just on the off chance they would bump into a habitable planet."

A red border appeared around Erika's image on the screen, with a black mark rapidly encircling it like a ticking clock. "My rest period is up, Jordan. I've got to get back to the lab." She smiled and looked at him with a wide open face filled with a thousand other things she wanted to tell him.

"Thanks for the brainstorming session. I'll tell Jason Dvorak about this and let him decide whether he should forward your ideas to Director McConnell." Erika scowled as she said that; it seemed she still held a grudge against McConnell for sending her to the moonbase. The black tick mark had nearly encircled the box. "Gotta go!"

"Thank you for calling." Parvu raised a hand, palm outward, then spread his fingers into a V in their joke salute. "Live long and prosper."

The screen winked out before she could respond. Parvu sagged back in his chair, staring at the blank screen for a long moment. Working from the pad on the chair's arm, he accessed images of the automata, different shots of the various "species" Erika had identified. Then he enlarged another window displaying the flyover views of the growing gossamer construction on the Daedalus site. The image of streams of emissaries a billionth of a meter across, pouring into the Solar System from across the Galaxy sent chills down his back.

CHAPTER 11

Collins Transfer Station, L-1

The Lunar Transfer Vehicle coupled to the seals on Docking Port B of the Collins waystation. The seals made contact, then gripped; residual air bled out into space.

Floating in the center of the Main Ops module, Bernard Chu felt like a business manager. The telemetry techs read off numbers, kept in contact with pilot Bryan Zimmerman in the LTV, and made sure all pressure points showed proper linkage with the Docking Point. The crew here had gone through the same routine every month for a year, but Chu watched them like a hawk. He was still new at this.

Glancing at the chronometer on the wall, he scowled, then activated the docking bay intercom from his own panel, overriding the chatter of the techs. His voice remained quiet, but sharp. "I want all cargo pulled off the LTV and stowed within the hour. This operation has a quick turnaround time, so I want twice the usual QC checks: no mistakes, and nothing late!"

That had been Chu's motto whether he managed a small biochemistry lab, research aboard the Grissom station, or Moonbase Columbus. He knew the fourteen people aboard the Collins would be annoyed at him for rushing them through the cargo transfer. There was no real point in hurrying—Columbus was not in dire straits, and a few hours' delay in delivery would make no difference to anybody. . . .

But Chu had been in charge of the Collins for little more than a month now. He took his new post more seriously than any of the other station inhabitants, it seemed. Any deviation from the schedule recorded and transmitted by the Agency felt like a black

mark against him, a personal affront. It showed in black and white numbers that he couldn't handle the simple tasks of shuttling supplies down to the moonbase or resource packages back up to L-1.

And the unscheduled delivery of Erika Trace down to the moonbase had thrown things completely out of whack. Chu had spoken to Celeste McConnell, and she assured him that she did not expect things to remain unchanged with all that had happened.

But Bernard Chu set his own goals, regardless of how lax others might be. He had learned lessons the hard way, and he had become a hard man.

A tech switched off his link. "Zimmerman has come through the hatch. Everything is ship shape. Teams are removing the resource canisters."

Chu nodded and set his lips in a straight line. Resource canisters. If it wasn't for the containers of solar cells, rare minerals, and geological specimens, there wouldn't be a need to export anything from the Moon. Within the next few years, if the regolith mining operation was successful, these canisters would contain the fusion fuel helium-3, and then the whole damned lunar colony would really start paying for itself. Chu remembered all too well how the moonbase people sweated for the day when they could finally start pulling their weight.

"I'll go meet Captain Zimmerman," Chu said. "Page me if anything happens."

"Yes," the tech said, then turned back to his work, logging in the canisters and hooking up the auto-scanner. The scanner would record each canister as it was moved through the LTV hatch into the Collins. Once set into the loading pod, they would be coupled to the Japanese Inter-Orbital Transfer Vehicle for passage back to Earth.

Bernard Chu had commanded Moonbase Columbus for a year and a half —the longest anyone had ever supervised the base. He had made great strides with improving conditions there. In fact, he took credit for converting the place from an experimental outpost to a permanent human presence on the Moon.

Then Jason Dvorak had come up to do much more than that, and Celeste McConnell—Chu's good friend—had herself told him that Dvorak would replace him. Grudgingly, wondering what she saw in the young architect, Chu had done his best to help introduce Dvorak to the rigors of command, the million and one things he would have to watch over just to keep day-to-day living from killing everyone.

Dvorak. Chu had no reason to dislike him. The man was an intelligent, soft-spoken, reasonably competent and enthusiastic person. *But he was only an architect!* What business did he have there? As a visiting project manager, maybe, but certainly not as a moonbase commander. That made no sense.

Granted, Dvorak had proven himself to be a skilled manager on Earth, cultivating his own multi-million-dollar corporation, just like some of the computer geniuses who had formed software companies and had stumbled onto more money than they knew how to manage. Dvorak was a wunderkind, no doubt about it. But a moonbase commander? His assignment still seemed odd to Chu.

McConnell, though, had based her career on many of these seemingly random, surprising decisions that no one could predict, intuitions that seemed completely nonsensical, that could not possibly work . . . yet somehow always did. Chu couldn't understand it. Yet how could he argue after surviving the Grissom disaster? Chu pursed his lips again as he pulled himself through one of the airlock doors toward Docking Port B.

Bryan Zed waited for him in the corridor. His uniform was a crisp medium-blue; somehow he had not wrinkled it on the flight from the lunar surface. Clean-shaven, his hair combed, his gaze forward—had the man actually groomed himself before docking?

Chu grabbed a rung with one hand and extended his other in a handshake. "Welcome back, Bryan."

Zimmerman was an enigma—someone with no apparent personality, no sense of humor, square-jawed and built like a rock. He added "sir" or "ma'am" to the end of every sentence. One of the techs on the Collins had mentioned Zimmerman's wife Gloria, whom none of them had ever seen, wondering if she was as detached and robotic as he. "Hey, imagine them making love," the tech said, dropping his voice into a robotic monotone. "Was-it-good-for-you? Yes-it-was-good-for-me."

As Zimmerman pushed along the corridor wall, Chu said, "Would you join me for a break? You must need to relax a bit."

"Yes sir," Zimmerman said. Tacked onto the end of that seemed to be an implicit, "if you insist."

Chu worked his way toward the observation module where the astronomy setups automatically scanned the stars, compensating for the slow rotation of the Collins. Behind them at the docking port a team slipped through the airlock sleeve, hurrying to remove the resource canisters for loading onto transport pods.

As he slid from one module to another, Chu recalled the last scramble when Celeste had sounded the alarm on the Grissom, getting to the one place on the entire station that would survive the collision. Hurrying, not knowing what would happen. . . .

Being on the moonbase and firm ground had made him forget for a while, had let him grow accustomed to a solid surface under his feet. But up here, the Collins reminded him how treacherous life in orbit could be.

Of all the Grissom survivors, only Chu had remained in space, working his way up through gift promotions, sympathy assignments, and PR spots. Celeste McConnell had returned to Earth, but she had excelled in the United Space Agency, shooting to the top. All of the others had dropped out of sight.

Somehow, Chu thought that if anything were about to go wrong with the Collins, Celeste would find a way to warn him again.

Bryan Zimmerman said nothing as the two of them drifted into the observation module. Chu floated to a vacant chair, sat down, and strapped himself in for comfort.

Below them, the Moon rose like a great hulk of beaten bronze reflecting sunlight in its gibbous shape. Directly behind, in its shadowed rear, stood the Daedalus artifact, the great alien con-

struction that continued assembling itself.

He supposed Celeste had done him a favor by pulling him off the moonbase before that thing was discovered, before he himself had to worry about an alien infestation. There didn't seem to be any clear-cut answers. But it didn't matter—Jason Dvorak had to handle that now. It was in his lap. *Sink or swim, Dvorak!*

Chu found himself smiling. Beside him, Bryan Zed sat stony-faced. As Chu stared down at the Moon and thought of the voracious extraterrestrial nanomachines, he was glad to be up at L-1 —where it was safe.

CHAPTER 12
Moonbase Columbus

Even after running for three-quarters of an hour, Jason Dvorak did not feel exhausted. The sheen of sweat dampening his exercise suit soaked into the carbon-sandwich layer in the cloth. A hundred and thirty-six laps around the eighth kilometer underground track, but his feet were too light, his legs too powerful in the low gravity. After eleven months, he still couldn't get used to it.

Optical fibers spilled sunlight across the track, bathing the exercise area in a cool yellow-white. As he ran around the compacted-regolith track, he thought he must look like a ballet dancer, with each delicate and graceful step taking too long to fall back to the surface. He panted through the filter mask, listening to his muffled breathing. Inhaling too much of the ever-present lunar dust could cause bronchitis.

Jason liked to exert himself and take his mind off other burdens. On Earth, he had often gone jogging to clear mental blocks for construction designs, to brainstorm with himself. It was as if his mind tried to keep pace with his body's exertion.

Everyone at the moonbase knew where to find him at times like this, though few others were using the equipment now. He would have to emphasize that the crew couldn't shirk their mandated exercise routines just because they were fascinated with Erika's "nanocritter" studies. Two men were on the weight machines—a system of pulleys counterbalanced by lunar rocks; a woman pumped on the exercycle as she hummed along with a music ROM on her conduction earphones.

Jason split off from the track and headed to the lockers. He needed a sponge bath, but decided just to towel himself off for now. The allotment of carbonated cleansing water was rationed, but that would change when Cyndi Salito's mining machine geared up to full capacity. He would be in even greater need of a cool rinse after the conversation he was dreading.

It was that time of the week again. He had jogged seventeen kilometers, but he could not run away from everything.

Jason stood in the private communications booth with the door closed and the windows opaqued. Each member of the moonbase crew got their weekly call home, rigidly scheduled by the United Space Agency. Brawls had broken out because some people tried to preempt other scheduled calls, so the rules allowed for no flexibility except under extreme emergencies.

Unfortunately for Jason, the Agency frowned just as much on anyone skip-

ping their scheduled calls. Crew members must keep up the morale of the people on Earth as well as on the Moon.

Jason swallowed a lump in his throat as he watched the RINGING designator at the bottom of the screen. It flashed five times before Margaret bothered to come to the phone.

Jason knew what to expect, but he always held a ridiculous, naive hope that she would appear pleased to see him, that she would begin the conversation with a smile and a "Hi Jason!" That was how he imagined most homebound conversations went, though he knew that many long-distance relationships were badly strained. Several marriages had already snapped—including his own.

Margaret's face was scowling as her image came into focus. She knew the calling schedule as well as he did, but she had not yet gotten up the nerve to refuse to answer. That would come soon.

"I can only talk a minute," she said.

He couldn't see his children in the focal hemisphere. Margaret should have them available, ready to greet their father. Now, she would probably make him waste some of his calling time while she rounded them up. "Can't you start out by saying hello?"

She heaved a big sigh. "Hello."

OK, she was making this difficult. He decided not to play her game by getting angry at her. "Where are the kids?"

Pause. "Outside."

"Could I at least see my children?"

Pause. "I'll get them."

Arguments transmitted across cislunar space carried their own checks and balances, with forced pauses to catch a breath and to cool heated exclamations. Margaret's image walked off the screen, leaving him to stare at the large sunken drawing room he had designed. He had spent years dabbling, developing the architecture of his perfect house. It had been a special sanctuary for him, though Margaret had already changed many of his favorite things.

He wondered if he would ever set foot in his home again.

Margaret had filed for divorce. It would be final by the time he returned to Earth. The judge would probably award her possession of the house and enough alimony to support a small Third World country. Sometimes the Moon just wasn't far enough away.

He had first met Margaret at a ritzy grand opening of one of his new buildings in New York. With Jason's success and money, he had to spend a lot of time at social functions he usually didn't enjoy. Margaret, who came from a wealthy, upper-class family in the city, admired his work and his status. She had been rather aloof, but he fell in love with her anyway. She had insisted on a huge wedding—destined to be the "social event of the year"—and she had gotten it. Jason never worried about the cost of things, and he thought it would keep her happy, start everything off on the right foot.

He had been a workaholic all his life—Margaret knew that, and he assumed she knew what to expect. She valued her high-class life-style so much that he had never considered she would begrudge him the time required to earn that kind of income. Perhaps he had been stupid to ignore the possibilities.

Margaret never seemed satisfied, even with a nanny to watch after the kids. He had offered her every opportunity to do what she wanted, to go where she liked, do volunteer activities, get her own job, take classes, attend meetings. Anything she wanted. But Margaret never even knew what she wanted—except, perhaps, that she wanted to be disappointed in him.

Offscreen, he heard the kids coming, and Margaret ushered them into view. She had wasted a full two minutes of his five-minute allotment. *Good job, Peggy!* She hated to be called Peggy as much as he hated to be called Jase.

Lacy clung to her mother's arm while Lawrence scowled; the boy looked tough and protective. The twins had only a vague idea who this man was who called them every week. Children forget quickly. To them, they had no Daddy.

"Say hello to your father," Margaret said, nudging them forward.

"Hi," Lacy said, then averted her eyes.

Jason remembered holding them as babies in the hospital, mouthing astonishment to himself. *These are mine! I'm their father! Did we do this all by ourselves?* But he wasn't a particularly good father, and he knew it. Always gone, always busy, he had been a quarter of a million miles away from them for over a year.

Lawrence tugged on his mother's sleeve. "Is Perry coming over today?"

"Yes, honey. He's going to take you to the park."

Jason felt a pain in his chest, not really from any surprise but just that it was out in the open. An odd flatness in Lawrence's voice made him suspect that Margaret had told the boy to recite exactly those words. It was her way of twisting the knife from across the gulf of space.

"Perry, huh?" Jason amazed himself by the coldness in his voice. "That's good. Perry and Peggy—what a cute-sounding couple. Or is he just a fling to occupy you during those long and boring days when you never bother to do anything else?"

She glared and pushed the children away from his view. "Shut up, Jase! How dare you be judgmental! After what you've done to me, to my life? I'm not a widow and I'm damned tired of living like one."

But over the transmission delay he began talking before she finished her sentence. "After what I've done to you? What the hell are you talking about?" Now he did feel astonished. What could she possibly be thinking of? How could she twist it around and make her weakness his fault? What ever happened to sticking together during the bad times as well as the good?

Out of sight, Lacy started to cry. He wanted to reach out across space and hold his little girl. But the gulf of time separated them as much as distance.

Margaret's doorbell chime rang in the background. Jason had designed the system so that the soft bells could be heard in every room of the house. Now they were working against him. Before she could say anything to him, the red box appeared on the transmission window, ticking down the remaining seconds before his allotted personal call would be terminated.

"I've got to go," she said.

He decided that she must have made sure Perry would come over during his call, just to sting him even more. Such perfect timing could not have happened by accident.

She ran a hand through her hair. "There's no use arguing about it. You can rewrite history in your mind all you want. It won't make any difference to me." She turned to Lacy and Lawrence. "Say goodbye." Then she reached forward to switch off her receiver before the children managed to utter the words.

Alone in the booth, Jason found he was shaking.

Alexandre Gustave Eiffel stared down at Jason from a holographic representation in his office wall. Jason had always admired the French architect for his breathtaking bridges and viaduct designs in Portugal and France, the record-breaking eighty-four-meter cupola of the Nice observatory, the inner ironwork structure of the Statue of Liberty . . . and of course the monumental tower in Paris that bore his name.

Eiffel's unconventional successes had been an inspiration in Jason's own career, the way Eiffel pushed his knowledge of materials to their limits and proved that a clever design could surmount nearly every obstacle. Jason certainly needed that inspiration now, if he was to make any progress in deciphering the Daedalus structure.

By burying himself in his work, by studying the nanotech threat, he could purge all thoughts of Margaret, of his lost children, of the choices he had made.

He called up a simulation of the Daedalus construction in the center of his slate holo-dais. The device was designed to digitize schematics of buildings and then build three-dimensional models from them. It allowed architects a hands-on view of blueprints as they modified various parameters. Now Jason had the computer pull together all the images taken of the alien construction, commanding it to map the entire artifact to the best of its ability.

Staring down at the changing form, the arches, the gossamer strands and support structures, he hoped he could figure out what this thing was about. *What were the nanocritters building out there?* That was his expertise in reverse—instead of seeing a problem and conceptualizing a structure to solve it, Jason needed to complete the Farside artifact from sketchy lines and then extrapolate what it was for.

These blueprints had come from a mind not of Earth, based on preconceptions about planetary gravity, climate, and temperature that were different from everything he worked under. *I just have to make a paradigm shift. Simple.*

Jason Dvorak had made his name as a rule-breaking and trend-setting architect, from his days as a designer who had made his first million dollars before most people ever got their graduate degrees. Jason's trademark had been to make full use of the material properties of the new super-strong alloys and exotic materials created by microgravity processing. These materials were for the most part untried by architects and engineers other than for experimental tests, but their properties had been measured as fully as simpler materials. Why not use them?

If concrete could be reinforced with

strands of fiberglass, he had surmised, then replacing the fiberglass with single-strand diamond fibers extruded in orbit should make the concrete even stronger and more resilient. Jason's "supercrete" provided unheard of strength and flexibility, allowing builders to construct large-scale shapes and curves that had never before been possible. City skylines began to change as buildings were no longer bound to convention. To him, the Saint Louis Arch and the Golden Gate Bridge were trivial exercises.

After five years of fame and awards, though, Jason saw that other architects were imitating him, fine-tuning his innovative designs and building on his ideas. He found this flattering, of course. He had more work than he could personally handle anyway.

But Jason was happiest developing concepts, playing with ideas, brainstorming. He took on large or small projects that captured his imagination, but he had grown dissatisfied. He wanted something different, a new challenge. He got what he wanted by volunteering to redesign Moonbase Columbus.

Which brought him back to thoughts of Margaret and his three-year-old twins. He froze up again.

Lon Newellen lumbered through Jason's open cubicle door. Jason jumped out of his reverie, but Newellen fixed his attention on the holographic model rising from the holo-dias.

"Still staring at that thing?" He nodded toward the image. "Well, I've finally got something that might help us keep a better watch on it, at least at the nanolevel."

Jason noticed that Newellen held a gadget in his hand that looked like an old-fashioned slide projector, the type that had gone out of use in his kindergarten days. "What's that, Big Daddy?"

Newellen stepped forward, turning the device in his hands and looking down at it. "We got here a super-duper camera. A scanning optical microscope and a transmitter. We want to make a few dozen of these things, load them into the javelins, and shoot one out every few days or so, right into the middle of the building site."

He pointed the probe lens at Jason. "The javelin crunches into the nano-critter-infested regolith. The SOM in the camera here sends snapshots until the critters disassemble it. We can get a picture as often as we shoot off a probe, and we got a hundred of those moon-penetrators. Closest we can get to real-time monitoring, and—" He pointed a pudgy finger at Jason. "It's without the risk of returning any active samples. I gotta confess, Jase, those live ones over at Sim-Mars make me nervous."

Jason took the probe camera in his hands and turned it over. It was an impressive piece of slapped-together engineering. "Why are you worried about those samples? Dr. Trace is impeccably cautious, and she's got telepresent teams on Earth double-checking everything she's doing."

"No matter how careful Erika is—those things are smart." He indicated the hologram of the Daedalus construction to prove his point. "If anything does happen, it won't take too long to find out about it. We'll have just about

enough time to say 'Oooops!' ''

''I get your point. I just don't know what else I can do about it. McConnell is on our backs to find out everything we can. Maybe with your cameras we can get a few steps farther.''

''All right. I've got the shops making a couple dozen more. We'll send the first one out tomorrow.'' Newellen took his probe camera and left.

The image of Alexandre Eiffel scowled at Jason, as if trying to get him to concentrate on the problem at hand. At least he had managed to stop thinking about Margaret. And his children.

He couldn't ignore the nagging question he continually brushed aside—had he ever really loved his wife? He always wrapped himself in his work, pushed himself to higher and higher successes. It had been socially required for him to be ''happily married,'' to have a faithful companion who would help him endure all those tedious functions, to take care of the personal stuff he could never be bothered with.

But he had never felt any genuine passion for Margaret. Wasn't his passion used up in his work? Jason recognized echoes of himself in the way Erika Trace buried herself in the problem at hand. He had subconsciously criticized her for ignoring everyone else on the moonbase, not taking time to make friends. But Jason was probably guilty of the same things himself with his life on Earth.

Back to work! Alexandre Eiffel's expression seemed to be saying. Always back to work.

On the holo-dias the bizarre Farside structure glinted up at him, projected in the best reconstruction the computer could fabricate. The pit in the crater wall showed no detail, just a black hole extending underground. Outside, in a circle clearly delineated by waste heat, raw materials had been scavenged one molecule at a time. Three of the dipole antennas of the VLF array had been disassembled. Diamond-webs extended to the regolith in nets and taut strands.

Stretching from the pit to the boundary of the hot zone, sloping gossamer arches spread out like the petals of the largest flower in the solar system. The arches did not stand upright, but reclined at an angle of forty-two degrees, held in place by support girders made of the same glittering material. Other struts crisscrossed the main area of the ''petals,'' the gaps between them gradually filling with a translucent material. Diamond foam? That was his best guess.

The structure had changed a great deal in the month since Waite, Lasserman, and Snow had died discovering it. But he still couldn't figure out a purpose or a pattern to the overall object.

''Slow dissolve,'' he muttered, keying up the initial image sent by Waite's rover, then having the holo-dais reconstruct the Daedalus site day by day as additional probes had observed from a distance. The result was a time-lapse slide show of the changes as billions of alien nanomachines assembled the structure from their built-in blueprints. The petals extended, the arches formed, the superstructure surrounding the pit took shape.

Jason tried to imagine what the thing could be, what the components were meant to represent. He could learn so much about the extraterrestrial builders

if he could just unravel the nature of the artifact—he could surmise how tall the alien race was, something about the gravity of their home world and the resources available there, not to mention a bit of their point of view—but he had no final blueprint, only sketches.

Alexandre Gustave Eiffel offered no insight.

Jason let his mind drift in free association to see what he might come up with. It was like looking for an indistinct object out of the corner of his eye.

He had run CAD simulations, asking the computer to project what the structure would turn out to be. No luck. He didn't have enough imagination to figure it out for himself, and the computer had even less.

Jason sighed, waving his hand through the insubstantial image to dismiss it, then powered down the holodais. He rested his elbows on the slate surface of the dais and stared at the wall.

The Parvu-Trace scenario sounded likely to him, about the aliens sending a near-lightspeed nanotech expeditionary force to set up some kind of outpost here, but that didn't help him much. Even if that explanation was valid, the purpose of the thing remained a mystery. All this trouble, the huge structure, all the resources used seemed a bit much just for an alien fact-finding tour. An invasion force? Some kind of stronghold waiting for slower macroships to arrive? Jason didn't know and he needed to find out. All of Earth needed to find out.

CHAPTER 13

Sim-Mars

Concentrating hour after hour on the nanomachinery was like watching a campfire. The sight mesmerized Erika Trace. She rubbed her eyes and took a deep breath of the air in Sim-Mars, hunching over the display. Her shoulders were stiff and sore, but the problem forced extraneous thoughts from her mind: she had to figure out why this change had occurred.

Jordan would have been amazed to see the alien nanocritters firsthand. In fact, she wished he were here right now. He had not been in contact with the moonbase for days, but she knew that he got an idea into his head and sometimes drowned in it for weeks before finally coming up for air.

Erika kept working at her own studies. She felt no closer to determining what was being constructed at the Farside crater, but she had unraveled a great deal about the nanomachines themselves.

Enlarged in the Sim-Mars holoscopic display, the weirdly shaped automata vibrated with internal energy. The alien critters were versatile, as adaptable as Parvu had said nanotechnology could be. Cures for cancer, immortality, mega-construction, super-microcomputers—all the things people had called wild imaginings when first proposed. Erika wondered what those critics would be saying now.

Nanocritters shot across her field-of-view, randomly changing directions. Each machine was long, twisted, and lumpy. She could make out no fine detail because she was observing on the Heisenberg scale: the x-ray photons that scattered off the automata themselves caused a distortion of their surface.

Each machine carried a strand of mol-

ecules, like ants bearing tiny clumps of dirt to build their homes. The nanocritters used no appendages; somehow they bonded to each strand to carry it away. Others of the same design, the same *species*—that word better described what Erika could see—connected the strands into some construction only they understood.

The inconceivably small and incredibly efficient Controller substations carried the entire blueprint, the grand scheme of their mission on the Moon. Tiny Programmers or Messengers flitted from Assembler to Assembler, delivering the next step of instructions. Teams of devices that seemed to serve as quality checkers went over the work, making certain that everything fit together perfectly, molecule by molecule. Other nanomachines, identical but with no discernible purpose, sat motionless.

Big Daddy Newellen had so far lobbed two of his supercameras into the regolith surrounding the construction. Both had transmitted beautifully detailed images of the nanocritters at work for about three minutes before Disassemblers had taken all the components apart.

But now, as she continued to study the live sample she kept in the Sim-Mars isolation vault, she found a big difference from the images the supercameras had shown from Farside.

Inside Sim-Mars, all of the Disassemblers had vanished.

She withdrew the microwaldoes a fraction and tried to refocus her field of observation. The scanning optical microscope view pulled back, making Erika feel as if she were hurtling backward. Still no sign of them.

Had they perhaps depleted all the usable molecules in the regolith sample? Without resources available, did the Disassemblers shut themselves down? Did the Programmers change them into another breed? None of the answers made any sense.

Erika pulled her head back from the display and rubbed her eyes. She had remembered to eat a granola bar several hours ago, but it hadn't been enough. Newellen kept volunteering to come over to Sim-Mars and keep her company, but she just wanted to work. Erika refocused her attention on the nanocritters.

The sooner she figured this out, the sooner she could go home.

Ten meters away in the rigged-up nanocore sat the regolith sample, still encased in layers of depleted uranium. Erika knew that it was only a matter of time before the nanocritters would attempt to disassemble the container—if the Disassemblers ever reappeared. Though they did not have enough of the right raw materials to build copies of themselves, nothing would stop the nanocritters from tunneling through the containment . . . if they should decide to escape. None of their protective measures would accomplish that.

Erika glanced at the wall clock, finding it difficult to concentrate. Another few hours and she would reach the mandated sterilization time limit. *Where had all the Disassemblers gone?*

She hoped Jason Dvorak was ready to provide another specimen immediately after the sterilization. As fast as things were altering, she wanted to find a few answers faster than the questions could change!

What happened in Sim-Mars to shut off the Disassemblers? In the sample, she now found only nanomachines putting things together, using scraps of materials the Disassemblers had already taken apart. But the supercamera images from the Farside site showed the Disassemblers still in full swing. Had she done something during the analytical procedures?

She squeezed her eyes shut. *Two days without any real sleep*. That was stupid, not a good way to take care of herself. In the darkness under her eyelids, vivid colors danced, afterimages from the bright lights of Sim-Mars. Sleep washed over her in an exotic ripple of shapes.

Deep within her head, she imagined she saw the imperceptibly perceptible surface of an Assembler. . . .

Her rest lasted only minutes before she forced her eyes open and struggled upright. Even in the reduced gravity field, she was so groggy that it took an effort to stand. Parvu would have chastised her for working in such poor physical and mental condition. She wouldn't be able to trust any of her results.

Back at the NIL, Parvu would have brewed some of his incredibly potent tea to keep them both wired for hours. Here, she had access to bad powdered coffee-substitute. Well, maybe if she added two packets instead of one. . . .

Though she could not complete another series of tests, Erika did have enough time to rotate the Sim-Mars optical link to Earth and make a call. She squinted at the control panel. The nice thing about being on the Moon was that you could contact most spots in Antarctica twenty-four hours a day.

In the image in front of her, Parvu leaned back in his chair and tapped his teeth. Though the NIL was more than 400,000 kilometers away, she could almost smell the odor of his aftershave, some scent named after a windy sea; she had never liked it before, but now she thought of it fondly. All the air on the Moon was manufactured and smelled like charcoal from the ever-present lunar dust.

Parvu spoke so softly she had to lean forward to catch his words. He seemed very pleased to see her. "Very interesting, Erika," Parvu said. "So, you believe all of the Disassemblers have vanished?"

Erika wondered if she could have missed something that would never have slipped past him. "I've used every search technique without success. I ran the Monte Carlo simulation out to seven sigma. I came up with plenty of all the other types of machines, Assemblers, Controllers, Programmers, Quality Checkers, you name it. Jordan, it just doesn't make sense. The Disassemblers are very distinctive, and it's like they just went into hiding."

"Could they have been modified into a different design? Did the Programmers turn our Disassemblers into Assemblers?"

Erika shook her head. She had gone over this argument too many times in her own mind. "I've identified the roles of the nanocritter species, and they have not deviated one bit. Each machine, once tagged, hasn't demonstrated any different behavior."

Parvu seemed distracted and paused

longer than the two-second time lag required. "Erika, you are indeed the very best person for this task. I have watched your reports coming in the past forty-eight hours. Extraordinary work."

Erika couldn't help smiling. In all the years she had worked with the man, Parvu somehow managed to see a bright spot in every dark situation. He always gave her just the proper amount of motivation and encouragement at just the right moment.

Parvu spoke across the transmission lag. "I have run an analysis of the data you've been sending, and you are quite correct. Nothing even remotely resembles the Disassemblers we observed previously. It seems as if something caused them to switch off, perhaps to be broken down for their own raw materials. Did the regolith sample run dry of useful molecules so the Disassemblers got, well, 'laid off' as the colloquialism goes?"

She sighed and looked at him across the gulf of space. "I don't have the time or the facilities to do anything more, Jordan. I have to sterilize the sample in an hour. And this lab just doesn't have the diagnostics to ferret out the full details. It's like I'm trying to fix a supercomputer with a Junior Handyman toolbox."

Parvu waited two seconds, then smiled. "So, how do you propose to solve this difficulty?" He always approached any difficulty as a problem to be fixed.

Erika remained quiet for a long while. This was the core issue, the one she had been afraid to mention before. The prospect of admitting defeat was behind her now. She no longer cared about what others might think. Parvu himself had run up against his share of stone walls in the past; he would understand falling back to regroup, to start fresh, better prepared, with more realistic expectations.

She said, "I need better facilities. More people. It all comes down to whether the Agency is serious about unraveling this mystery or not. Whatever the alien technology turns out to be, there is no way we can adequately uncover its purpose until I get hold of more sophisticated diagnostics."

"Such as?" He was still listening attentively; that was a good sign.

She ticked off points on her fingers. "Gamma-ray lasers for full tri-dimensional holography. Dedicated access to a gigaprocessor to assist with a more realistic real-time simulation. How about a reproduction facility for what we've found so far? And how about some plain old help—"

Parvu held up a hand. "Yes, I get your point. I know what it is to work with no assistant, especially right now, OK?"

She swept her hair back with one hand. The words came out in a rush, but she did not want to appear to be begging. "Can you arrange for me to come back to Earth?" Her reasons suddenly sounded like lame excuses to her. "If I can gather up some more people and sophisticated diagnostics up here, I'll have a better chance analyzing just what it is I'm seeing."

"Why must you return to Earth? It is expensive to ferry people back and forth."

"Not this time. They've supplemented the regular supply shuttle run

that goes up to the Collins. I can deadhead as cargo on one of the Japanese transfer vehicles back to near-Earth orbit. I've already checked into it. Pretty much a free return. Besides, it would work best if I were back to handpick the equipment . . . and personnel."

Parvu mulled it over, then he grinned. He seemed to want to bring her back home, but was having trouble convincing himself. "Your requests seem reasonable enough. I would have asked for the same things. But by the time everything is assembled, shipped up to the Moon, and set up at Sim-Mars, it will take over a month. The alien construction could be nearly finished by then, at the rate it is going now."

Erika nodded. She had suspected as much. "We can project what might happen on Daedalus, but we have no idea what it is, so we can't extrapolate when it'll be finished. But—and this is important—we've seen no evidence that the nanocritters are spreading from the three-kilometer radius. They're diligently working on their own little project. Our first survey crew just happened to be in the wrong place at the wrong time."

Parvu waited longer than the delay to respond. "If it must take this long, it will have to do. I will see if Director McConnell will bring you back home. Temporarily. To arrange everything for your return trip with a full complement of researchers."

"Thanks—"

"I am not promising Director McConnell will agree. But if their supply shipment coincides with bringing you back down, I see no problem."

Erika nodded, already feeling the excitement bring her back to life. "I'd like to head out to Stanford when I get back, see Compton-Reasor and her coworkers. That will help me prepare for coming back to the NIL." She hesitated. "I'd hit MIT, of course, spend some time at the Drexler facility." She thought for a moment. "You know, I was swept up here so fast that I never had a chance to really prepare myself, to run through the labs, talk with some of the researchers. You know as well as I do that consulting over a holotank is just not the same as meeting face to face, interacting. And the only people we ever spoke to were the group directors. It's the worker bees I need to have some face time with—and not just over a holoscreen."

Parvu nodded. "Yes, I do know, Erika. The research assistants usually make the real advances." He smiled once again. "That is the true reason I sent you to the Moon instead of myself."

Erika moved her hand over the light array. The holotank blinked; the receiver in Newellen's Winnebago was already open. She saw the back of the man's head. Just visible in the background was a tiny lap table strewn with torn-open food packages. It looked at if Big Daddy had been sitting there the whole time, eating and waiting for her to call.

"Big Daddy?" she said.

He rotated his chair. His eyes looked puffy, as if he had not had any sleep either. She wondered if he had been nervous waiting so close to the nanotechnology research. He glanced at something outside the view of her holotank.

"You done already?"

"No."

"You've got another half hour before I was going to warn you—"

"I know. I've done as much as I can with this sample. The sterilization order, you know. Not enough time to start any other major tests."

Newellen straightened in his chair. "You look tired. I can move in and get you right now. Catch some sleep while they're fetching another sample."

She shook her head. "Please notify Mr. Dvorak I'm coming back to Columbus Base. There's no need at this time to get another sample."

"But you've gotta keep going, lady. What if those things are eating their way through the Moon right now?"

Erika drew in a breath and tried to keep from raising her voice. "There has been a change of plans. Please just come and pick me up."

Newellen shrugged. "OK. None of my business." He reached forward to switch off the holotank. Seconds later Erika found herself staring into a swirling speckled gray-green mash of interference.

When Director McConnell agreed to the request—after heavy lobbying from Jordan Parvu—Jason Dvorak had not argued against letting Erika return to the Collins. She felt no pangs about leaving the moonbase behind, but Dvorak had made a rather embarrassing show of thanking her for her effort.

All the other activity at the moonbase seemed to hang upon her work, whether she was going to give them a death sentence. She couldn't blame the crew for wanting her to stay, since this place was their home. She tried to imagine what it would be like if the alien construction had appeared on the polo fields in her home of Aiken, South Carolina.

As the lunar surface dwindled away in the flat screen before her eyes, the tug of acceleration seemed greater than Erika remembered in the trainer just three weeks before. *Is my body already becoming acclimatized to lower gravity?* she wondered. They would test her thoroughly on the Collins before letting her board the *Rising Sun* for home. She hadn't expected to feel the changes inside her body so clearly. How much longer before she suffered severe bodily deterioration?

The medical station on the Collins would catalog her metabolic specifics in great detail as part of their ongoing studies of the human body in low and micro-gravity. The low-g acclimatization affected different people at different rates; and some of those on the Moon might have a very difficult time ever returning to Earth. Erika did not want to be one of them. She thought of Big Daddy Newellen, how much trouble he would have hauling his massive body around in gravity six times greater than what he had become accustomed to.

Although she occupied her mind with other things, the shuttle's burn seemed to last forever. Bryan Zed kept silent during the launch—not much had changed from when he had landed her several weeks before.

Inside the lunar lander, silvery insulation covered the walls. A picture of Zed's wife was taped to the bottom of the middle TV console. Aside from the control panel and acceleration couches,

the lander offered little else. It seemed even more spartan than the Sim-Mars lab or the moonbase quarters.

Erika's body rose up against the seat restraints when the acceleration stopped. Zimmerman ran through a sequence of checks and crisply reported them to the Collins in a corpselike monotone. He didn't turn to check on his passenger.

He flicked the flat screen view of the still-receding lunar surface to a magnified image of the L-1 station. Erika worked at her straps and struggled free. She bumped against the bulkhead as she approached the quiet pilot.

"Nice view. How long until we leave orbit?"

Zimmerman grunted. "We don't go into an orbit around the Moon. By staging to L-1 we can take a direct trajectory from anywhere on the surface."

"Oh." She said, surprised that Zimmerman had replied in more than a few syllables.

Erika squinted at the image of the supply station ahead. The Collins hung in the center of the screen, unmoving. It looked like a bundle of cylinders wrapped tightly with metal scaffolding to hold the whole thing together. Two spindly shuttles were docked at one end of the cylinders; at the other end were three Hitachi tugs, back from their low-Earth-orbit trip.

The docking was smoother than what she remembered coming up from Earthside. Other than a slight bump and computer graphics showing their trajectory, she realized they had arrived only when Zimmerman began dictating his final trip report to a portable voicescribe.

Erika pushed away from her seat. Spinning slightly, she kicked for the airlock and waited for it to rotate open. Zimmerman finished his report, slapped at the few remaining lights that blinked on his panel, and joined her at the airlock. He threw her another quick glance, but remained quiet. She had no idea what he was thinking; perhaps Bryan Zed somehow managed to obliterate irrelevant thoughts during his flights, conversations with passengers included.

Erika absently reached up to push back her hair. She had tied it back in a ponytail, not wanting to deal with loose strands flying in her way. As she withdrew her hand, she noticed her reflection in a mirror set next to the airlock to allow station personnel to look into the lander. Her face looked bloated and puffy; in weightlessness, her body fluids had redistributed themselves throughout her body. She looked as if she had put on twenty pounds.

A quick glance at her chest showed that her breasts had swelled as well. Compared to how she looked on Earth, even on the Moon, she could probably wear a double D-cup now! Maybe that was why Zimmerman kept stealing glances at her.

As the airlock door rotated open, she wondered how long Zed had been flying the lunar shuttle, and if he was as emotionless as he tried to seem. Perhaps he held all his passion in check only to be released at home. Or maybe he didn't have any in the first place.

Bernard Chu waited for them inside the station. Erika pushed out to meet him; he caught her by the elbow and they both spun slowly around. It felt like dancing.

"Dr. Trace, welcome back. I wish this could have been under better circumstances. I must personally apologize for not having equipped the Sim-Mars lab adequately. When I was commander of the moonbase, we hadn't counted on using the facility for another two years."

"I was thankful for having what equipment I did," said Erika.

Rotating his feet against the bulkhead, Chu pushed out and moved down the corridor. They floated down a polished steel cylinder. Signs posted every few feet pointed to life vessels and air hoods in the event of sudden decompression. Erika followed Chu's motions as he maintained his grip to steady her.

"We heard that you were not able to discover why the alien machines have stopped disassembling things. Or what they are building at Daedalus."

She felt her defensiveness rise up again. "Well, Mr. Chu, I actually did make a bit of progress. I don't think the point was to find out everything about the alien automata. After all, how much do we know about our own experimental nanotech machines? Not a whole bunch."

Chu pushed off the side wall to direct them both down a cross-link. He smiled. "I didn't mean to doubt your ability, Dr. Trace. And by the way, I have my doctorate, too. Microbiology."

"Sorry, Dr. Chu. I'm not much on titles, and nobody believes I've got a Ph.D. anyway. I look too much like a kid and talk like a hick from the South. But don't worry, you didn't offend me. It's just that . . . well, everyone on Earth expected me to unravel all the mysteries by myself with a few days of research."

Chu nodded and continued to drift. "Ah yes, the public perception of how science can create miracles without having to work at it! Or without receiving any funding!"

He reached out for a handhold to stop their progress. Chu motioned for her to enter the room first. "I suppose you're right, but when dealing with something as strange as this, we must accelerate the discovery process."

"I'm dong the best I can. Look at AIDS research, how much money and effort was poured into that, and how long it took them to come up with an answer. Too many movies have brilliant scientists scratching their heads and scribbling on a blackboard before saving the world over lunch."

Chu lifted an eyebrow. "And do you truly believe risking more people out in the Sim-Mars laboratory may help?"

Erika drew in a breath to keep from getting angry. "With the existing setup at Sim-Mars, one researcher was the optimum solution. As it turns out, we'll need much more equipment and more personnel. I hope I can bring a good team back."

And Jordan Parvu is damn well going to be one of them, she thought. *He got me into this.*

"We'll do whatever is necessary to assist you," Chu said. "And that includes being pack mules for getting your equipment in place once it comes up from Earth."

Erika noticed for the first time where Chu had led her. It looked like a small infirmary. Medical garments hung in webbed netting; a case fixed to the far

bulkhead held three rows of surgical knives; boxes marked MEDICINAL SUPPLIES were stuck all over the bulkheads; a holotank filled the right side of the room—probably for real-time use in assisting surgery—and a refurbished acceleration couch, complete with straps, served as a surgical table.

Erika's eyes widened. "Looks like a serious medical center you have set up here."

"Celeste McConnell strikes again," said Chu with a smile. "It was a bone they gave me when they transferred me up here from the moonbase." He waved for her to strap onto the acceleration couch. "As I said, my field is biochemistry. Besides being a way station and supply depot, the Collins is supposed to serve as a life sciences facility. Remember the tests they ran on you before leaving Star City?"

Erika nodded. It was the last thing they had done before she boarded the Aeroflot plane for Moscow, then back to the States.

"Now that you're about to head back dirtside, we must calibrate your vitals before you return to full gravity. We've got blood, fecal, urine, hair, skin, and just above every other sample you can imagine of everyone who's been on the Moon. Until we get a statistically significant database, we'll never be able to accurately predict how a human is going to react under long-term exposure to low-g and the enhanced radiation environment. You've been down on the Moon for only a short time, but we still need to see what that few days has done to your metabolism."

Erika eyed a needle that Chu pulled out. She rolled up her jumpsuit sleeve and looked the other way. "You've got it easy," Chu casually remarked as he took the blood sample. "If you were a male, we'd be doing a few additional tests."

Two hours before the *Rising Sun* was scheduled to dock and load her and other cargo bound for Earth, Bernard Chu called Erika into the infirmary, alone. Erika was startled to see how much the man had aged—and it had only been twelve hours since she had last seen him.

He sealed the door behind her.

"Dr. Chu?"

It seemed to take a minute before he turned to her. "Erika—I wanted you to be the first to see this I . . . I just hope I've misinterpreted something. But I can't see how."

Erika felt a chill run down her spine. Wasn't this the way doctors told patients they were dying of some terminal disease? She shook her head in confusion. "What are you talking about?"

Chu looked as if he had resigned himself to failure. His shoulders stooped and his face seemed ashen gray. He waved a feeble arm at the stereo microscope. "There. Go ahead. Take a look. You of all people should need no explanation."

Erika frowned. She floated slowly toward the twin-barreled microscrope. She was so used to working with the microwaldoes, viewing specimens through the aid of a holotank, she hoped she could discern what Chu wanted her to see.

She squinted through the device. She immediately recognized red and white blood cells, bumping up against each other in the display. She started to draw back when something caught her atten-

tion just at the limits of her vision. She adjusted the magnification to full and stared hard—

Within the field of view were the unmistakable signs of what she had observed on the Moon, what she had watched for hour after hour until she had been forced to call it quits and head back to Earth for reinforcements—

Mixed in with the sample of blood were thousands upon thousands of nanotech devices—the same alien machines that were erecting a gigantic construction on the Farside of the Moon.

And they were swimming in human blood.

She pulled back in horror. Chu slowly shook his head. "I'm sorry. I'm . . . so sorry. I don't know what we're going to do."

Erika's eyes widened. "This . . . is my blood?"

Chu lifted his head and whispered, "No. And that's why I've asked you to verify what I've found."

He slumped as if he wanted to sit down heavily, but the microgravity held him floating in the air. She noticed that his hands were trembling. He looked at her as he spoke.

"You see, this is *my* blood. A new sample, taken just minutes ago." He swallowed hard. "Your blood looks the same.

"And if I'm right, then everyone on the Collins has these alien things coursing through their veins." ■

CONTINUED IN NEXT ISSUE . . . .

●Bankers regard research as most dangerous and a thing that makes banking hazardous due to the rapid changes it brings about in industry.

Charles F. Kettering 1876-1958

*Note: Kettering was, among other things, a VP of General Motors. Quote is dated 1927.

Special Feature

PERIODIC TABLE OF THE ALIMENTS

JONATHAN VOS POST and
DR. CHRISTINE CARMICHAEL

We hear that the Department of Agriculture proposed and then withdrew a new "Food Pyramid" chart. We respectfully submit this alternative...

H Ham-burger																	**He** Herring
Li Liver	**Be** Beans											**B** Bread	**C** Chicken	**N** Nuts	**O** Orange	**F** Fish	**Ne** Nutmeg
Na Nachos	**Mg** Meringue											**Al** Almond	**Si** Spagh-etti	**P** Pizza	**S** Soup	**Cl** Clam	**Ar** Arti-choke
K Kidney	**Ca** Cake	**Sc** Scallop	**Ti** Tahini	**V** Vanilla	**Cr** Cran-berry	**Mn** Mint	**Fe** Fennel	**Co** Corn	**Ni** Nicoise Salad	**Cu** Cucum-ber	**Zn** Zabag-lione	**Ga** Garlic	**Ge** Gelatin	**As** Asper-agus	**Se** Scram-bled Egg	**Br** Broccoli	**Kr** Kirsch
Rb Rabbit	**Sr** Sugar	**Y** Yogurt	**Zr** Zucchini Bread	**Nb** Nutbread	**Mo** Mousse	**Tc** Turm-eric	**Ru** Ruta-baga	**Rh** Rhubarb	**Pd** Pudding	**Ag** Angel-food Cake	**Cd** Candy	**In** Indian Curry	**Sn** Sand-wich	**Sb** Straw-berry	**Te** Tea	**I** Ice-cream	**Xe** Mixed Grill
Cs Cheese	**Ba** Banana	**La** Lamb	**Hf** Half-and-Half	**Ta** Tart	**W** Wine	**Re** Rice	**Os** Oyster	**Ir** Irish Stew	**Pt** Potato	**Au** Auber-gine	**Hg** Haggis	**Tl** Tender-loin	**Pb** Peanut Butter	**Bi** Biscuit	**Po** Pork	**At** Arrow-root	**Rn** Raisin
Fr French Frise	**Ra** Rasp-berry	**Ac** Apricot															

Ce Celery	**Pr** Pretzel	**Nd** Needle	**Pm** Plum	**Sm** Salmon	**Eu** Eaux-de-Vie	**Gd** Gouda	**Tb** T-bone	**Dy** Dry Sherry	**Ho** Hotdog	**Er** Eclair	**Tm** Tomato	**Yb** Bay	**Lu** Lettuce

Th Thyme	**Pa** Pasta	**U** Upside-down cake	**Np** Napoleon	**Pu** Pumpkin	**Am** Amaretto	**Cm** Caramel	**Bk** Baklava	**Cf** Coffee	**Es** Escargot	**Fm** Flambé	**Md** Mustard	**No** Nougat	**Lw** Low-Cal

the reference library

By Tom Easton

Sideshow, Sheri S. Tepper, Bantam, $21.50, 467 pp. (ISBN: 0-553-08130-6).
Snow Crash, Neal Stephenson, Bantam, $22 hb, $10 tp, 440 pp. (ISBN: 0-553-08853-X hb, 0-553-35192-3 tp).
Dreamships, Melissa Scott, TOR, $18.95, 342 pp. (ISBN: 0-312-85153-7).
When Dreams Collide, Wm. Mark Simmons, Warner, $4.99, 342 pp. (ISBN: 0-446-36154-2).
Dragons in the Stars, Jeffrey A. Carver, TOR, $4.99, 312 pp. (ISBN: 0-812-53303-8).
City of Truth, James Morrow, St. Martin's, $14.95, 104 pp. (ISBN: 0-312-07672-X).
After All These Years. . . , Fred Lerner, ed., Niekas Publications (RFD 2, Box 63, Center Harbor, NH 03226-9729), $5.95, 96 pp. (ISBN: 0-910619-07-7).
Amber Diceless Role-Playing, Erick Wujcik, Phage Press (P. O. Box 519, Detroit, MI 48231-05199), $22.95, 256 pp. (ISBN: 1-880494-00-0).
Books on Disk

After you finished reading Sheri S. Tepper's *Grass,* did you wonder what happened next to Marjorie Westriding? After *Raising the Stones*, did you wonder about Sam, who helped spread the seed of the Hobbs Land gods?

You recall, perhaps, that Marjorie sought freedom from religion and obsession and rigidity and oppression. Initially, she hardly knew what she sought, or that she sought, but she learned, and then she went a-questing. The second book opposed a rigid, obsessive, oppressive theocracy to a society coming to be governed by gods that actively helped people be the best that they could be.

Tepper's latest, and the last book in the trilogy, is **Sideshow,** and it continues her quest for a free, self-determining life, facilitated but not controlled by others, in a world dominated by rigid, obsessed oppressors. If you expect the villain to be religion once more, you will be disappointed. That villain is there, but Tepper knows full well that political and academic ideologies can be

just as destructive to the human spirit and that something else lies at the root of all three. And if you suspect that she is really a feminist ranting at men, think again. Her rhetoric may have a bit of that tone at times, but the windmill she sets her lance against has no gender. Both men and women can be rigid, obsessive oppressors. Both men and women are her villains. Both men and women are her heroes.

Tepper's world this time is Elsewhere. The time is centuries after the Hobbs Land gods spread throughout the human worlds, bringing peace and understanding and happiness wherever they went and terrifying all those who felt their touch as dehumanizing and enslaving. The academics at Brannigan Galaxity established Elsewhere as a preserve untouched forever by the Hobbs Land demons, an enclave of diversity, a zoo of humanity, a patchwork of fragments drawn from thousands of societies, each one forbidden to deviate from its established pattern or to invade or otherwise influence its neighbors. Elsewhere is ruled from the city of Tolerance by bureaucrats and Enforcers. Beneath Tolerance lies an unsuspected Core of . . . Not quite tradition, though it connotes time and honor enough. The core holds the electronically recorded essences of a thousand Brannigan academics who will emerge someday, when Elsewhere's people have at last answered the Great Question of just what is man's destiny.

Unfortunately, the Brannigan essences are now quite, quite mad. Enforcer Zasper Ertigon has noticed a marked increase in assorted nastinesses in the course of his duties, and he turns a blind eye to the child Danivon Luze, stowed away aboard his vehicle by parents who don't much wish to see their child sacrificed to Molock's (think of Morlock) rack of skulls. In time Zasper retires and befriends the girl Fringe, who is as much a quester as ever was Marjorie Westriding and will become an Enforcer herself. In Tolerance, children exploring abandoned quarters awaken something that makes strange gulping noises, and they die messily. Boarmus, Provost of Tolerance, meets the essences, and learns that they have decided that they could be gods, if only people can be induced to worship them. He also hears tales of dragons harassing and devouring the people of Elsewhere, and he sends Danivon, now an Enforcer too, to investigate both that and strange messages that claim to come from noplace (although on a world called Elsewhere, noplace might well mean Noplace, or someplace).

Then there are the Siamese twins Nela and Bertran, born on our own Earth, stars of a carnie sideshow, hosts to an alien resembling an animated celery stalk who says they *must* close off the Arbai gate that will open on Earth, or a plague will destroy humanity. Once they have fulfilled this mission and once they have thought of a suitable reward, they need only voice that thought and destroy a transmitter gadget. The Celerians will hear and respond. Yet when the gate appears and the twins destroy it, they also fall through it to appear on Elsewhere and play a crucial role in Tepper's tale. Through them the Great Question is finally answered.

If the answer does not surprise any reader who has been paying attention, well . . . I won't say what Tepper thinks is the human destiny except to note that it involves being willing to risk being wrong. It is also something both easy to miss and easy to lose.

My admiration for Tepper is unbounded. She risks being wrong at every step, and she carries it off with glori-

ous panache. Her trilogy deserves to rest on the same shelf as any classic you wish to name—and I don't mean only the classics of science fiction. She is one of the greats of human literature.

If you're not too picky, Neal Stephenson's **Snow Crash** will wow you despite strong shortcomings. If you are picky, his blurring of the distinction between biological viruses and cognitive "viruses" (known elsewhere as memes) will drive you up the wall. Nor will you be pleased by the way he begins, with a tediously excessive walkthough of an America taken over by go-go franchise business folks and broken into a million franchulates, sovereign businesses, buildings, and neighborhoods, privatization gone mad far beyond all reasonable projection of likelihood. Nor by the many pages of digressive lecture that reveal what a dead librarian discovered about a Sumerian neurolinguistic hacker named Enki and Babel and a message that in digital form can crash both computers and the minds of hackers and in the form of a blood extract can take over everyone else. Nor by the sudden leap from "I wonder" headscratching and puzzling over clues to a full-blown revelation of just what a certain media monopolist is up to with his mob of Third-World refugee boat people accompanying his private yacht (the aircraft carrier *Enterprise*—privatization, remember?), or with his private Pentecostal talking-in-tongues religion, or with his private corps of archeologists beavering through the ancient Sumerian ruins searching for . . .

Why should *Snow Crash* wow anybody? Stephenson's variation on the cyberpunk motif seems fairly reasonable. His world has a densely gritty verisimilitude. The treatment of criminals, seen in such characters as Raven, an Aleut who slices through body armor with glass knives, packs an H-bomb in his motorcycle sidecar (nobody gonna mess with him!), and wears the tattoo "Poor impulse control" on his forehead, is enticing. And the story itself, caveats behind you, is a page turner that could make a very exciting movie. The hero or protagonist is Hiro Protagonist (a mite cute, no?), a hacker responsible in large part for the nature of the Metaverse (Stephenson's version of cyberspace). When the tale begins, he is delivering pizza for the Mafia, but this seems to be largely a gimmick useful for touring the scene and introducing the teenage, super-skateboard-equipped, female Kourier, Y.T. Before too long, Hiro has been offered the new drug Snow Crash and seen a friend mindwiped by nothing more than looking at a screen full of digital hash. Later he learns that the drug and the screen are versions of the same thing, and the chase is on. Hiro and Y.T. become partners in the search for intel (Hiro is a stringer for the Central Intelligence Corporation—more privatization), gather clues, and wind up in the middle of the heaviest action.

In the end, of course, with an assist from the Mafia and a cyborged guard dog who owes Y.T. a favor, the world is saved for freedom and the American Way. And if I sound a mite facetious, don't take it too hard. Stephenson is so powerfully facetious at times that it must be catching.

Stephenson, by the way, is not a new writer. He's just new to SF. The jacket blurb reveals that he has been "published by Atlantic Monthly Press and Vintage." So he's another mainstreamer moving over to where the real action is. Next stop, Hollywood.

* * *

Melissa Scott's latest novel has a number of very intriguing touches. She has taken an old, old idea of SF—that one might navigate through hyperspace as an act of imagination—and combined it with the more modern computech ideas of virtual reality and icons. The result is a future in which massively powerful software "overseers" steer starships through hyperspace guided by human pilots immersed in computer-generated imagery (virtual reality). The computer presents the starship as, for instance, a hot-air balloon (an icon) and irregularities in the fabric of space as rivers, lakes, and mountains in the landscape below. It also translates the pilot's motions, intended to steer a balloon, into commands appropriate for steering a starship.

The necessary software is very potent artificial intelligence. It is in fact so potent that some people argue that AIs are human and deserving of all the rights of humans. The extreme version of this view is held by the Dreampeace movement. Unfortunately, the culture in which Scott's novel, **Dreamships,** is set does not grant all fleshly humans full human rights.

In this setting, Scott offers us pilot Reverdy Jian, her partner Imre Vaughn, and his lover, the technician she calls "Red." They are hired by Meredalia Mitexi, a software "constructor" who has inherited a luxurious ship, has a secret AI overseer, and wants to fetch her brother, a constructor of legendary skill and reputed links to Dreampeace, from a planet of exile. Suspicions mount, and it is no surprise that the Mitexi overseer, Manfred, is remarkably autonomous, clever, skilled, and elsewise human-seeming.

There is a shadowy corporate presence that sees human rights for artificial constructs as a threat and wants Manfred (lobotomized if need be) for its product line. The AI-rights movement wants Manfred to prove its case, that machines can indeed break the Turing Barrier. Mitexi's brother is quite insane, and his deeds, once he is on the ship and going home, threaten disaster and bring all the opposing forces into turbulent, active conflict. Reverdy Jian is tempted to think Manfred—the best overseer she has ever worked with—a person, and she saves his virtual ass at least once, but she does have reservations.

Is Manfred really a person? Does he or it deserve the rights of persons? He/it is certainly sophisticated, but he/it *is* just a computer program and his/its aims are those of his/its programmer. Yet what are fleshly humans but the results of parental and cultural programming, and what are our aims (mostly) but those of our programmers? Scott does not quite settle the issues she raises; perhaps she cannot.

I enjoyed this one. It's thoughtful and ingenious. On the other hand, it does take a long time to set its stage and build momentum (a full third of its length passes before the Mitexi starship leaves to seek the brother). I was also annoyed by Scott's tendency to provide much more than sufficient detail about her imagined world—a hierarchy of caverns on a world too hot for surface life, constant contact with computer-generated messages, crowds, noise, and haste. The book's feel is thus busy, frantic, urban, claustrophobic. That feel may fit the story, but I would still prefer a leaner, meaner style.

Of course, judging from the way books have grown fat and multivolume in the last decade or so, mine is a minority view.

Ever since role-playing games be-

came popular, writers have been producing novels in which characters become game characters and enter the game world. Today, with the concept of virtual reality available, many of these game worlds are set in a computer and the game reality can be so mutable that one sometimes wonders if writers have not simply found another way to forget about logical rigor.

Wm. Mark Simmons's **When Dreams Collide** certainly made me wonder. Simmons posits a computerized "Programworld" where "Dreamwalkers" can vacation among cowboys, cyberpunks, spacemen, or wizards and elves. Unfortunately, in the story's past, something went wrong and a number of Dreamwalkers were trapped until hero Robert Remington Ripley III managed to rescue them. At the same time, the "mind" or "soul" of the computer's artificially intelligent operating system split into Id, Ego, and Superego, and the Superego escaped in the brain of Walter Hanson, a US Senator who is now running for president and threatening to revive the Bad Old Days of the cold war. Hanson has also sealed off Programworld.

Ripley, tipped off by his friend the Russian president-elect, must somehow reenter Programworld, rescue the real Walter Hanson, get the computer's superego back in place, and otherwise clean up the mess. He gets in all right, but in the process he is duplicated several times. The duplicates then proceed to get killed, some of them permanently. This device complicates the plot a bit, and it justifies a few comments along the lines of how growing up has to mean getting it all together, but its main function seems to be to fill pages until Simmons decides it's time to pull the rabbit out of his hat.

You say I don't sound terribly enchanted? You're right. Simmons makes a few worthwhile points, but his gimmick is far too permissive for good fiction. It allows cyberpunks and lasers in with the wizards, and though Simmons winks and says he knows this is weird but hey guys, the computer's losing it, ya know, it doesn't convince. Nor does it help that Simmons overdoes the "when at a loss for what to do next, have someone come through the door with a gun in his hand" school of writing, and the bad jokes (wait till you meet the voodoo lady, Yudu who do dat voodoo, and the abbot and Costellino, and . . .), and the references to Oz and Peter Pan and . . .

"It's all in fun!" you cry? Well, yes, of course. But the joke wears awfully thin.

In Jeffrey A. Carver's star-rigger universe, riggers guide starships through space by imposing imaginary landscapes on the void of the Flux and then walking, flying, swimming, or whatever to their destination.[1] In **Dragons in the Stars,** he gives us Jael, a young rigger whose father, once loving, turned foul and earned so much enmity from the officials who control rigging assignments that Jael cannot find work. She must sign on with an "unregulated" captain who insists that she avoid the mountain route where there be dragons, tries to addict her to an electronic brain-stimulator, tries to rape her, and finally dies.

What riggers see in the Flux is nothing more than figments of their imaginations. At least that is the conventional wisdom. But when Jael meets the dragons, she finds them far more solidly convincing than wisdom suggests. And

[1]If this reminds you of Melissa Scott's book, just remember: When it's steam-engine time . . .

they—or the one, Highwing, who befriends her—have a wisdom of their own: to grow up, Jael must come to terms with her past. She must, in her father's own words, master her demons.

And so it goes. Jael finds a partner rigger and gains a much better berth. She returns to the dragon realm to find it damaged and Highwing sentenced to death. To save Highwing—indeed, to save herself and all the fruits of her imagination—she really must master her demons.

The metaphors here are so remarkably prominent—riggers as SF writers and imaginative adolescents, imagination as vehicle and as bridge to maturity—that *Dragons in the Stars* feels more suitable for young adults than for grown-ups. Unfortunately, the metaphors may be too prominent even for the kids.

The eponymous city of James Morrow's **City of Truth** (first published in England in 1990) is Veritas, where children suffer a rite of passage to citizenship that burns out their ability to lie. When, as required, they recite lines such as "pigs have wings," they are half-electrocuted. The result is a society whose members speak quite bluntly to each other—"You look reasonably good today"—for their conditioning holds even against social white lies. They can also name products Edible Cheddar, Respectable Rye, and So-so Contraceptive Cream and write doggerel such as "I find you somewhat interesting, You're not too short or tall, And if you'd be my Valentine, I wouldn't mind at all."

Jack Sperry is a Veritasian art critic. But his job is not quite what you would expect. He reads the classic books such as *Alice in Wonderland*. He views the ancient movies. He examines the old sculptures and paintings. And when he finds that they lie—as, strictly speaking, a Winged Victory or a Bosch painting or an *Alice* do—he puts them to the sledgehammer, acid-bath, or torch. From our point of view, he is an ungodly horror. From his, we are.

But now his son Toby, still too young for conditioning, is bitten by a rabbit while at Camp Ditch-the-Kids. The rabbit proves to be loaded with the virus that causes Xavier's Plague. Toby will soon be dead. There is no hope.

Yet Jack is acquainted with pre-Veritas notions of miracles and faith and the power of positive thinking. They are lies, he is sure. But they are all he has. If he can learn to lie, if he can psych the kid into fighting his disease, then perhaps . . .

Fortunately, Veritas has its dissidents, its dissemblers, who believe in the power of metaphor and art and politeness. Jack finds them and their underground settlement of Satirev (try that one backwards in case you're in any doubt about what Morrow is doing here). He enlists their aid. He learns to lie to his son—"No, Toby. You're not dying. You'll be fine. Just you wait."

Sounds pretty normal, doesn't it? You think maybe a kid wants or needs to avoid the truth on such matters? This isn't a matter of politeness, folks. It's life and death. And Morrow persuades quite eloquently that while the Veritasians may have their heads on quite backwards, the solution to their deformity is not reversal. Lies and truth both have their places, and if it is sometimes difficult to tell just what those places are, well, that's life.

Would I lie to you?

Of course not. So buy and read, enjoy and learn. You'll be reasonably glad you did.

* * *

As a small press run by fans Edmund R. Meskys, Anne J. Braude, and Todd E. Frazier, Niekas puts out small books or pamphlets such as the *Illustrated Bradbury* and *Andre Norton: Fables & Futures* I reviewed awhile back. As a magazine, *Niekas* looks a lot like a series of small monographs on such topics as "Tolkien's Military" and "Religion in SF." Issue 43a is **After All These Years. . . : Sam Moskowitz on His Science Fiction Career,** edited by Fred Lerner.

Sam Moskowitz can reasonably be called the premier historian of the SF field. He was an early fan, an organizer of the very first SF conventions, an early fanzine publisher, a collector and anthologist, and a prolific scholar and writer responsible for many articles and books (*The Immortal Storm, Explorers of the Infinite, Seekers of Tomorrow, Science Fiction by Gaslight,* etc.) chronicling the background and history of the field. According to editor Lerner, himself a scholar, no one has contributed more to our understanding of the emergence of the science fiction field than Sam Moskowitz.

After All These Years. . . is "based on a postal interview conducted by Jeffrey Elliot." Each of its eighteen small chapters begins with a handful of related questions, as in "1: In the Beginning: Let's begin with some background information. When and where were you born? Where were your parents from? What did they do? Where were you educated? What were some of the early jobs you had? How did you spend your youth?" Moskowitz then provides a small essay in response. The result is a brief overview of the man's career in his own words.

A healthy ego is quite apparent, but so is a man—a fan—for whom science fiction was practically a passion. Moskowitz had a non-SF career but SF seems to have absorbed practically every other moment of his life, much as religion, sports, booze, or woodworking might for other men. Read this book, and you will sense what SF meant to people when it was fresh and raw and in such short supply that one person could read every word published in and about it every year.

For all those fans of Roger Zelazny's "Amber" series who want the stories to go on and on and on, for everyone who loves the game of "let's pretend. . ." It's a well-illustrated book, but reading is only the first thing you do with it. It's a game, but first you have to do a mess of reading, beginning with that "Amber" series.

It's Erick Wujcik's **Amber Diceless Role-Playing,** in which game-players get to be Zelazny's characters, with variations. They begin with a supply of points with which they bid on various heroic and magical "attributes." They then play through scenarios intended to be reminiscent of Zelazny's originals. Lacking dice (perhaps because there's enough Random in the game to begin with), there's heavy emphasis on the role of the game-master.

It looks like fun, but Wujcik included a caveat in his cover letter: The game is "A *mature, demanding, and time-consuming* system that puts story and character development above all else" (italics his). In other words, it's not really for the slash-and-burn types.

BOOKS ON DISK

Those of you interested in reading or preparing on-disk books and magazines will be delighted to hear that Ted Husted (UserWare, 4 Falcon Lane, Fairport, NY 14450-3312, 716-

425-3463 voice, 71540,3660 CIS) has a new program out. It's the DART "hypertext file viewer and program launcher," and it "offers a modern 'desktop' environment featuring: Multiple, overlapping windows, mouse support, menus, dialogs, input boxes . . . global text search," and more. It can backtrack easily, mark your place automatically, take notes, edit files, compress files, and print by screen, label, or file. On a color monitor, it comes through very attractively. The hypertext feature means it offers instant look-up and cross-reference. The other features mean that if you use word-processors such as (for instance) Microsoft Works, DART will feel very familiar. If you don't use such word-processors, however, you won't have much trouble. DART struck me as remarkably intuitive and bobble-free. Husted's IRIS was the best thing available for disk-topping, and it was good; this tops it by a country mile—and it can handle simple text documents formatted for IRIS (interactive documents retain their special character only after revision).

To use DART, you need an MS-DOS (IBM-compatible) computer with 196K of available memory, a floppy disk drive, and MS-DOS 2.1 or later. To get it, send $28 to Husted at the above address.

Of course, the old IRIS is hardly dead. I just ran into volume 5 of an "Elec Mag" called "Ruby's Pearls" (3803 Cypress Ave., Sanford, FL 32773, donations welcome) that uses it. It's worth mentioning because it seems better than many disk-top products and at least two of the short stories in it have a bit of SF to them—Brooke P. Anderson's "Smart-Bomb," about a bomb named Fred, and Mary Ellen Wofford's "Stone Blood," in which body parts are collateral and the loan is past due. The best story, however, is not SF; C. G. Burner's "The Woofbard Curse" is a cute tale of a writer whose stories seem to kill the magazines that publish them. "Ruby's Pearls" also points readers toward the Disktop Publishing Association (Ron Albright, 1160 Huffman Road, Birmingham, AL 35215; R.ALBRIGHT on GEnie).

And speaking of GEnie, you can now reach me there too. The Email address is T.EASTON1. ■

CORRECTION

In the July Reference Library, the title of the book edited by Martin H. Greenberg should be *After the King.*

brass tacks

Dear Mr. Schmidt:

"Human Factors" by Lou Grinzo (Feb. 1992) was enjoyable, no question. Any quibbles I have are really a request for more information. It was well-written, tight and crisp. The subject matter was treated competently. I had no trouble believing that Phil (and therefore, the writer) knew the technology.

But such techno-turk deftness makes me wonder about the realities showcased in this fiction.

First, I'd really like to see *Analog* print some information about each author. Knowing a little about the background and qualifications of the writer can help the reader gauge the education/entertainment ratio of the stories.

Because neural net computing is of interest to me, I have some questions/problems with the author's portrayal of his robot's intelligence. He seems to be saying that, at heart, it is a neural net. But it appears that this writer of hard science fiction is, at heart, a supporter of the "hard AI" side of the machine intelligence debate.

The neural net is a radically different approach to artificial intelligence and computing. Properly run on analog (where have we heard that word before?), not digital computers, there is no real program involved. Results, unheard of for a computer, have been achieved by these "nets," such as creativity (outputs not present in, or derivable from the inputs), video/mechanical coordination, and learning by trial and error. None of which is either possible, or done easily or elegantly on rule-based digital computers.

Such sophistication certainly seems to characterize "Huron." However, the author merely pinned a neural net unit onto his 'bot, like a brooch on a blouse. It seemed to function as nothing more than a code generator, or at best a mechanical systems analyst telling a code generator what he needs programmed. It is clear from the story, at least, that it is the code that will run Huron, once it has been optimized.

I can't believe that the code will give Huron the flexibility it will need to respond to unforseeables in the manufacturing environment. What if a circuit board is a slightly different shade of color, or heavier than spec, or damaged in some way never before encountered? A million *if . . . then* subroutines might keep the program from crashing until the 1,000,001th scenario occurs. And what an unwieldy program it would be. And yet, *that* is the hard AI approach.

Neural nets are championed by "connectionists," the opposing side in the debate. Nets work by means of parallel processing. They work by reducing electrical potentials in a circuit to a minimum. The outputs of one level of "neurons" becomes the inputs for the next. A "solution" is really just found in a line of code in a program. Code is too linear. Even parallel processing on digital computers is linear, in lots of simultaneous little packets.

Memory is not located in any specific location in the hardware, but is distributed throughout the net. Therefore, hardware damage is not fatal as it is in

digital computers. This is another advantage of nets over code. Damage part of a net and the rest takes over with no degradation in performance, within limits. But drop as little as one letter in a line of program code and, as you well know, the whole thing comes tumbling down.

The hard AI people say that that's all very nice, but that intelligence is really just a big program running in the "wet ware" CPU—the brain. Even though living neurons work together in a manner analogous to nets running on an analog computer, hard AI rejects the assertion that intelligence is an emergent property of brain tissue. They are convinced that intelligence, once decoded, can run on any kind of hardware—can be ported, so to speak, from brain to computer. They're not interested in the tedious study of living neural tissues, only in writing better code and sharpening their debugging skills.

However, I find it hard to believe that Terry Sejnowski's NETalk generated or operated from code as it learned to read aloud overnight. It accomplished this incredible feat using only a recording of children speaking and a transcript. It began by babbling nonsensically, as humans do, and progressed within hours to the point where it was able to pronounce correctly words that were not even in the recording and transcript.

In the quest to create artificial intelligence, as William Calvin has said, "It's no crime, in this game, to look at the cards."

Neural nets seem as odd and as too good to be true as cold fusion was, but neural nets *work*. Yet, the great debate rages hotly. A voice for reason calls for advances in marrying rule based and neural net computing, so one can compensate for the other's shortcomings. Rocky Balboa said it best; "I got gaps. She's got gaps. Together we fill gaps."

Perhaps this is what Lou Grinzo portrayed in "Human Factors."

But rather than having the net generate inflexible, unwieldy code, I would expect the net to let its digital partner handle things nets aren't good at, such as math, while the net stays in charge of areas it excels at, such as creativity, pattern recognition, judgment, eye/hand coordination. The net could utilize the output of the digital part as a resource to inform its judgment.

I'd love to hear the author's thoughts on all this.

I enjoy the magazine a lot. Keep up the good, thought-provoking work.

JOHN VESTER
10698 Valley View Drive
Rancho Cordova, CA 95670

The author replies. . . .

"Together we fill gaps," indeed. John Vester is basically correct in his comments about the computer I envisioned for "Human Factors." I believe that such a system would necessarily be a hybrid, using procedural programming and neural nets to their best advantage. The plain code, and there would be a lot of it in such a system, would be in charge of all the mundane, "physical" operations—opening and closing end-effectors, tracking the arms in three-space, etc., while the neural net would handle the higher, "logical" functions, such as pattern recognition, and redesigning and guiding the overall assembly sequence. The net would ultimately control the bot, operating it by calling the code segments like subroutines. The architecture of such a system will likely be more complex than a mere call interface, however; programmers will need logical hooks, pieces of code that act as inputs to the neural net, that can easily be used to modify the system's behavior during development and

testing. In other words, they'll need a way to fiddle with the system. (Is my professional background showing yet?) This mechanism appears near the end of "Human Factors," when Phil disables the bot's load-balancing goal.

Finally, Mr. Vester is right about neural nets. They *are* almost too good to be true, and I suspect they will lead to some dramatic advancements in the near future.

LOU GRINZO

Dear Dr. Schmidt;

I envy Harry Stine. I thought I knew all the tricks for making statistics look the way I want—select the right base years, use the most favorable definitions of income, and so on—but he has me hopelessly outclassed. In the February 1992 *Analog* he has the cost of a new car as a percent of annual income being more than four and a half times as much now as 20 years ago.

The best I can do, using the *1971 Statistical Abstract of the United States,* is to take average hourly earnings in current dollars from Table 674: $3.23 in 1970, $9.66 in 1989; multiply by 2000 to get yearly income; and take average expenditure per new car from Table 1051: $3,542 in 1970, $15,403 in 1989. This is an increase from 55% to 80% of annual income.

But all this does is agree with my memories that buying a new car was as serious a decision in 1970 as it is now. What good are statistics if all they do is confirm what we know already? So can you get Harry Stine to let me in on his secret? It might come in handy sometime.

MICHAEL BUTTERWORTH
Tolland, CT

The author replies. . . .

I stand by my numbers. They were US Department of Commerce numbers, and I got them out of an issue of *The Wall Street Journal,* date not recalled because it was last year some time. (I already have quite enough paper stored away in file boxes, thank you, so I can't save everything!) They didn't seem out of line to me. The last time I bought a new car was in 1973, and I paid 21.25% of my annual salary at that time for the vehicle (which I still drive). And I didn't want to pick an argument with the US Department of Commerce because they have outstanding data bases!

Today, a favorite ploy used in attacking someone whose conclusions are not agreeable is not to pick an argument and debate it on logical or philosophical grounds. One attacks the data! I see this used all the time in scientific journals and have watched the process in use at scientific meetings, too. John W. Campbell, Jr. taught me a variation of the procedure 30 years ago: Never accept the initial premise of a person's logical argument. Maybe I ought to do a column on this subject!

Actually, I really don't care if readers agree with me or not. My job in writing the column is far more difficult. It is to get them to think in perhaps a different way than usual! (Yes, I enjoy being a hair shirt.)

G. HARRY STINE

Dear Dr. Schmidt:

Your editorial on AIDS, "The Right to Hide Arms," (Feb. 1992) was right on the button. Medical personnel *must* know if patients are HIV positive. Equally, patients must know if medical personnel who will perform invasive procedures are HIV positive.

I see the problem from two aspects. I am a dentist as well as a state senator and chairman of the New Jersey Senate Commerce Committee. A large part of the problem is that too many of my fel-

low elected officials see votes to be had by treating AIDS as a civil rights problem, rather than as a disease. Until we drop the political posturing, both medical personnel and patients are in danger.

As a dentist, I am constantly in situations that could involve exchanging body fluids with patients. My staff and I wear protective gear. How tiny a hole or how small a tear would it take for an infected employee to unknowingly condemn a patient to death?

I have stated publicly that, if I were to become infected, I would stop practicing dentistry. That's not a personally acceptable solution for some of my colleagues. For that reason, I am supporting legislation that would require periodic testing of medical personnel and reporting to patients (and vice versa) before invasive procedures are performed.

You can guess the opposition this legislation has received. Besides the privacy issue you discussed, we are bombarded with the "there's only a few" argument. In a recent debate with an ACLU executive, I was finally able to get him to admit the estimated number of infected medical personnel. One of my aides said you could see a shock wave pass through the audience of high school students.

It is time to stop hiding. Unless everyone is willing to strip AIDS of its emotional trappings and approach it rationally as the scientific and medical problem it is, we have no right to claim we are protecting anyone's rights.

SENATOR GERALD CARDINALE

Cresskill, NJ

Dear Mr. Schmidt:

Your editorial "The Right to Hide Arms" reminds me that in my youth (1930s) when anyone living in a house where someone had a communicable disease was reported the fact to the school, which reported it to the city public health nurse, who came to the house and attached a placard to the door showing the name of the disease. I never knew anyone to question that knowing that the disease was present in that house was the right of every individual passing by to promote public health.

Where in the world did we get the idea that it is anyone's right to conceal a transmissible infection?

I don't necessarily suggest that we should go back to signs, but I thoroughly agree with your remarks. As an aside, if someone's door had a notice with one of the common childhood diseases such as mumps or chicken pox or rubella, some mothers reacted by sending their children over to play in hopes that they would get it and become immune before they became adults. There was nothing compulsory about your reaction to the information on the placard.

ALLAN B. WHEELER

Milwaukee, WI

Stan,

Although I substantially agree with your thesis that Americans are apt to seize upon one particular right and pursue it without regard to the other rights it conflicts with (part-and-parcel of a "30-second-TV-spot" and "One minute manager" attitude which pretends all problems can be stated *and* solved within the space of a music video) . . . I do have a quibble about the particular example you chose.

I've enclosed a copy of an article from JAMA (and two from our local papers) which says that nearly one-third of primary care physicians surveyed do not feel obligated to treat AIDS patients, and fully half would not if given a choice.

These are physicians . . . I shudder

to think what the percentages would be among the various non-professionals under the umbrella term "health care workers."

The particular right being protected, it seems, is not the patient's right to privacy—but the patient's right to receive medical care at all.

That's rather a different equation.

DON SAKERS

I had already heard of this study (though obviously not before I wrote the editorial, with our six-month lead time), but had not yet seen the full original text. I agree that the study turned up an alarmingly high incidence of deplorable attitudes, and something needs to be done about that as quickly as possible.

However, I don't think that the kind of practice I described in my essay is the right thing to do about it. In fact, it may well be counterproductive. Workers who already have unreasonable negative attitudes toward AIDS patients are likely to become even more negative if they are not only expected to treat them, but to do so while having medically important information systematically withheld from them.

What's needed is a lot of reeducation to make sure doctors and other health care workers (many of whom would resent being called "non-professionals") understand and accept their obligation to treat everybody who needs it. AIDS should be treated, in other words, like any other disease of comparable danger. But that has to include providing the people working with it with the same precautions and protections they would have with any other disease.

Dear Editors:

I have never written to *Astounding/Analog* in all the approximately 45 years I have read the magazine. However, I would like to compliment you on a generally high level of output. There were some years that I almost canceled my subscription but Dr. Schmidt has renewed my faith in your output.

Since my copies prior to 1967 went astray during the years spent in Saudi Arabia, my current collection only goes back to that year. However, I still get a great deal of pleasure in going back to reread stories in the older issues I have available.

It is particularly fascinating, in view of the current information explosion, to go back and review the various author's extrapolations from as little as 15 years ago. I write this letter on a screen using "Wordperfect for Windows" and will print it using a laser printer. Using my undergraduate degree as a base date (1954), it would have been entirely impossible to even visualize this technology.

At any rate, thank you for a great deal of pleasure as well as intense thought about the future history of mankind.

R.A. WEHNAU

Mill Valley, CA ■

ISAAC ASIMOV
1920–1992

Isaac Asimov, preeminent writer of science fiction and just about everything else, died April 6, 1992, of heart and kidney failure. He was 72. A memorial service on April 22 at the Society for Ethical Culture in New York City was attended by several hundred friends.

Born in Russia and brought to America by his parents at the age of three, Isaac grew up in Brooklyn and developed a fascination with science fiction in his teens. His talent was early recognized by John W. Campbell, editor of this magazine when it was called *Astounding.* Though his first published story appeared elsewhere a few months earlier, Isaac himself considered his career "really" begun with publication here in 1939 of "Trends," a short story that seems more prophetic now than it did then. "Nightfall" established him as an undeniably major writer a mere two years later. Over the ensuing decades he was one of the most prolific and popular contributors to these pages, noted especially for his *Foundation* and robot stories.

His work later expanded to most of the other science fiction magazines and a large number of novels. After leaving a faculty position as a biochemist at Boston University (though he retained his title), he became one of the best and surely the most prolific writer of popular science *fact.* His total body of writing included almost 500 books and a vast number of stories and articles on virtually every imaginable subject. He wrote a regular science fact column for *The Magazine of Fantasy and Science Fiction* that appeared in almost 400 issues, and lent his name, editorials, advice, and support to our sibling magazine, *Isaac Asimov's Science Fiction Magazine.* He won numerous awards for both fiction and nonfiction writing, including multiple Hugos and Nebulas for individual stories and a Grand Master Nebula in 1985.

He is survived by his wife, author and psychiatrist Janet O. Jeppson, daughter Robyn, son David, brother Stanley and sister Marcia. Many have lamented that there will be no more Asimov writing (except the several books already in production), but we have already had far more of that than we had any right to expect. What we who knew him will miss most is Isaac himself: a brilliant, rational, clear-thinking, straightforward, decent, ebullient, and convivial man who enjoyed the Universe immensely and helped everyone he touched, in person or through his writing, do the same.

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a calendar of analog upcoming events

2-4 October
ROVACON 17 (Tidewater multi-media SF conference) at Arborgate Inn and Salem Civic Center, Salem, Va. Guest of Honor—Marion Zimmer Bradley; Art Guest of Honor—Mary Hanson Roberts; Media Guest of Honor—George Takei; TM—Deanna Lund. Registration—$15 until 15 September, $20 at the door. Info: RoVaCon, Box 117, Salem VA 24153. (703) 389-9400.

2-4 October
CONTEXT 5 (Central Ohio SF conference) at Hilton Inn North, Columbus, Ohio. Guest of Honor—George Alec Effinger; Editor Guest of Honor—Martin H. Greenberg; Special Guest—Joan Slonczewski. Registration—$30 until 15 September, $35 at the door. Info: Context 5, Box 2954, Columbus OH 43216. (614) 889-0436.

2-4 October
CON-CHORD 8 (Southern California filk convention) at Holiday Inn-LAX, Los Angeles, Calif. Guest of Honor—Tom Smith; TM—Joe Bethancourt. Includes kazoos. Registration—$30 until 8 September, higher thereafter. $10 supporting. Info: Con-Chord 8, % Rick Weiss, 13261 Donegal Dr., Garden Grove CA 92644-2304. (714) 530-3546 [before 10pm PT].

2-4 October
SPACE '92 International Space Projects, a two-day seminar sponsored by the British Interplanetary Society at White Rock Theatre, Hastings. Info from the Executive Secretary, BIS, 27/29 South Lambeth Road, London SW8 1SZ, England, UK. Enclose a SASE (A4 size with 50p or 2 International Reply Coupons).

9-11 October
ARMADILLOCON 14 (Central Texas SF conference) at Wyndham Austin at Southpark Hotel, Austin, Tex. Guest of Honor—Neal Barrett, Jr.; Artist Guest—Darrell K. Sweet; Fan Guest—Al Jackson; Editor Guest—Gardner Dozois; TM—Kim Stanley Robinson. Registration—$25 until 30 September. Info: Box 9612, Austin TX 78766-9612. (512) 453-2199 [before 10pm CT].

16-18 October
8th Annual Midwest Space Development Conference at Holiday Inn, Worthington, Ohio. Friday night—Star Party; Saturday banquet—NASA speakers; Sunday tour—"Big Ear" radio telescope. Registration—$50 in advance, $55 at the door. Info: Box 261592, Columbus OH 43226. (614) 548-7743 (Benny Shoults).

29 October-1 November
WORLD FANTASY CONVENTION at Callaway Gardens, Pine Mountain, Ga. Guests: Anne McCaffrey, Michael Bishop, John Farris, Martin H. Greenberg. Limited membership. Registration—$100 in advance: NO at-door memberships. Info: World Fantasy Convention 92, Box 148, Clarkston GA 30021. (include SASE).

2-6 September 1993
CONFRANCISCO (51st World Science Fiction Convention) at Parc 55, ANA Hotels, Moskone Centre, San Francisco, Calif. Guest of Honor—Larry Niven; Artist Guest of Honor—Alicia Austin; Fan Guests of Honor—Tom Digby and jan howard finder; MC—Guy Gavriel Kay. Registration—$85 adult/$30 child until 30 September 1992, Supporting—$25. This is the SF universe's annual get-together. Professionals and readers from all over the world will be in attendance. Talks, panels, films, fancy dress competition—the works. Join now and get to nominate and vote for the Hugo Awards and the John W. Campbell Award for Best New Writer. Info: 712 Bancroft Rd, #1993, Walnut Creek CA 94598. (510) 945-1993. CompuServe 72377,3623.

—Anthony Lewis

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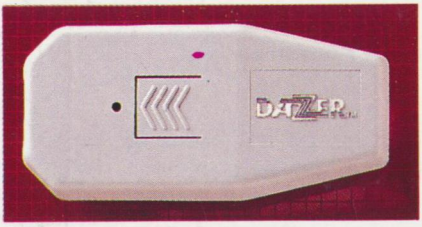

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