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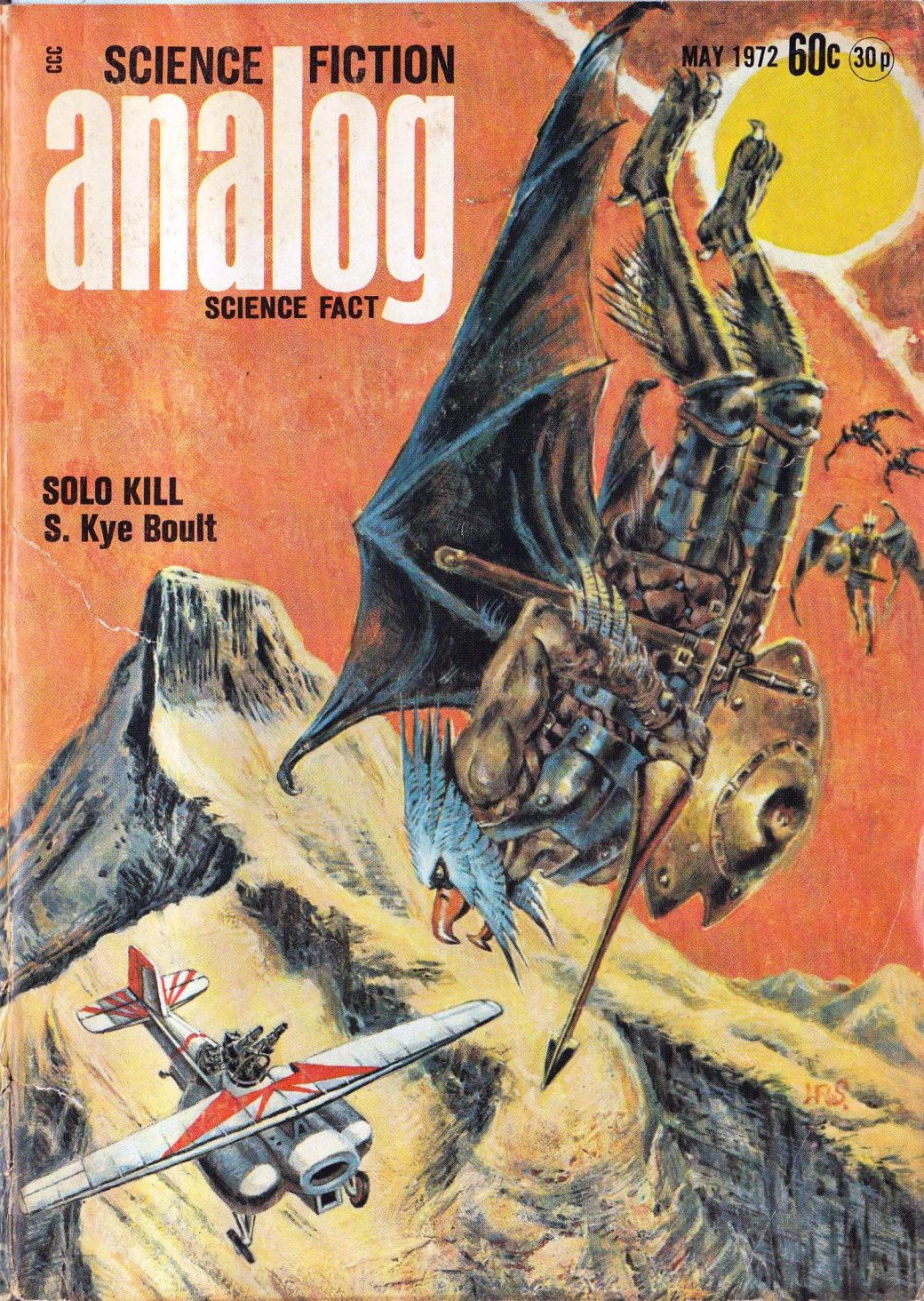

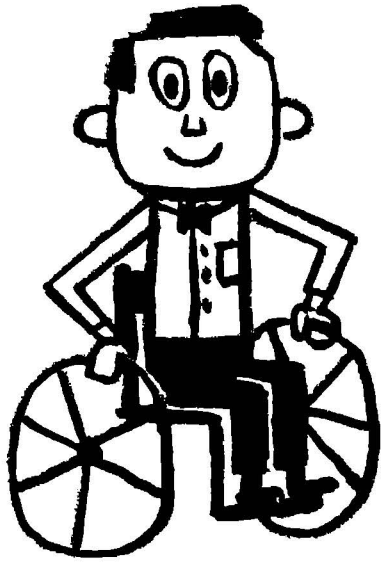

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Next Issue On Sale May 9, 1972
$6.00 per year in the U.S.A.
60 cents per copy
Cover by Leo Summers

analog
SCIENCE FICTION | SCIENCE FACT

Vol. LXXXIX, No. 4 / May 1972

Editorial and Advertising offices: 420 Lexington Avenue, New York, N. Y. 10017

Subscriptions: Analog Science Fiction/Science Fact, Box 5205, Boulder Colorado 80302

editorial

life cycles

This is being written during the last week of the year, in the depths of winter, to be read in the spring. Right now there is snow on the ground and a freezing wind races beneath a dead sky. Yet it takes no psionic powers of foresight to know that in the spring the world will be turning warm and green again.

Every year, in the so-called Temperate latitudes, the world goes through a cycle of death and rebirth. Perhaps the tilt of our planet's axis has much to do with our outlook on life. Perhaps it's shaped our attitudes about the life cycle of birth, death, and rebirth.

Ideas go through life cycles, and so do scientific theories. All of human activity seems subject to the cycle of birth and death . . . and sometimes rebirth.

The concept of life existing elsewhere in the universe has gone through many such cycles. For most of human history, many, many people firmly believed that Earth was the center of all creation, and Man was the purpose of it all. There was no concept of life on other worlds, because there were no other worlds, in that view. Yet even then, people believed that the heavens were the dwelling places of nonhuman entities: gods, angels and such.

In our own century, the question of life on other worlds has moved from religious to scientific argument. Not that the scientists are able to define exactly what life is; after all, the only samples they have—so far—come from our one little planet. So they are forced to speculate about life *as we know it.* The chances are, of course, that life on other worlds—or between them—will be very much unlike our own.

. So we've begun to search the Moon for life as we know it, even though no one seriously expects to find anything even vaguely alive there. Yet evidence for water has been detected by the SIDE instruments left by the Apollo 12 and 14 astronauts. And a team of biochemists has announced that the lunar soil samples they examined contain organic material—long-chain carbon molecules. Not life. Not even pre-life. But the basic building material is there.

The Mariner 9 and Russian Mars probes have so far returned no new information on the possibilities of life on the Red Planet, as of this writing. Indications are that the famous *canali* are illusory, that Mars' atmosphere is almost pure carbon dioxide and thinner than Earth's stratosphere, that liquid water can't exist on Mars' surface. But there are still the color changes each Martian season, and recent radio telescope findings have led Carl Sagan and his Cornell University colleagues to conjecture that there might be liquid water in the soil of Mars, a few centimeters under the surface. What if the canals are underground? What if the dark patches of "oases" which link up to form the optical illusion of straight lines in our telescopes, are really patches of vegetation fed by underground waterworks? Fantastic, yes . . . and yet . . .

George Gaylord Simpson, the eminent Harvard biologist, once twitted NASA for setting up a group of scientists to study exobiology: the biology of extraterrestrial life forms. Simpson remarked that it was the first time a scientific discipline had been established before anyone had found proof of its subject matter.

Well maybe.

But look at some of the evidence. In the late 1930s astronomers at the Mount Wilson Observatory found that simple two-atom molecules such as the basic hydrocarbon, CH, and cyanogen, CN, exist in interstellar space. Their technique was based on measuring the absorption of light from several bright blue giant stars in the wavelengths of the "near ultraviolet" region of the spectrum, the part of the UV that squeaks through our atmosphere's ozone shield and suntans us.

An interesting find. Up to that time, it was more or less assumed that interstellar space could hold only hydrogen and perhaps some helium—and precious little of either. Finding carbon-based molecules was unexpected.

A quarter century later, in 1963, radio astronomers began to find signals that correspond to the radio frequency "signature" of another diatomic molecule: OH, the hydroxyl radical, two-thirds of water. The OH signals were—are—coming from regions of the sky that are thick with interstellar gas clouds, cosmic dust and very young stars.

continued on page 174

OOBE'S DOCUMENTED!

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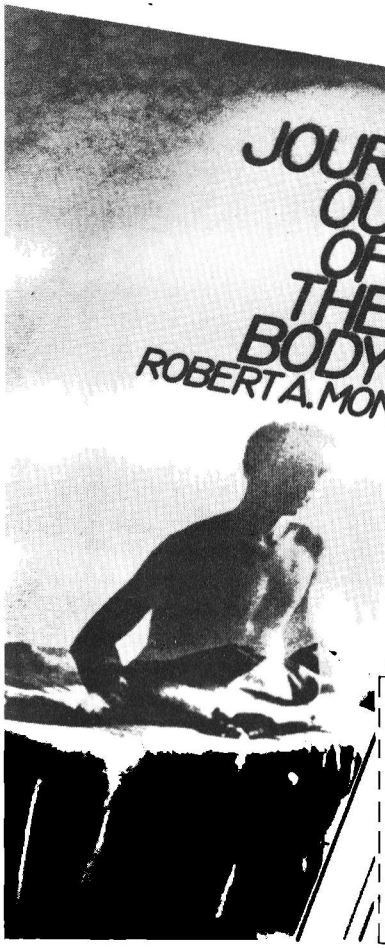

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solo kill

S. KYE BOULT

Competing species may battle each other until one of them is driven into extinction. An intelligent species can speed the process—but pays a cost of guilt.


LEO SUMMERS

Amarson was kneeling in the meadow, waiting for the Drak to attack. The wide sleeves of his ceremonial costume weighed at his arms and shoulders. His eye and ears were bound by a jeweled helmet. He was all alone—waiting.

The costume was a fake. His chest and torso were bare, the wide sleeves were slit to free his arms, and the helmet would fly off with a flick of his head. The costume was bait, magnifying his solitary position here in the meadow, far from the trees at the jungle's edge.

He clenched his hands to control his nerves and felt his claws run out against the grass. He cleared his lips back away from his teeth to put a fighting grin on his long jaws. The costume was bait, and so was the picture of his unarmed helplessness.

In the sky, high above the edge of the meadow, the three Draks changed their flight from a straight flyway course to circle. One of them began to spiral down. The trap was set, baited and about to be sprung.

The Drak flapped its long wings and slowed its spiral. The red glow of the rising Father Sun shone from its armor and turned the skin of the heavy-muscled wings purple when they beat in an upstroke. The Drak was being cautious, but it was coming down the sky. Amarson's helpless posture, alone in the meadow, had lured it out of a hunting sweep. Soon the bait would become too inviting and the Drak would dive down for a solo kill. The slowly beating wings carried the Drak out of Amarson's sight behind his back. He held his position, motionless. The Drak would not attack from back there. The yellow Younger Sun was up in front of Amarson, to his right, almost at the point where it poised in the sky. With both suns low in the morning sky, the Drak would dive out of the light of the yellow sun. Amarson was facing in that direction.

The Drak wheeled back into the helmet's line of sight. The yellow sunlight caught the point of his hunting spear with a flash of brilliance. The Drak was a flying hunter. He flew on his own wings; long-muscled wings of furless skin. He used the spear as a thrusting weapon when he dived.

The spear was one of the weapons Amarson had to face; the spear and the Drak's own fierce beak. The beak was curved and thick for tearing flesh: the hunting spear was one meter of triangular metal blade and a short half-meter shaft. The Drak used both to kill the animals it hunted for food.

Amarson was one of those *animals* the Drak considered food. He ran his claws out again at the thought.

The Rivermen, in their city, and the Valley People, in their safe, crop-filled fields, have forgotten this fear; his thoughts ran quickly. They have been safe too long. By the Ancient Compact we have kept the Draks out on the Jungle Marches with our air and jungle patrols, while they, the

town dwellers, have forgotten fear. They should send men out here, so that they could learn to be food again. Then there would be new fliers for my cubs to use—to carry killing into the air and death to the Draks.

Amarson snarled at the thought. He should be leading his fliers from Base XII against these Draks in the air, not kneeling on the ground in an open meadow. But someone had revived an old ritual and used it against him. Someone who knew that Amarson fostered the old prayers and rituals at his Base.

The Drak turned in the yellow sun and began its dive. Amarson started the fighting chant. The rapid guttural cries brought his blood pressure up and quickened his nerve speed, but he held himself still; kneeling in apparent helplessness as the Drak fell toward him.

At the last second, the Drak's wings snapped open, spread wide to brake its dive.

Timed by the flap of the wings, Amarson straightened his legs and jumped straight up at the Drak. His voice yelled the combat cry that mingled with the scream of the Drak.

One hand batted the Drak's tearing beak aside and the other struck at the Drak's throat. His claws ripped and tore.

Amarson threw his weight sideways and down, pulling the Drak over on one wing, pinning the wing and the spear arm beneath him as he jerked the Drak to the ground.

The one free wing beat and whipped across his back as he drove his knees into the Drak's body and crushed it to the meadow. The wing struck him again, and again, then snapped back against the grass and was still.

The Drak was dead.

Amarson's reflexes began to come down from their peak. The helmet was gone, but the costume robe had protected his back. He had hardly felt the wing blows. There was a hot burning pain in his right leg. The spear had hit him! A sense of wet blood came through to him. He started controlling the skin and muscles in his hurt leg to stop the bleeding. The blood on his hands— No pain there. That was Drak blood. Hah! *Blood only stains the hands!*

The Drak was still beneath him. He realized that he was kneeling on its body holding the beak closed in one hand, while the other hand was at the Drak's throat. The throat was gone, shredded by the fighting sweeps of Amarson's claws.

The Drak was dead.

He felt a movement of bodies near him and reared backward, his right hand arcing to strike.

"Baron!" The Jungle Patrolman yelled once. He took Amarson's blow on a leather-covered forearm with a grunt. He caught the blow precisely, as if he had expected it, then he simply held Amarson's arm and waited for the fighting passion to pass.

Amarson saw the Patrolman as he started his blow and retracted his claws at once. The blow landed with only an open-wide hand and Amarson's rolling weight behind it. Amarson heard the grunt and gripped the friendly, solid arm tightly as he struggled to control his heartbeat and nerve speed down to normal.

A roar of flier engines filled the meadow and two of Base XII's standby fliers swept over the trees. One slid into a low turn and began to circle the meadow protectively. The second lifted and headed into the yellow sun, climbing vertically on combat power.

"Can you walk, Baron?" the senior Patrolman asked. "He's going up after the other two Draks. The spent darts will start coming down soon."

Amarson threw his head back and caught the gleam of Drak weapons. High in the air, the two Draks had circled to dive out of the sun. They had been unable to break their hunting habit. This time the habit meant death.

The flier was climbing to intercept them before they could dive. There! He was firing his darts, right overhead . . .

"Darts!" Amarson choked, his breath still gasping. He lurched to his feet and began to run. A wild, hot pain cramped his right hip and his leg gave way after three steps.

A Patrolman was at his side, the senior Patrolman still supported his left arm, and between the two of them they half carried Amarson to the forest edge without a pause. They had undercut a bank into a command post dugout, and they hurried Amarson into the protective cover. The three other Patrolmen stumbled up, carrying the body of the Drak and dumped it on the ground. They faded away to right and left in the jungle.

The falling darts arrived. Dropping spent from the flier's dart launcher, they covered a wide area on the ground.

The *swak* and *thunk* when they hit the meadow was like rain, then they tore through the leaves and branches above the dugout and bits of forest drifted down. The whole thing lasted less than a hundred heartbeats and impressed Amarson with its impersonal deadliness.

"That's the end of it," the senior Patrolman announced. "Here come the fliers back."

The two fliers slanted down low across the meadow and the leader blipped his engine.

"Mardon, give him a flare," the senior Patrolman called. "Then check out the meadow."

A flare blazed up out of the trees.

"That tells them you made your kill and are alive, sir." The senior Patrolman turned to Amarson and held out a metal bottle. "Better have a drink. It's Valley *frooge* and not very old, but drink it anyway. My thought is: it's got power. I want to look at your leg." He began untying the panels and skirt of the costume.

"While I'm doing this, you can tell me why my squad is risking their lives protecting a Baron Flight Commander while he plays cub tricks in the jungle. You command Base XII, don't you? Can't you find enough Draks to kill in the air?"

"I crashed my flier in the mud sea, last patrol, and walked home. Somebody decided I was *Inhacru*, a Warrior-who-has-lost-his-weapons. Somebody with more knowledge of the ancient rituals than is good for him; or me."

"The Warrior's Code?" the senior Patrolman asked. "My thought is: we were more modern than that. You should find your, 'somebody', and tell him to sleep with his claws out."

"I suspect *he* is a Riverman. The orders came from there."

"And there is no honor in killing a Riverman!" the senior Patrolman grinned. "They pay us, by the Compact, to guard their Marches and keep them safe. My thought is: they don't pay for killing Draks one at a time."

"There was support for the *Code* in our own people, Senior . . ." Amarson drank from the bottle. "Superstitions die hard.

"Base XII was grounded; not allowed to fight, until I had regained my, 'battle honor.' "

"Well, you've done that and with a wound to cap it. Nice work, too. I've never seen anyone move so fast. Glad I saw it. My thought is: it's good to know you can kill a Drak with your claws if it gets close. Fine thing to know.

"I'm going to have to cut this uniform.

"Not much blood, it can't be too bad. Ah, no, just a clean graze on the inside leg muscle. Any pain?"

"Not much," Amarson gasped. The two swallows of *frooge* made speaking difficult. *Aaargh,* it was hard to breath.

"My leg . . . just wouldn't work . . . folded up.

"*Aiyha!* I can feel your fingers, Senior. If you want to cut the leg open use a knife, not your thumb. Or let me finish this bottle and you can use a dull rock. Power, aha!"

"No need, Baron." The senior Patrolman laughed and took back his bottle. "You have the bleeding stopped. The Drak lance must have gone between your legs. The cut is small and clean. Your fold up was shock, my thought is, and drop out of battle tension. It's no big thing.

"Try moving the leg."

Patrolman Mardon stuck his head in the dugout.

"The meadow is clear," he said. "Lots of *frooge* tonight. We each got a double handful of darts." He held up a bundle of the small metal missiles from the flier's launcher. "A real good day. How is the Baron?"

"Bring in your aid kit: Leg wound," the senior Patrolman ordered.

The Patrolman slid into the command post and looked at Amarson's

leg. "Hm-m-m," he said, professionally. He shoved the bundle of darts into his kit with one hand and brought out a field dressing with the other.

"A real hero's wound, sir." He began to apply the bandage. "No blood, no call for surgeons, and you'll be able to limp with honor and dignity. Best of all the only time you can show such a wound is in bed with a woman.

"And a woman who will want to look at a wound, there. . . Why she will. . . Ahh, me, she certainly will."

"That's where the hero part comes in, obviously," Amarson joined the banter. The *frooge* was warming his tongue.

"You talk too much, Mardon," the senior Patrolman said. "Snap it up, or I'll give *you* a wound."

"All done. Ready to move. Do you want trophies, Baron? Head or wings?" Mardon pulled a wicked skinning knife.

"Neither, Patrolman," Amarson's voice became curt. "We take the whole body.

"The Riverman ambassador has requested a fresh killed Drak brought to him. I don't know what he wants it for, but he gets this one."

"Calm down, Mard," the senior Patrolman said. "You've got enough darts to keep you drunk for a week. Don't be greedy.

"Get out there and put some poles under that Drak so we can carry it fast and quietly. We go as soon as the baron wants to walk."

"You trade darts for liquor?" Amarson stood up, half crouched in the dugout. His leg seemed to want to work.

"That weapon is brand-new, not more than ten fliers carry the launchers. How could a trade develop so fast? What do the Valley People want with launcher darts?"

"Your *pilots* buy them back, Baron. They say it brings them good luck. Maybe? My thought is: that any chance of having your fliers run a pack fight over a ground patrol, and anybody not getting hit by the spent darts, or attacked by Draks; then finding a bitty dart. . . Well, my thought is: the luck is all on our side."

"All ready, Senior," Mardon reported promptly. "The patrol is already formed."

"We should go, Baron." The senior Patrolman backed out of the dugout. "We are still ten kilos outside our perimeter, and this is a Drak flyway."

"I can walk, Senior." Amarson came out of the dugout and demonstrated, to himself as much as the patrol.

"Mardon, out and front!" the senior Patrolman ordered. "Let's move that Drak out of here!"

Mardon moved past Amarson and handed him the short Drak lance. The jungle patrol closed up around Amarson and he recognized that he was still being protected. Only the bright grin and the shine in Mardon's eyes when he passed the spear,

told the change in the character of the protection.

Mardon had remembered the reason for the ritual killing in the meadow. Mardon had closed the ritual and given him back his honor and a weapon. A warrior's weapon, captured by killing.

Amarson carried his honor and followed the patrol into the jungle.

The next morning, Amarson's Second Commander woke him.

"Draks, Baron!" he said, shaking the bed. "Wake up! Draks!"

The words snapped Amarson up out of bed, standing. Then he realized the sound of the alarm bell was missing and sat back down on the bed. His eye caught the empty bottle of *frooge* on the floor. He kicked it sourly and growled away the sickness in his head and mouth.

"*Aarrgh*! That's a dangerous way to wake me, Mitch."

"I had to, Baron. I meant it. The Draks are here. A giant mating swarm. Over the field and as far south as we can see. I've canceled all operations. We've forted up. SOP."

"What!" Amarson was awake, now. He struggled into his uniform and headed for the outside door.

"Not that way!" Mitch stopped him. "The Draks will strike at anything moving on the ground. Come inside, to the ops. room. You can see across the field from there."

"Go! I'm right behind you. Run!"

The two went out the corridor from Amarson's quarters and up the stairs to the windowed operations office. Inside the operations room, Amarson slowed to a walk and began to put on his shirt absently. His eyes were focused out the window.

"They came in just as the Father Sun rose," Mitch said. "The Chief Groundsman held the morning patrol. He got two fliers in the big hangar and shut up the base. Damn good man. But he's seen that before, I expect."

"That" was the sky over Base XII. It, the sky, was filled with Draks, hundreds of them. Amarson, literally couldn't see across the field. They were not screaming, fighting Draks, the kind he was used to seeing. These moved slowly through the air, barely flapping their wings to gain height. They drifted and glided into wide spiral patterns and flew around and around.

Suddenly, with no reason, a single Drak would fold its wings and strike at the ground, recover, and beat clumsily back up to where he could join a spiral again.

The Draks, all of them, moved sightlessly, trancelike, through the air; not seeming to avoid one another, but never touching.

"Both males and females," Mitch said. "I've only seen them swarm like this twice before, myself—and that was way south, on the mountain shoulder . . . but never so many."

"How many?"

"No way to guess. Thousands at least," Mitch said. He handed his baron a warm drink. "Breakfast be-

hind you, when you want it, Baron. I launched one combat flier from inside the big hangar,—catapult. He had orders to scout the edge of the swarm and see how big it is. Aahh! It was weird to watch him fly through that—" He pointed outside. "None of them touched him, or noticed him. They just got out of his way."

"As long as he's in the air with them," Amarson said nodding. "Be absolutely sure you brief anyone else who flies. Don't fire on them. If they think they are menaced, they will mob the flier. They have females to protect and there are just too many. Live and let live while the swarm lasts; even if we don't like the idea."

"Of course, anything else is suicide," Mitch agreed.

"The groundsmen are working with a covered truck to get ropes on the fliers out by the tents and pull them over to the big hangar. We can launch them two at a time, from there, but I can't crowd the hangar floor."

"Right. That's our only landing field. Better get the crash crews doubled up. If anybody misses a landing, they'll have to clear away fast."

"Understand." Mitch nodded. "We've already taken one flier in."

"What? Who?"

"A courier. He came in from Base III. We flagged him into the hangar before he could make the mistake of landing and trying to taxi. He made a good landing, but he's got the shakes. Too many Draks.

"He brought in a written order for you. You are ordered to Riverton: Conference with Ambassador Theiu."

Amarson picked up the order form Mitch indicated and read it.

"New weapons, heh? Most personal contact; and urgent. Do you suppose they knew about that. . ." he waved at the window.

"I don't see how," Mitch said. "I've had your flier spotted on the catapult. Do you want it called down?"

"No. I'll go. You aren't in any danger here. All those Draks make you want to climb a tree, but they aren't dangerous if you take proper precautions.

"I'd double up the scout patrol, though, and keep everybody under cover. Don't let them shoot, just keep them out of sight."

"Sightseers *will* be a headache."

"They'll get killed if a Drak sees them," Amarson growled. "They do strike at the ground while they are swarming; they're not all that safe.

"This spiraling should go on all day, maybe into the night . . . and they will be back tomorrow. Two days, then they will all go to ground to mate. *That* they will do in the hills—higher up.

"Two days, I'll be back before that."

The flight to Riverton was not long, but at the end of it he had to come down and fly in among the circling Draks again. It was an eerie feeling to lose height into that mass

of deadly wings; to have a full armed hunter match course and height with him; to fly wingtip to flapping wingtip with a Drak that was not screaming to kill.

They ignored him as they had done when he climbed away from Base XII. They flew lazily out of his path and ignored him.

But, he was conscious of the killing power of those beaks and weapons. The wound in his leg tightened and ached whenever the sunlight glinted from one of the hunting spears.

Amarson eased his grip on the controls and flew lower across Riverton. Some of the streets he could see below had covered walkways. A hasty plank structure had been thrown up on the waterspray system the Rivermen used for comfort in their town. How? Who? A Drak swarm like this was new to Riverton. They couldn't have seen one—since before the Ancient Compact. . . Oh, of course, Jungle Patrolmen. On duty in Riverton, they would have spread the word. . . organized. . .

He circled the converted rivership yard that Theiu called his *weapons factory,* to find it deserted. The two buildings and the open yard where the fliers were built were closed and locked. They had no protective cover for the workers. With the Drak swarming, the factory had to be shut down.

A flag waved at him from the big hangar, signaling him in to land. It was the wrong sort of signal, but the Rivermen's intent was clear. The doors of the hangar began to slide open and the flag waver signaled frantically.

Amarson threaded his way around a spiraling formation of Draks and dropped down to line up with the hangar. He took his flier down steeply, rolled it out and held the nose high to kill his speed. He flew with one hand, the other he held near his fighting knife. The Draks were leaving him alone in the air, but as he tried to land, one of them might rush him. If he was attacked his knife was his only weapon, this close to the ground.

The ground came up to meet him. He held the flier off the field until just before he got to the big hangar doors. He touched down right in front of the doors and flashed inside; completing his landing roll down the center of the long hangar.

As he went by the door threshold, he caught a glimpse of two Jungle Patrolmen manning a dart-thrower installation. They were guarding the door in case a Drak followed him into the hangar. Theiu was well organized.

Amarson completed his landing, still inside the hangar. He had managed to slow his flight enough in the air before touchdown, so that his rollout was short. He cut off his engine and heard the big hangar doors slide shut behind him.

A Riverman fire patrol came up with parking blocks. They explained that the shutdown was more to let

everybody work the riverfish harvest than the Drak swarm.

"We were expecting you, Baron," the leader said. "Ambassador Theiu left a direction plaque to his hunting boat at the docks. We will look after your flier."

Amarson took the hand-size square of wood and checked the map printed on it. The factory was not far from the river, he'd seen that from the air, so the directions were brief and simple. Amarson allowed himself to be conducted to the factory gate and set off to the docks. The walk took only a few minutes. The direction plaque kept him on covered walkways all the way, so he was in no danger. The Draks were only black shadows gliding on the street and buildings.

The fire leader had said that Theiu was down at the docks with the fishing fleet, but he hadn't said anything about the ceremony.

Fifty or sixty boats crowded the finger piers under the spreading dock sheds. The dock area had been roofed against Drak hunting parties early in the post-Compact period and the fishing docks were the safest place in Riverton during this swarm. To Amarson's eyes it seemed that all of Riverton was here, under the shed.

As he watched four of the hunting boats left the tip of the finger piers and slid out into the water. They sank as they went out, so that they were submerged by the time they cleared the protective roof. Another group of five boats were cast loose, with much singing, chanting and movement, and maneuvered slowly toward the deeper water.

Amarson watched them submerge and wondered how he was going to find Theiu in all this. He was not used to seeing Rivermen, didn't see enough of them, to be able to pick Theiu out of a crowd.

He went over to the nearest boat, where a Riverman was sitting on the low deck with his feet in the water.

"I am looking for Theiu, the Ambassador to the Jungle Marchlands," he called. "Do you know where I can find him?"

"Theiu? Ah, yes." The Riverman was a little startled by Amarson's size. He picked up a handful of water and poured it over his head, nervously. "Yes, I know him. His boat is just down the float. Three fingers that way." He pointed.

"Thank you," Amarson said. "Will these floats hold my weight? I would not want to damage the dock."

"They will hold you. We bring our fish cargo up on them."

Amarson nodded and went down onto the float and along to the finger piers. The floats had a movement of their own under his feet and he was a little uncomfortable. He evidently made the Rivermen uneasy too, for they moved away from him and quickly left any dock float he was standing on.

Theiu saw him coming and saved him the need of further questions by

jumping off the deck of a boat and coming down the finger to meet him.

"Baron Amarson," the Riverman called. "This way. Come see my boat. The dock out here is private. The townspeople will leave you alone, out here."

Theiu's words were strange. Amarson turned back to look at the crowd. In his anxiety over the swaying dock, he had missed the look on their faces; missed the reason they had avoided him. They were angry. His fighting instincts now, felt the hate and anger; smelled the fear in the crowd. The hair on his head stiffened and his ears erected alertly.

"This way. This way," Theiu said. "You got here just in time."

Amarson followed the Riverman down the dock float. With an effort, he retracted his claws and forced himself to relax. He deliberately sat on a convenient box, in full sight of the crowd. He made no attempt to board the boat.

The boat was long enough, sixty meters or so, and wide enough to support his weight, but the curved deck was only inches above the water. The boat was visibly rocking in the harbor chop, so Amarson had no intention of trusting it as a fighting base. Instead he sat balanced on the dock and, in an exaggerated fashion, for benefit of the crowd, admired the boat from a distance.

Like all Riverman machines, it was simple and uncluttered in its design. A small curved cabin and covered deck were mounted aft and the whole forward deck was taken up with six hunting sleds. These were clamped into depressions in the deck and Amarson noted the familiar shapes of dart launchers under their weather covers. These were the water weapons the Rivermen used in their fish hunting.

"You recognize the weapons, Baron?" the Riverman said. "They are basically the same as the ones on your fliers, except these do not operate by pressurized air as yours do. These are water weapons and we use pressurized water to work the mechanisms. They are all completely water proofed, of course. We have some massive corrosion problems here in the river-delta waters. The water is filled with mineral salts of every kind. Any material we use on our boats has to be tested extensively."

"I recognize them," Amarson said. "But I was surprised at the size. I would have thought they would be bigger. Don't you need more force to propel the darts through the water?"

"Actually it's about even, Baron. Your flier's mounted launchers were designed for lightness, of course, so they are smaller in that respect, but the speed at which your fliers move through the air dictates the propelling force behind the darts. My designers tell me the air is very much like water at these speeds. Then, too, we are compressing and accumulating water for the charging mechanisms. We can work with much

higher pressures. When we went to the air system in the flier units some of the components had to be made bigger for safety. Storing really high pressure air is very dangerous, you know.

"As you can see, the size of the two launchers came out amazingly close. Once we had developed a dart launcher small enough to be handled by one man on a hunting sled, the task of converting it to your airborne fliers was not difficult." The little Riverman sprayed his head with water.

"Do they kill riverfish as well as mine kill Draks?" Amarson asked.

"Oh, yes. They are quite lethal up to fifty meters. We can't see much farther than that underwater, so they are perfect. Your air launchers are actually more brutal in shocking power, Baron. We were quite amazed at your report of tearing up a Drak hunting platform—on your first combat patrol—with them. We had never test-fired them against solid targets. The impact energy is very high. Our ordnance men were breaking up boxes for days after your report came in. They tell me, at two hundred meters, a dart will penetrate four inches of ship timber. Amazing! They must kill a Drak instantly, from shock."

"They do that. My cubs are out hunting whenever they can get a launcher equipped flier off the ground. The groundsmen have to steal the control levers in order to service the engines properly. We need more fliers fitted with them.

"But that is what you called me down here for, isn't it? You said, last week, you might have new weapons. New fliers?"

"Not out here, Baron." The Riverman turned his head and looked up the dock. He worked his water spray, nervously. "A bit later, please. We are going to have company in a moment, and there are people in Riverton who do not believe in new weapons.

"In fact, they are marshaling much political force to stop me arming you with dark launchers."

"What! They must be mad!" Amarson was stunned. "Theiu, that must not happen. Why, for the first time, we can fly out and kill Draks when and where *we* want to; without waiting until they go hunting. We *must* stay aggressive, Theiu! It is the only way!" He stopped and glanced up at the dock proof, thinking of the Drak swarm, that he could neither control nor attack.

"Yes, I know," Theiu said. "They swarm at a bad time. We are getting our boats away and underwater as fast as they can dive here in the harbor, but we have lost lives. The big boats cannot go deep until they clear the channel." Theiu sighed.

"They are coming, now," he said, looking up the dock. "Say nothing, I ask you. Please, Baron. Control yourself. Be patient until after the ceremony. We will have our meeting then, I promise you. There is another person I want you to meet . . ."

Amarson looked up the dock. A religious procession was coming rapidly down the float ramp. The faction that Theiu was talking about must be religious. Then the arguments against new weapons would be emotional, not practical. Let Theiu handle his own negotiations on that level . . .

"Very well, Ambassador," Amarson agreed. "I will be good."

The little Riverman sprayed himself with water.

"Good. Just until after the ceremony, you understand."

The procession was headed for Theiu's boat. The priest leading the group was angry. At least there was anger in his walk and the way he carried his hands. The rest of the group seemed peaceful, if a little bit harried. They were chanting a prayer of good hunting for the riverboats, but they had chanted it too many times this morning. The rhythm was hurried and off count.

The priest came down the float ramp and stopped to stare up at Amarson. He was fat for a Riverman and the robes he wore made him look square. His robe was jeweled with an ornate design of the yellow Younger Sun on the left and the red Father Sun on the right side. The two designs overlapped on the front of the robe to symbolize the midpassage rites.

A young assistant hurried into position and sprayed the priest with water. Another brought up a large orrery made of jeweled metal and mounted on a pole so it could be carried above the crowd. The orrery pole was grounded with a ritual thump and flourish and the mechanism of the symbolic two suns began to rotate past the jeweled disk of The World.

The priest did nothing until these symbols were in place, then he glanced back at a group of four men standing behind the singers. They wore solid color robes: Red of the Father, yellow of the Younger, black of Night and the motley of the World. Amarson saw anger and fear on their faces. These then, would be part of the antiweapon faction: elders of the priest's church, to judge by their robes of ceremony.

The priest turned back to Amarson again. A flash of anger showed in his eyes and faded quickly. Amarson had a twinge of sympathy for the man. The priest was being pushed into something by the elders . . .

"Your badge of rank and your presence here with Theiu, tell me that you are the baron who attacks Draks." He paused, was sprayed with water, then went on in a loud voice: "My people speak of you, Baron. They say you are not welcome here. They say you provoke the Draks into flying . . . Provoke them by your senseless killing. Draks fly over our Rivercity. Our people are being killed. All because you attack the Draks. My people cry against you, Baron!"

"The Jungle People of the border

Marches are killed by the Draks, too," Amarson said. He held his voice tight. "Killing Drak is my profession, Priest. Your Rivercity pays for my skill against the Draks. The Valley grainfood; the Rivercity factory and riverfish; a fair share of food and craft: All pay for the killing skill of our jungle patrols and my cubs in the air.

"Stay with your religious ceremonies, my friend. The Jungle People will guard the Marches in their own way, according to the Ancient Compact, as they have done since the aging of the Father Sun began to turn our seas to mud.

"In any case, let us have peace between us." Amarson forced his voice to calm tones. "I'm sure this is a peaceful rite, you celebrate."

"This is a food-gathering ceremony!" The four elders called, their phrases coming one behind the other; hissing with anger.

"You are not welcome!"

"Do we need a border beast . . ."

". . . To teach us how to kill the riverfish for our children's bellies?"

I can teach you fools! Amarson's anger flared. He was irritated by the insecurity of the dock and startled by the verbal attack. "I have seen the Drak kill and prepare Rivermen for their food supplies . . . to fill the bellies of *their* children. I can teach killing. I am well qualified." His claws ran out. "Who will be my first student," he growled.

"There will be no students in Riverton!" the priest said. He spoke to Amarson, but he was facing the four Rivermen, glaring his displeasure at them. "My people have spoken out in ceremony, despite their promise to me. You have heard the words of my people, Baron. Listen; do not teach.

"If you are proud of killing, Baron . . . proud of being paid to kill Drak, then go and kill Drak. Do not spend your time walking in our city . . ."

"Holiness," Theiu interrupted, "will you come aboard my boat?" He shoved himself between Amarson and the priest so as to maneuver the priest into facing the boat. "We have new barrier nets this season. Will you come aboard and sanctify them, Holiness?"

The priest looked down at the boat. One of his staff quickly handed him a water sprayer on a ceremonial ribbon and set it swinging. The priest began to chant the required prayers. The ceremonial group closed in around him and took up the chorus of the chant.

Amarson heard the anger leave the priest's voice as the professional tones took over. The priest worked the water sprayer and began spraying the boat, then stepped aboard and went aft to the cabin, preceded by a sanctifying mist of water.

Amarson's own control began to dampen his quick anger. There was no reason to sustain it and it drained from him quickly, to be replaced by amusement. He was amused at the four Rivermen who were still stand-

ing, mutely antagonistic, behind the chanting group. Their anger was so futile; the swarming Draks overhead made it futile. Like it or not, the Compact between the Rivermen and the Jungle People would stand. The Draks were a constant menace and killing them was a political and military decision. Religious emotions meant little to hunting Draks; killing Draks was all that mattered.

The sanctifying sprays of water squirting from the cabin ports and openings seemed to indicate that the priest was turning *his* emotions into a rainstorm. Rivermen always had to get things wet.

Last month, when Theiu had visited Base XII to watch Amarson fly the new dart launchers in combat, the Riverman had sprayed himself every minute or so. That had been Amarson's first close experience with the Riverman's psychological need for a wet skin. He had recognized the need and tolerated it. He had never considered the philosophy of advancing that need to a religious ritual—and one covering a superstitious need for luck in hunting, at that—until today.

Even as he smiled tolerantly at the sanctifying of the nets, a picture rose in his mind of his own combat flights; and himself, kneeling in the red light of the rising Father Sun to hold his hands and claws into the blood red sunlight.

"By the holy suns! It's the same thing," he muttered. *"The blood only stains the hands!* We all are slaves to the old rituals, no matter how modern we get." He shook his head from side to side. These Rivermen became more interesting as he came to know them.

The ritual on Theiu's boat came to an end. The chanting stopped.

Amarson put his hands behind his back and prepared himself to be peaceful and absorb any future insults. Unless he held himself in check, these religious Rivermen could goad him into a killing fight. Amarson had no delusions about what would happen if he killed a priest, here in Riverton, but aside from that, he really had no reason or desire to test the courage of the short, fat Rivermen. Least of all because four richly clad fools had chivvied him into striking. The priest was brave enough. Considering the differences in size and weight, and Amarson's claws, the priest had already shown his courage.

Courage, hah! Amarson said to himself. *I won't fault a Riverman there. I wonder how many of my high-flying, hero cubs could get on a hunting sled and go diving deep in the water for a riverfish.*

I wouldn't want to! The thought of groping around in the murky river for a riverfish made his muscles tighten. These fish, teeth, tail and size, were as deadly in the water as the Draks were in the air. The riverfish actually outweighed the Rivermen, kilo for kilo, and the need for the dart launchers was obvious. The Rivermen had no natural weapons

either—Amarson's claws twitched out and back in—just a habit of courage. That they did have. Rivermen have been eating riverfish for a long time.

The priest came back on the dock and looked at Amarson. He gave his sprayer a sudden movement and sprayed Amarson with water.

Amarson's ears flattened and his eyes blinked closed, but he kept his fingers locked behind his back. He bowed.

The priest turned and walked toward his retinue. He handed the sprayer to the assistant and began to take off his robes. He beckoned and two of the chanters came forward to help him, folding the robes reverently for carrying.

"The ceremony is over. Return to the temple!" the priest ordered. "I will walk alone for a while before my prayers. Go!"

The procession left, moving to its own rhythm and taking the four belligerent Rivermen with it as unwilling leaders.

Amarson felt the float rock under his feet and looked up. The riverboat was already pulling away from the dock, its crew moving purposefully around the hunting sleds on the bow. Theiu was standing on the float watching Amarson and the priest.

"No, I'm not going, yet, Theiu," the priest said, unnecessarily. "Let the boat get a little farther out in the stream and then I want to talk to Baron Amarson."

They watched the boat slide under the water as it left the covered dock. A Drak screamed and broke his dive just above the water. Two dartbows twanged from the sinking cabin, but there was no damage; either way. The Drak missed his kill, too.

"Theiu will take you presently to look at a new weapon, and meet the man who designed it," the priest said abruptly. "He will tell you what you want to know, then. . ."

"Why the two of you wanted my Drak?" Amarson asked, trying for a shock reaction.

"Heh?" Theiu turned to look at him. The change of subject was unexpected, but it evidently meant something to the Riverman. "Yes, I'll tell you about that," he said. "The Drak is a most important part." He sprayed himself. "Most important." He glanced at the priest.

"I agree," the priest said. "But save the telling for later, my Theiu.

"For now. . .

"Baron Amarson, I am Dell Paudre, Priest of Riverton. . ." He paused. "I am a man who must say things, in public, before certain people that I would not say in private—nor believe. The compact is as real to me; your job of killing Drak as vital; as . . . my prayers—or the swarming black-winged evil over our city. They are things real beyond doubt.

"Those four who challenged you are leaders in my church. I am its priest, but they govern and, to an extent, they govern me. What I say. . .

What I said to you. What I do."

"*Blood only stains the hands*," Amarson said. The priest was trying to apologize. Amarson relieved him of the strain.

"The old rituals are very useful," the priest said. "Thank you." He reached for Theiu's sprayer and wet his head and eyes.

"Now, we can leave here," he announced. "Walk with us, Baron. Down to the end of the docks."

They walked in silence for a while, Theiu bringing up the rear.

"Baron Amarson," the priest said, again opening the conversation abruptly. "This morning you risked your life because of a sense of honor. You call it, *Warrior's Code*, I believe. Would you risk your life again, against the Draks, if the possibility existed that there would be no *honor* in the mission?"

"A mission to kill Draks?"

"Yes, that I can promise, although not killing them in the way you have been killing them."

"Priest Paudre, killing Draks is my job. There is no, *Code*, attached to the task. I do it wherever, and however, I can. The Warrior's Code does not apply to Draks. Tell me how you want them killed—forget such thoughts as honor and code."

"How do I want them killed? Secretly, Baron; without the knowledge of any of those four; especially their leader, the one in red—Domne."

"Is that his name? Well, agreed, and easily. Keeping secrets from that one comes without effort."

"Don't underestimate him. He studies the old rituals and has ambitions of becoming Riverton's Priest in my place. He *must not* know. None of them must know. That means that Theiu and I must hide our plans from half of Riverton, too."

"The pressure to stop arming my fliers comes from this, Domne?"

"Yes. He also had the orders sent that resulted in your ritual kill yesterday. So you see; he has power."

"*Aargh*!" Amarson showed his teeth. "And he still picked a fight with me just a while ago. He is braver than I would have believed; shouting from the safety of a crowd. Still, he may have heard our Jungle saying: *There is no honor in killing a Riverman*."

"It wasn't bravery. Domne believes he is powerful enough to direct the fighting on the Marches. It was power he was displaying on the dock; not bravery."

"Perhaps." Amarson smiled. "However, the next time you see him, tell him I said: *Sleep with your claws out*. If he knows the old rituals, he will know the meaning of that."

"*I* will tell him," Theiu said. He sprayed his head again. "But, if you agree to this mission, I plan to spend most of my time avoiding Domne; officially, privately, and, if possible, religiously."

"There, I can help a great deal," Paudre said, laughing. "Our riverfish season is a time of long ritual and many prayers, for me. I can and will

keep Domne by my side through most of the ceremony. That *I* can do, willingly.

"But we are here, at the mole, and I must leave you, Baron. As much as I may want to, I cannot come with you. As Riverton's Priest I cannot be publicly connected with the new weapons. Not publicly. As I said, Baron; Domne governs my church. Perhaps later—"

The priest looked at Amarson for a moment, as if he wanted to say more, then he looked at Theiu and nodded.

"Baron," he said. "Thank you for accepting my mission on faith. Theiu will tell you more—brief you, is the term, I believe—on the new weapons. We will meet later, perhaps, but for now; good-bye. Good luck."

He turned quickly and walked away.

BARON AMARSON

"Let's hurry a little, Baron," Theiu said. "The Patrolmen are waiting and I want to cross the mole as soon as possible."

Their walk had brought them to the end of a long mole jutting out into the river. The mole was not covered and three Jungle Patrolmen were setting up one of Theiu's dart throwers on a high post mount. The pressure bottles and charging motor for the firing system were strapped neatly on a small two-wheel truck.

At the other end of the mole was a square block of buildings, dominated by a squat, round tower. The cluster of stone was an island in the river, except for the heavy stones of the mole. They, the stones, were not natural. They had been placed there by the Rivermen and they looked newly cut. The mole was not very old.

It was also not covered; exposed to the Drak.

From the presence of the dart-thrower crew, Amarson judged the next plan of Theiu's was a run along the mole under the covering fire of the Patrolmen.

He stepped near the edge of the dock roof to look at the sky—judge the Drak swarm.

The senior Patrolman took two

steps to his side and put a fighting knife in his hand. Amarson took the knife and stepped clear of the roof.

The sky above the mole was clear. The main Drak swarm was behind them, over the city, in three high, spiraling flights.

"Clear, except for some isolated Draks on the fringe," Amarson reported. "The weapons and the man you want me to see are out there?" He looked at the tower.

"Yes," Theiu said. "Be patient with me a little longer, please."

"Doesn't Domne like him, either?" Amarson wanted to know. "That looks like a prison."

"No, it's not a prison," Theiu managed to laugh. "The man we are going to see likes privacy. Also he sometimes has explosions and makes vile smells in the night. His neighbors in Riverton were delighted to help him build his island."

"Senior, when you are ready, we will run."

"Ready now," the Patrolman said. "Baron, here is a dartbow. I'll yell if anything gets past us on your back. Keep the knife."

"I won't even look around," Amarson said. He took the bow. "The trophies will be all yours." He slid his claws out and felt his stomach tighten.

"Standby." The senior Patrolman exposed himself to check the sky and then snapped: "Go!"

Theiu started off across the mole. Amarson matched his run and checked the sky above and ahead of them.

They neared a barred gate; a Drak hunting scream broke out in the air behind them. The clatter of the dart launcher cut it off. Amarson rushed Theiu through the gate, across an empty courtyard and through the heavy, wooden door of the tower.

At the door, Amarson turned and looked back through the gate. The Drak—knocked out of the sky by the launcher crew—had fallen on the mole. The senior Patrolman already had a man out collecting darts and the head and wings.

Amarson returned the senior Patrolman's wave. They were good with that dart launcher. Amarson's leg and stomach muscles began to relax. His claws disappeared. He turned and closed the door. It moved on well-oiled hinges. The gate had opened smoothly, too. The privacy of the tower's owner was evidently maintained by some other means than locks and gates.

Inside the doorway, Amarson found himself in the ground floor room of the tower. The room was largely empty; seeming to serve as an entry hall for the rest of the buildings. the stairway to the rest of the tower above, circled the right wall to a wooden balcony.

The only article of decoration, or

furniture, was a large orrery in the center of the hall. It was larger than a man, about twenty meters tall and strangely designed. The proportions of The World and the two suns were all wrong—and so were the movements.

Theiu was not going any farther. He stood waiting for someone, spraying himself and looking at the orrery. It was the only thing to look at, so Amarson watched it, too. His eyes followed the arms and gears of the movment and he realized that the only orrerys he was familiar with were all religious symbols, luck charms, altars. His contact with the priest this morning had made him sensitive to religious symbols. This orrery was different.

Of course! This one must be a scientific instrument, scaled accurately, to be used in time-keeping and sun predictions.

The Rivermen would be able to make such a thing . . . and this man—the owner of the tower—must be a major scientist among them, to need such a large orrery. If size meant accuracy; this was a precision tool.

Now, he was definitely curious about the different size and motion relations he was watching. The World was small, barely large enough to contain the gears that made it turn as it circled the Father Sun. The yellow gem of the Younger Sun was set in the matrix of a looped track about the shape of Amarson's thumb, but wider at one end. The wide end was toward the disk of the Father Sun and the small end pointed at The World, but was separated from it by a space as wide as Amarson's hand. The yellow sun gem moved in and out along this looped track. As it did so, the mechanism of the orrery caused the small end of the loop track to move in a path around the spinning World.

The center representation of the Father Sun, was a dull red disk, not a ball at all, and the distance between the Father Sun and the system of The World and the Younger Sun was what made the orrery so big. Well, that was explainable. You could go outside and see that the Father Sun was *big*. It covered half the horizon when it rose.

Amarson went back to watching the yellow sun move around The World, until the complex movement made him a little dizzy.

"The movements are too complicated for anyone to understand," a deep voice said. "That is why we make charts and tables for the course plotters."

Amarson turned to see a tall Riverman standing in the archway at the back of the hall. He came forward slowly, without the usual darting appearance of a Riverman's walk. He was dressed in a common coverall and was wearing a dark cape with a cowl. His face was long and lined with either age or the effects of illness. The large brown eyes, and the webbed hand he raised in greeting

marked him as a Riverman, but he was a full head and shoulders taller than Theiu. His height, thinness, and the slowness of his movements gave him a massive air of dignity.

"We, who watch and weigh the movements of the two suns," he said, "spend long hours marking their movements into diagrams and columns of figures so that our technicians can devise machines to guide the hunting boats on the river, and your fliers in the air. We spend long watching hours. Even so, we still do not know why there is a period of darkness in the rhythm of the Father Sun.

"But I am a bad host." He turned to Theiu. "One of the things I do know is why you are here, and my reason tells me who you are, but. . . Introductions are a social convention. Ambassador Theiu, will you be social?"

"Certainly," Theiu sprayed his face and spoke formally. "Scientist Lewyll, may I present Flight Commander Leon Amarson, Baron Rufus, Commanding Flight Base XII. Baron Amarson, Scientist Lewyll is the man I have brought you to see. He has developed the new weapon."

"Scientist Lewyll." Amarson bowed to acknowledge the introduction.

"Welcome to my tower, Baron," Lewyll's voice relaxed into a deep whisper. "What you have come to see is in the room above us. I have just been confirming my experiments in the lower chamber. I won't ask you down there. I have butchered the body of your Drak and several riverfish. It is not a pleasant smelling place."

"My Drak?"

"Please follow me." Lewyll started up the stairs. The whispery quality of his voice was evidently normal, not any attempt at secrecy. "Yes, Baron. The Drak you killed yesterday in your ritual combat. Delivery was prompt. I have had a standing request for a new-killed Drak for some time. Theiu has told you of it. This one was brought in most quickly. Your senior Patrolman was most helpful.

"Tell me, Baron, why are you so dedicated to Drak killing that you risk your life in a ritual?" The scientist didn't wait for an answer, but went on up the stairs.

Amarson followed and found himself shepherded into a room that the scientist used for a chemical laboratory. Amarson didn't recognize the equipment, but his nose told him the purpose of the room. He shut off his sense of smell to protect his stomach.

One thing in the room was familiar to him, however. A large scale combat map covered one wall. He walked directly to it and looked at the codings marked on it. The arc of protective flier bases, the colored paths of the main Drak hunting parties—strike corridors down which the Drak flew to kill the Valley people—

yesterday's combat strikes; the details were all there.

"This map is as accurate as mine at Base XII," he said. "Not many Rivermen know so much about our fight against the Draks."

"One of your liaison types comes over every afternoon," Lewyll said. "He provides me with data and some very good recruiting speeches."

"Recruiting?"

"He tells me how wonderful the war is, now that we have begun to attack and kill Draks."

"He is a fool!"

"The Baron does not like to call Drak fighting, a war, Scientist," Theiu put in as explanation.

"Oh? Then what is your dedication, Baron, if not war with the Drak? The senior Patrolman who delivered your Drak kill was pretty basic about *his* business of killing."

"And so am I." Amarson gestured at the map. "All that these pretty pictures show is a series of pack fights. Oh, we're good at it. Dedicated! We still fly rocket fire against the Drak jungle camps, when the ground patrols find them, and your new launchers, Theiu, are giving us more kills in the air. Air fights are no longer knife and spear melees. We *are* attacking the Drak and killing him and with almost no losses. My flying cubs are very, very happy with *their* business of killing.

"But it's not war, gentlemen. I am still sending my cubs up to kill Draks who are out *hunting food!* my people, of the Marches, the Valley People, you in Riverton, are simply good to eat and the Draks fly in to hunt us. They like to hunt and kill my cubs in the air and they stalk us whenever we fly near one of their hunting parties. My cubs kill Draks willingly, but also because the Draks *always attack* and will kill a pilot if he doesn't strike first.

"Again, with these new launchers we have been able to do a little stalking on our own account. We kill Draks! In the process we are guarding the Valley and protecting your riverfish harvest in the way we have always done.

"As your priest, Paudre, said: We're paid to kill Draks; we're proud to kill Draks. . .

"But it's not war!"

"You have stopped the Draks' deep penetration flights," Lewyll said. "The Valley harvest is almost complete."

"We accomplished that much when we first started fighting the Draks in the air with the fliers you built for us," Amarson said. "But the Draks still fly and hunt and *feed!*"

"Can't you be satisfied with that?"

"No! It's not enough. . . Stopped their deep hunting flights, you say." Amarson swung his finger in an arc along the length of the Valley, beyond his bases. "Inside our base perimeter I can cut them out of the air. Your riverfish harvest is usually safe, here along the delta. . .

"This swarm—Draks have never swarmed this far down the plains before—I hope is unusual. If it becomes

seasonal . . . I don't know. There isn't a thing I can do about a Drak swarm. We don't dare attack them.

"Up to now, your fishing has been safe in deep water. Up stream, too far . . . I can't say that. Without special air patrols over your boats, the danger is still great. The toe of the great mountains comes down here, and we cannot fly into the Drak mountain passes."

He stopped and looked intently at a group of course lines marked on the map.

"Your liaison is posting false data," he snapped. "There have been no patrols here. That's right in the center of the alps. The peaks around there are higher than our fliers can climb."

"I'll have him disciplined. There's no reason for jokes like that."

"Relax, Baron," Lewyll said. "I marked that course, myself. That is your next combat flight." His voice went to a lower tone. "This flight might even qualify as *war*."

"Can't do it," Amarson cut in. "Our fliers wont. . ." He let his voice die away as he remembered that Theiu's reason for bringing him here was bound up in a new weapon. Those course lines and the tall Riverman must mean that they had some way of getting there. He turned his back to the map and stopped being irritated.

"Tell me," he said. He even managed a smile.

"We have six new fliers that will go to that height," Ambassador Theiu said. "They are being delivered to your Base XII by truck today. By truck, armed against the Drak swarm and in force enough to fight their way through. By truck, so that no one in Riverton can see what they look like, until you fly them."

"Have they been tested?"

"Yes, test flown and dismantled. A Riverman assembly crew is with the trucks."

"That is not all," Lewyll said. "Getting a flier to that height would be useless unless the Draks could be attacked.

"I doubt that the Draks fly that high. I'm certain they can't. What you will find in those mountains are the Drak camps, gathering places and their main water supply. But these camps will be in a deep central valley, or a high plain in the mountains."

He went over to a bench and put his hands on two polished wooden boxes.

"Now, as to why I want you to go there—

"About a year ago a Valley village on the Delane River designed a new nutrient fluid for their fields. They sprayed it on the ground and improved the crop. In the Delane, however, the results were death."

"The Delane is the breeding ground for a type of fish we harvest, some of them we supply to your base, the *lenief*," Ambassador Theiu explained.

"Very tasty, I like them," Amarson nodded. "Go on."

"We maintain a fish count and watch station at the mouth of the Delane. Hatch time came and passed. The fingerling count was twenty percent of normal. The fish watch called an alert and we sent Scientist Lewyll in with a team, looking for some new predator in the area."

"Predator! Hah, I found the worst one there is," Lewyll said. "The hatch was still in the breeding pools. All up and down the river. The eggs were unfertilized: dead. Dead? They had never lived.

"The water and the valley nutrient!" He put his hand on one box. "The nutrient killed the *lenief*. . . Still is killing them. The fingerling count is one percent, this year. We don't even know where they are coming from. Some tributary of the Delane, not the river itself."

"Has it got to any other riverfish?" Amarson asked the obvious question.

"No!" Lewyll clapped his hands together. "That was the wonderful part. Completely selective!" The Riverman was almost gleeful. "In fact it was the selectivity that made me see a great discovery in this disaster on the Delane.

"I brought specimens of the original nutrient and the water back here and started to work on a line of chemical change. It worked, Baron. Theory said it should, and I have proved it.

"I got final confirmation this morning from your fresh killed Drak, and my work is complete. Here it is."

He opened the wooden box and took out a glass cup filled with a blue liquid.

"This will kill Draks!" The scientist held the cup up and looked at it. "Spray this nutrient on the ground, and near the water supply of the Drak camps, and they will not breed. The next generation of Draks will die like the *lenief*; unfertilized and unhatched."

"That is the combat mission we want you to fly—using the new fliers, Baron," Ambassador Theiu said. "They have tanks in them to hold many liters of this nutrient. The Valley People are making it for us right now."

"You should appreciate the irony of the situation, Baron," Lewyll said, slowly. "Yesterday you, alone, killed a single Drak. This afternoon, I am asking you to kill a whole generation. We make progress in our weapons when we serve Death, don't we?"

"Death for Draks, Scientist." Amarson matched his intensity. "I am tired of seeing Drak food camps and butcher points on the Marches. I am sick of being *food* for Draks.

"If your way of killing is Death for them, you have my help."

"I guarantee it, Baron," Lewyll held up the glass cup. "This is Death."

"Very well.

"But I see why the church elders would oppose you. Death of a whole

generation is a terrible thought.

"Are you certain the priest, Paudre, sides with you in this?"

"Absolutely," Theiu answered.

"His aid has been valuable," Lewyll said.

Amarson nodded. He wasn't so certain, however, about a man who had two voices: one public; one private.

"He does not know about killing Draks. The Compact has kept it from him—safe on the border Marches, until now . . ." He lifted his hands and ran his claws out and back in.

"A whole generation . . . a terrible thought. But against Draks . . .?

"You have my aid! *Blood only stains the hands!*"

"This will mean secrecy, Baron," Theiu said. He worked his sprayer. "Not only about the new flier, but about the purpose of that deadly nutrient."

"Hm-m-m. Secrecy. I don't know." Amarson looked at the map; not really seeing it. "That means assembling the fliers, training six pilots and crews, flying them . . . My pilots would have to have test flights . . . a new flier. All in secret?"

"More than that," Lewyll put in. "The Valley People, the ones making the nutrient, will deliver and fill your tanks from trucks. They must stay at Base XII until you fly. Also you will need six more men . . . to fire the dart launchers. The fliers are built for two men."

"Show him the flier, Lewyll," Ambassador Theiu broke in. "You have the model, there."

Lewyll put the cup of nutrient back in its container and opened the second wooden box. Amarson came across the room to look closely at the polished quarter meter model.

"It has one large wing," Theiu began describing it without needing to see it closely. His factory had made the model and his designers had shown it to him many times. "The wing is thick and wide to lift heavy loads. The body is really just a big tank. The pilot's station . . . far back, near the tail, for visibility and to allow a bigger tank. The dart launcher is in front of the pilot and can be swiveled to any angle and all around. That's why we need a second man.

"Scale? The flier is big. The biggest thing I've ever built; except a boat. It's four times as big as your combat fliers, Baron. Four times.

"That's another reason for the flexible dart launchers. You can't chase Draks around the sky with this.

"You have flown this, loaded?" Amarson asked.

"Yes. Including dives and penetration of the thermocline. You can talk to the test pilots. They went up to Base XII with the first flier."

"Test pilots!" Amarson tore his blue eyes from the model. "How many more people are in on this secret? Did you tell the Draks?"

"That's all." Theiu worked his sprayer. "My factory people will stay at Base XII after they assemble the flier, like the Valley nutrient experts."

"Impossible!" Amarson almost shouted. "You are talking about fifty people. That's not a secret; it's a troop movement. I can't hide anything that big. Nobody could."

"We will have to try. If Domne hears of our work, he will stop it. He will not be out looking. He has heavy religious rites and duties during the riverfish hunting season. Paudre will see that he is kept virtually in seclusion for most of the time we need.

"If questions are asked, we can say we don't know what is happening; *if* you can hide the fliers."

"I can't hide them in the air! Four times as big as a combat . . . Be realistic!"

"Can't you fly them just at the rise of the Father Sun," Scientist Lewyll's voice was slow and calming. "Once in the air, these fliers are designed to fly high. You could train at altitude, where none could see."

"Landing . . .?" Amarson considered. "Accepting a takeoff at first light, I'd have to land in bright light. Specially with a new flier; a new, big flier. I'd want both suns in the sky; not even risk a chance on one of the periods when the Younger Sun is setting. The light is too uncertain . . .

"A low approach from the jungle . . . perhaps."

"Exactly," Lewyll said. "Your Base XII is ideally suited for that. You are far out on the perimeter. Visits are not common. We could even undertake to see that they stopped altogether, for a time, heh, *Ambassador* Theiu.

"Your Jungle Patrol could help with that, Baron. Also the rest of your flight commanders and your headquarters have agreed to help—without knowing about this nutrient weapon, of course."

"It will take some massive planning," Amarson said. "And I don't really believe it will work, but I will do it."

"I tell you it must work," Theiu said. He worked his sprayer in emphasis with his words. "The secret must be kept.

"Don't underestimate, Domne. Remember, he almost had you killed by simply playing on an obscure regulation and your own warrior superstition."

"I am not likely to forget." Amarson put a finger on the little model. "When will I get to see these fliers?"

"The first will be at your base when you return tomorrow," Theiu answered. "All six by the end of the week. If I moved them all at once, the size of the convoy would be suspicious."

"And I will begin today," Scientist Lewyll put in, "And calculate the precise hour of first light for you at Base XII. A table for every day, from now, for a month, should do it."

"More than enough," Amarson said. "The secret won't hang together that long. There will be a leak.

"How long will your men need to assemble the fliers, Ambassador?"

"One day, each. A week."

"Then I train in a week. No, I begin training as soon as a single flier is ready and rotate pilots. I can't have all six in the air at once until mission day. I couldn't hide that.

"And the Drak swarm . . . By the two Suns! They could have picked any other place in the world to swarm." He smashed a fist into his open hand. "This particular swarm won't last long. They will go somewhere else, land, rest and mate. They may swarm once again, or they may not, and then its all over till next season. But the time; now . . .

"The time is bad for us. I will have to hold my training while the Draks are gone. I can't use my field for take-off, you see. Not while they are swarming. The Draks dive on fliers on the ground.

"I can catapult my combat fliers out of the hangars; we are set to do that . . . but these new fliers . . ."

"They will need almost all of your field for a takeoff run," Theiu put in. "You will undoubtedly need clear skies."

"I hope they are easy to fly, these toys of yours. We will still be learning about them on the mission. I wouldn't like surprises, especially unpleasant ones."

"You will fly them," Lewyll said. "We know the skill of your pilots. That is why we picked Base XII for this job.

"Now, if you'll come over to the map I will show you the mission and tell you what we think you will find on top of the alps."

Amarson followed him to the map and the planning went on in detail, as it was to go on in greater and greater detail for a week to come.

Amarson held the flier in a wide spiral climb through the blood-red light of the rising Father Sun and let the other five form on him. He kept the heavy flier circling for altitude while he began the ritual chant to take him through the thermocline. His timing was off and the chant was completed well short of the required height. There was no indication of the rough turbulence where the heavy air and the lighter air met at the barrier. The flier climbed slower with the liquid tanks full, and Amarson was rushing the ritual. The newness of the unfamiliar flier, its visual shape in the air, all added to change his sense of timing. The flier was bigger than the ones he usually flew in combat. Also he missed the lower wing. Flying with only the one large top wing was still strange, uncomfortable, even though the wing was longer and wider than both wings on his combat flier.

The Riverman technician had lectured him about the thick wing and its skill at flying heavy weights, but the distrust of newness was still with him. He did not fully trust the idea

of *hanging* a heavy engine, body pod and pilot underneath a wing instead of sitting naturally on top of the wing. And the thought of the two liquid filled tanks up in front of him, adding their weight to the whole . . . Amarson's eyes kept scanning the curved pylon that covered the metal frame holding the wing and body pod together.

The ritual was completed for the second time, Amarson's pulse speed and nerve response had quickened again to the rhythm of the chant, when the flier finally hit the thermocline and bulled its way through.

Amarson was totally surprised. The flier bucked and pitched as it slid through the turbulent air at the barrier point. The fat wing waggled slightly, and then the flier was through. There was no violent maneuver of any kind and, with his senses heightened by the chant, Amarson had control throughout the penetration.

There was noise, however! The wing groaned, its covering screamed and crackled. The tank area up front made horrible pops and dings, as the slosh barriers dampened the liquid movement. The flier moaned and screamed. Then it was through into the thin air above the thermocline.

The silence, as the flier slid through the smooth air, was almost as distinct as the noise.

The noise brought Mardon, the Jungle Patrol bowman, up out of the firing port just in front of Amarson. His head was turning from left to right, in near panic. His hands gripped the dart launcher frame around him and his claws were out. He had been briefed on the flier's rough movement during penetration, but not on the noise. He had been sitting down in the body pod when it began. The racket must have been heart stopping.

Amarson pounded on the launch-strut that was part of his windscreen and, when the Patrolman turned, made a combat gesture with his left hand. It was a signal that a Patrol leader always gives before a fight and it meant, *"Charge forward gloriously for home and hearth,"* in the books, but had a more vulgar meaning in the Patrol. He got an equally obscene reply and a wide grin, that told him the bowman was still a fighting unit.

And so was the big flier. It had survived penetration with full tanks . . . the liquid in those tanks was a potent weapon aimed at the Draks . . . and Amarson's big flier was very much a fighting unit. It wasn't any combat spinner, but the speed went up in the thin air and the big wing was lifting the load higher and higher. Amarson began to feel better.

He had left his Base XII in a mess below him. The tightly organized training schedule of the last week had come apart on the last day. Too much had to be done, too fast.

The Valley tank trucks had arrived late and had to be driven right into

the shelter tents with the fliers, in order to fill the fluid tanks. Theiu's technicians and the Valley drivers had pumped all night to finish the job. Amarson had broken one of his own rules about working during the darkness hours.

Then there had been a Drak raid, a spin off from the grounded, mating Drak-swarm in the foothills. The six Jungle Patrolmen—set up to fly with the dart launchers—had been pulled out to the jungle perimeter to fight. They'd missed their one and only training flight. So, now, those six men were riding up here in the air for the first time in their lives. Amarson hadn't had time to reschedule their flight experience.

They *had* spent the week shooting the twin-mount dart launchers from the back of a truck. Some of them could hit a moving target; some of them couldn't. If the Draks attacked the big fliers . . . Well, the bowmen would kill the Draks or somebody would get hurt. It was a weak link, but Patrolman Mardon said they were good. Mardon knew his men, and he, Mardon, was riding Amarson's dart launchers . . . It might work. They all had listened to Lewyll's dry lectures on lead, relative motion and judging distance. At least they had listened, like professionals, as if their lives depended on what they heard . . . The possibility existed.

If they soldiered in the air like they did on the ground . . .

On the ground . . . Well, Base XII had Valley men, Rivermen, Jungle Patrol, and its regulars, all cluttering up the tents. The secret could leak out of that pot . . . The fliers were in the air, but . . . Amarson smiled a little at the thought of his second commander, coping with the mob and the mess.

The mess . . . The mess was on the ground and he'd worry about it when he got back. The work was up here in the air. The job of killing Draks.

He looked behind him and saw the other five spread out, slightly below him. He waggled the wings—wing—to signal them into the flight pattern and watched the strange silhouettes form behind him. They looked even odder from another flier, but with a singular purposefulness that Amarson found he liked. One wing, long tank pods and all, they looked powerful, these new fliers.

Their pilots handled them well, too. The pilots were almost as loosely trained as the bowmen. The takeoff and fighting tactics, indeed all the flying pattern work, had been studied with blocks of wood on a table top. Now, and here, the flight was working in the air for the first time.

However, they could fly, these cubs. They were working out in the air. They'd be all right.

Amarson turned onto his course and increased his power setting to climb. The six fliers were aimed at

the high mountains and they drove up the sky, higher and higher.

Amarson locked his controls for the climb and began to adjust his muscles to control the flier with the tiny relaxed movements of his flier's skill. He found, to his amazement, that the flier didn't seem to need this attention. The ritual words for his flying drill were thrown out of time as the movements prescribed by the words produced no effect on the flier.

Amarson broke off the ritual and studied this. He had been conscious on the test flights, and on takeoff and climbout, that the controls had to be moved farther and held longer, but he had expected that—because of the flier's size. This was no combat flier. He had expected to fly slowly. What he had missed, was the fact that the big, slow beast flew so smoothly from one maneuver to another . . . without a twitch, or hike, in the air. In fact, once the controls were moved, the flier seemed supremely indifferent to anything except a firm, positive movement in another direction. For a while this worried Amarson. He was going to be doing some flying near the mountains at the end of this mission. The tanks would be empty then; the flier lighter. He didn't want to be overcontrolling and fighting a sluggish flier, then.

He began to experiment with his controls and soon found out that he wasn't overcontrolling—probably couldn't overcontrol. The flier simply had an incredibly smooth ability to fly itself.

All this time, as Amarson had been learning the fine points of his controls, he had continued to climb. He had to top the alps ahead, if he could, and he had to get up high before the Draks sent scouts up to stop him.

The height gauge began to register in the shaded portion of its dial—time to use the breathing air.

Amarson reached-out and slapped the launcher support again. The bowman, Mardon, turned. Amarson unhooked his face mask from the breathing tank and held it up.

Mardon nodded.

Amarson pushed the mask up over his nose, like he had been taught, and slid the head band over his ears. He turned the valve on the air tank and felt the cool pressure inside the face mask. Just as the Rivermen needed these tanks under the river, so pressurized air was needed to breathe up here at this height. The Scientist, Lewyll, had said the pressure would help him breathe. Without the pressure, he would be able to breathe out, but the thin air would not be able to force itself back into his lungs. At this height, the pressure in his lungs and the outside pressure were equal. He could breathe out, not in; hence the pressure tanks.

Amarson lifted his head and sat up a little to check that the bowman was masked and then he glanced back at the fliers following him. He

waggled the tail of the flier to signal them into their masks.

That is, he started a waggle. What he got was a slow, lazy tail-wave. This flier just wouldn't maneuver. He made wide hand motions at his own face mask. They caught that.

The pilot on his left blipped his engine and yawed out, so Amarson could see his signals. He was pointing down and forward. Draks!

Amarson tipped a wing down to locate them. They were far below. A large party and they were rising, but they were too far below to worry about.

A shadow swooped over his head. What the . . .!

The bowman was up; standing in his harness. The two dart launchers slid around on their firing rail, the curving tubes of the engine powered air-pump system standing out in rigid loops around the Patrolman. Mardon had seen the sign from the other flier and located the Draks. Then he had switched on the air pumps, armed his launchers, and was ready for a fight. All this without orders and on his first time in the air. The Jungle Patrol certainly made tigers!

The shadow that Amarson had ducked was the dart launcher riding across the protective stop-bar over his head. This kept the bowman from stitching darts through the flier's tail by accident. There were two more such bars protecting the wings. The pneumatic pressure generated to launch these darts gave them enough energy to shatter timber at two hundred meters. The damage they could do up close, was unthinkable. Amarson was fully in accord with those protective stop-bars.

The bowman relaxed behind his launcher. He pointed to the Draks and shook his head. The Draks weren't going to attack.

Amarson gave him a break-off signal. The bowman was right. The Draks were out of range and falling behind. They were no problem.

It was the Draks ahead that they had to worry about.

A quick automatic check of his instruments showed Amarson that the flier was high enough to clear the alps. He leveled off and studied the peaks ahead. They were only minutes away and already he could see beyond them. Lewyll was right; there was a high valley.

The flight swept over the peaks and the wide valley became visible. Amarson signaled the flight into the pattern they had planned for the spraying. It was like a combat line, but with the big fliers grouped in units of two; wing man and leader. Another difference was the space between fliers. Amarson was going to take them down close to the ground. He wanted to give them plenty of air room.

He checked the pattern as it formed and started to pound on the launcher frame to alert Mardon. The bowman, however, was up, standing

in his harness, and the tubes to the dart launchers were still rigid with pressure. The Patrolman was ready.

So was Amarson. He dropped the nose of the flier, pushed the speed control to full power, and took the flight pattern down over the Drak highland.

The instant the ship straightened in its dive, Amarson put his eye to a ranging bar. He pushed his face plate close to the bar and sighted at the ground. The image he saw was doubled, rocks, trees, a Drak berm; two of each. He had no way of knowing the height of the highland here and his height gauge was useless for telling the distance above the valley floor. The ranging bar was a Riverman device to gauge his distance above the ground. When the split image came together he would be low enough to pull out of his dive. There! Now!

He pulled up and flew level. The flight followed him. A quick reset of the bar and a little juggling with height gave him the range for dropping the liquid in his tanks. He noted it on his height gauge.

By this time the flight was far enough over the valley to start the spraying. Amarson found and pulled the wooden lever that had been added to the flier. The liquid began to stream backward, forming droplets as it fell. The spray stream glowed a frothy pink in the light of the Father Sun.

The other fliers made their drops as he did and the flight swept across the valley, trailing falling plumes of glistening fog.

Ahead of the flight was a Drak henge. A great circular mound of earth with wooden living camps inside. None of the camps had roofs of any kind—the Draks evidently flew in and out. Amarson was able to see into them as he flew across the henge. Most of the Draks crouched, startled by his engine noise, but some of them took wing. Ah, that was one point Scientist Lewyll had wrong. The Draks could fly at this height. The air on the valley floor must be thick enough.

Amarson could see the red sun glint on weapons, but the Draks were slow and heavy from their swarming and mating. Their wings beat in the thin air, but his flight flew on beyond them before they could climb to fighting height.

There was another henge off to the left. Amarson changed his course slightly to fly over it. This one was larger, about fifteen hundred meters across and crowded with inner structures . . . but not many Draks.

Amarson was puzzled. In the fleeting glimpses of the two henges, he had seen very few Draks. Those camps could hold hundreds. Only a small group had come back here from the swarm over Riverton. Where were the rest? Where would they swarm next?

The dart launchers rattled and shook, startling Amarson. Draks! *Aiee!* Some of them were up here in the air at fighting height.

The bowman was shooting forward, over the wing. Three Draks! Only a single hunting flight?

The bowman fired again and missed again, as the Draks drifted above the flier and curved down to attack from above and behind. The yellow Younger Sun was almost below the peaks in that direction, but the Draks still curved to attack from the sun.

The bowman swung his dart launchers and fired again. The flier shook with the rattle of the dart belts moving up into the launchers.

Then the Draks were hit!

Amarson's wingman was firing, too. He saw the smoke trails from the launcher on his wingman's flier converge with the stream that Mardon was swinging through the sky. The two lines of darts seemed to touch the flying Draks and instantly two of them were rolling in the sky, stopped in the air by the dart impact, and falling.

The third came on, his beak open in a scream Amarson couldn't hear for the rattle of the darts. Mardon bounced the launcher over the deflector plates and across Amarson's head to pick up the Drak on the other side of the flier.

The Drak missed his dive and flashed by not more than ten meters out. At that range, Amarson saw the darts take the Drak. They tore into his body and an arm and a shoulder were literally ripped away and fell clear. The Drak's head and beak disappeared and then the body fell. The bowman stopped firing.

The lack of noise was so violent, Amarson thought the engine had stopped and jerked his eyes to the instrument panel. The engine was still running. The liquid level in the tanks was down one-half weight. Good, that finished the job here.

Amarson pulled back on the spray lever and cut off the valve. The spray stream stopped. The rest of the tank would be dumped on the watershed outside this valley.

Amarson controlled the flier into a wide climbing turn and fired a recall flare with his signal gun. Then he set his course south for the Jungle Patrol perimeter nearest the coast of the mud sea. He waited for the flight, scattered during the Drak pack fight, to form up on him.

The three Draks had been an isolated hunting party. There were no more Draks in the sky near Amarson's fliers, only the straggling group of six over the henges. The six that had first climbed to challenge Amarson's spray run.

The fliers closed in from their spread-out fighting pattern without hindrance, but one flier was in trouble. He was still spraying fluid. Amarson could see the pilot, his head down in the body pod, trying to free the controls. After a moment, he gave up, lifted both hands over his head to mean failure, and slid his flier across to join the tight flight pattern.

Amarson signaled, *follow me,* and altered course slightly to lead them

back across the valley. He kept the flight climbing steadily to clear the mountains, but the new course took him back across the Drak henges. The falling spray from the one flier would not be wasted.

That spray was death for the Draks and he wanted to leave it falling on the henges and the Drak home camps; Leave as much as possible, drifting down in ruby drops of death, as the Younger Sun neared the horizon in its mid-passage setting.

Mardon's dart launcher rattled across its frame, as he trained it forward and to the left. The Drak flight was close and he was tracking them.

Amarson signaled his flight to stay closed up and continued to climb. He had seen two of the Drak waver on their wings and miss a beat. The height, their fatigue after swarming had cut into their endurance in the air. Amarson thought he could climb above them, avoid combat, or let Mardon get a shot as they flew by. He held his course.

He was right. The Draks began to drop. Their wings lost beat and stiffened to glide them to ground. Four were left . . . then two . . .

Mardon shifted his launcher mount to shoot under the wing, now tracking a single Drak, still coming at them.

The bowman in the flier on Amarson's left tracked his launcher to support Mardon.

The fliers swept by the Drak and it was still below them. Its raging cry screamed over the engines . . . then the straining wings collapsed, folded and the Drak fell . . . down, behind them, its fighting spear still clutched in both hands.

Mardon had not fired. The Drak had never reached the flight.

On Amarson's left, the bowman secured his launcher and waved, then settled down in the body pod to ride out the rest of the flight.

Amarson's flier cleared the mountain peaks and nosed over to lose height in a long slanting dive along the face of the alps. The rest of the pilots held station on him and followed him down. For twenty hundred-pulse counts Amarson held a steady course and kept up the rate of descent that held him close to the mountain slope. The Younger Sun slowed even more, in its midpassage setting, and seemed to hang in the sky. The Rite of Pausing . . . and the yellow light mixed with the red to change the color of the land below. The wet gleam of the mud sea was visible far ahead of him.

Amarson was searching the ground for two crossing canyons, turning points on his course map. He found them about the time of the Younger Sun's *Point of Pausing,* and, as the sun stood still in its setting arc, Amarson turned the formation steeply and flew over the canyon junction. He headed back toward Base XII.

Now, they were flying parallel to the mountains, just about at the tree

line. As the flight banked into the turn, the flier with the defective spray tank stopped spraying; his tanks empty.

A moment later, Amarson pulled the lever and began to dump his own tanks. The flight tucked in behind him in a wide arrowhead formation; his wingman out to his right and the other four, two to the left and two to the right, behind and above him.

Amarson took a quick glance to check their positions, then brought his attention back to his flying. The ranging bar was no help here. He was flying along the sloping side of the mountains. This was contour flying by eye and instinct alone and it took concentration.

There was another danger, too, and Amarson kept a check on his height gauge. The thermocline was below him at about seven hundred meters. He didn't dare fly through that turbulent air, or the barrier, while he was so close to the mountain side.

So far, the flight and the mountain shoulder they were spraying were high above the thermocline, but Amarson was being careful. This contour flying could take them down a mountain curve and into lower altitudes.

Amarson's spray tanks ran dry and cut off. He signaled to his wingman and a falling plume dropped from that flier. The formation would continue spraying, one flier at a time, to cover the maximum ground here on the mountain watershed. These were the places where the Draks rested on the way home from their hunts. The water draining from these foothills would carry Scientist Lewyll's deadly nutrient to every canyon and valley on the watershed. Death to the Draks! Death would go wherever the spray fell and spread.

The rising falling flight went on minute after minute as the mountain side swept by in a blur. The Younger Sun had set now, in the first of its three daily passages. The Father Sun dominated the sky; its giant disk filling the horizon and rising almost to the zenith. The Younger Sun would rise again about the end of this mission, or so the planning timetable noted. In the meantime, Amarson sprayed death by the light of the Father Sun; a symbolism he found highly appropriate. *Blood only stains the hands,* could become part of this killing ritual, if we needed one, he thought.

The spray plumes switched from one flier to another and fell down through the sky to snag on the forest tops below. The liquid fell on the forest floor, some fell in streams and water runs, but that didn't matter. In time the liquid would end up in the water as it had on the Delane. Then, wherever a Drak camped, or fed, or drank, the death liquid would find it. In the food it ate, in the water it drank, would be Scientist Lewyll's subtle death. The Draks would carry it back to the henges with them. That's where it would kill. In the

mating of the Draks there would be death.

The liquid falling on the forest would be unnoticed, because it was timed to kill the sons of Draks; the next generation. Kill them like the *lenief*; forever. As the falling spray drifted down Amarson was setting a trap; a trap in which no more Draks would be born—ever.

Amarson shuddered a little and took his mind away from the thought. The feathering tails behind his fliers were only a weapon to kill Draks. That was his job; kill Draks!

The tension of the contour scraping flight brought back the uneasy feeling of worry. Something was wrong. Amarson hit the launcher frame to alert Mardon. The bowman

nodded, stood up and began scanning the air around the flier. Amarson kept his attention on the ground ahead, except for a brief glance at his instruments, and over to the last flier on his left. His height was good and the flier was still spraying. It was the last one and its tanks ought to be almost empty.

The bowman signaled, *nothing*, but Amarson kept him at it; on watch. There was something. . . Amarson trusted his combat instincts. Combat! That was it! *Draks!*

He tightened his hands on the controls and his claws ran out. A flight like this should have attracted a lot of Draks. That falling spray could be seen for. . . By the Suns, they had been flying parallel to the Marches perimeter, for hours.

Where were the Draks?

Their swarming had been over for days. the mating and their ground period should be finished, too. There should be clutches of Draks in all the foothill ravines. . . Hunting parties should be out. . .

A combat patrol would ordinarily be fighting Draks all over the sky by now.

The Younger Sun rose again. It climbed swiftly to *Point of Pausing* on its rising cycle. Amarson welcomed the added light. He wanted to be able to see the Draks. The yellow light helped.

Points of light flashed on the ground under the rising sun!

The Draks were ahead! He saw a long line of them first; eight or ten, flying just above the edge of the forest. Then another group, spiraling this time, and in the center of the spiral . . . Draks diving vertically . . . to attack. Their weapons glittered again in the light.

He searched the ground, although he didn't expect to see anything from this altitude. He found a road, then recognized a pattern of meadow and fields. His eye flashed west and he saw—*Base XII.*

Base XII; and above it, spiraling patterns of Draks; evil specks in the sky that grew larger as he watched. There were three, four—no, five of the swirling attack patterns over the Base. He'd never seen so many Draks in a hunting attack.

They were as thick as when they swarmed, but this was no swarm. The Draks were wheeling swiftly in the air. They were making hunting dives and beating quickly back into the spirals.

Aiihee! he caught a flip and flash of color against the background of the jungle and recognized a flier. It banked high in a wing-tip turn and slid back into the milling Draks. His cubs were up fighting! Of course they were. . . And we'll be there to help—starting now!

He drove the nose of his flier down and took the flight away from the mountain side. He signaled, *Land in Pattern*, to them and throttled back to the penetration speed. His flier dropped faster, headed toward the thermocline.

The flight penetrated in good order and tightened up the pattern as close as they could fly. There was no need to signal, *Draks sighted.* Everybody could see them. The sky ahead was filled. Wherever you looked . . . Draks!

Amarson saw columns of them flying toward Riverton. Theiu was in for . . . Riverton! They still had riverfish boats out hunting. They would be unloading cargoes at the docks. The covered docks wouldn't stop hunting Draks. The Rivermen would be caught. . .

Yes, there was another column flying on—heading for Riverton.

By the Suns! The Draks *were* swarming! But not the lazy trance-like flight of their mating ritual. This was new. This was a combat swarm. The Draks flew to kill. All of them; every one that could get in the air. *Aargh!*

Now, the flight was getting close. The Draks would sight the big fliers any time, now. Amarson kept in his dive. He was headed directly at the landing field.

He couldn't fight with these fliers; not even with their fluid tanks empty. He hoped the pilots behind him would remember the plan he'd worked out on the tactic table and stay in close pattern when the Draks struck. He had made the pattern so that the bowmen could help each other with their dart launchers. Those launchers and staying together were the only weapons these big fliers had.

Amarson looked at the fuel weight gauge. The tank was almost empty. The decision was no decision, really. He had to get these fliers out of the air—quick.

He shoved the engine control to full power and flattened his dive toward the end of the field. He took the flight straight in.

Now, the Draks were full size and their armor and weapons were clearly visible. They swirled and braked in frantic effort to fly out of the way of Amarson's flight. He saw a spiral scatter in front of him, as he flew right through it. The dart launchers began to fire. Mardon got a kill. The bowmen had plenty of targets.

A rackety roar distracted Amarson briefly, and he looked up in time to see a combat flier roll over the top of a turn and slide across the sky above the formation. Amarson let his teeth show in a fighting grin. He was proud of those cubs of his. . . They could fly!

A Drak stalled in the air above his wing and was hit by a stream of darts. Amarson saw him die, in a flash, on the edge of his vision. The body hit the top of the wing and slid off. The flier put a wing down with the shock.

Amarson fought the controls and rocked the big flier into contact with the field. The wheels hit before the wing and the tail slammed on the ground—hard, but it stayed down. He pulled back the engine control to

keep on the ground, but kept the speed up, because of the fliers landing behind him. He took the flier across the field, dragging its tail, just under lift-off speed.

In front of him, Mardon swirled the dart launcher and fired. He was still fighting Draks. Amarson could hear his killing-yell over the engine.

Fighting Draks! These fliers with the swivel launchers could fight on the ground! Amarson couldn't fight them in the air, but here, on the ground, he had a new weapon.

He ran straight in, as close to the service tents as possible, but well out of line of the big hangar. The combat fliers in the air—when they ran low on fuel and darts—would have to try to land inside the hangar; just as they did during a swarming. That hangar had to stay empty for them. He couldn't take his big fliers in under cover; they'd take up too much precious room.

Besides, the grounded formation of fliers, their massed fire, seemed to be a powerful weapon. Draks were diving on the fliers but none were getting through. Mardon's bowmen were fighting . . . killing.

Amarson led the flight into position and controlled his engine to stop the flier. He left it running; it didn't turn off Mardon's power. Those launchers had a lot of Drak killing to do and Mardon was firing as fast as he could find targets.

Amarson unfastened his straps and grabbed at Mardon to attract his attention.

"Keep at the launchers!" he yelled. "I'll get you help."

Mardon nodded and stabbed a hand at the dart storage bins. He needed a reload. Well, he'd get it.

Amarson rolled out of the flier in time to meet the chief groundsman jumping out of a truck. It was the truck they had used to train the bowmen—its dart launcher was armed and joined in to support the flier's fire.

"We have fuel in the back, Baron," the chief shouted.

"Tie them down here, Chief!" Amarson ordered. "Refuel and keep those launchers armed and loaded. Don't turn off the motors. The bowmen need power. Understand?"

"Yes. We've been fighting the mount on the truck." The chief signaled his crew. They rolled a fuel drum out of the truck and went to work.

"We are refitting the combat fliers as fast as they come in, Baron," he went on. "They have been ordered out to defend Riverton."

"Good. They can't do much here. Keep them in the air."

Amarson ran out under the cover of a wing and over to his wingman. He slapped the body side and the pilot climbed out. They ducked back under the big wing.

Amarson fell over a thrown Drak spear and rolled forward. His hands grabbed the spear as he rolled and he came up defensively. There was no need. The Drak's body crashed

onto the field; torn and broken by the steel darts from the flier's dart launchers.

Amarson turned and found a Jungle Patrolman beside him. It was the senior Patrolman who had met him in the meadow, so long ago.

"My thought is: I'm playing with cub's toys," the Patrolman snarled, uncocking his dartbow. "That rattler has long claws."

"Senior, get your squad in around these fliers," Amarson ordered. "We've got a fighting fort here. Keep the bowmen armed—and replace them . . . if necessary."

"My thought," the senior Patrolman agreed. "The squad's on your fuel truck." He rolled off to collect them.

Amarson grabbed his wingman. "Get the pilots out!" he yelled. "Keep the engines running and the bowmen on the launchers. These fliers will stay on the ground.

"I want all the pilots at the fuel truck. I'll get them combat fliers and get them in the air.

"Move!"

The pilot nodded and went off.

Amarson ducked under the body pod of the flier and found the fuel truck rolling toward him. He waited for it.

A movement in the sky caught his eye. He looked at it directly and saw four columns of Draks, flying low over the forest. They were headed for Riverton. Riverton.

Riverton; the Rivermen, would be woefully unprepared for this massed Drak attack. They would expect the Drak to be swarming again and slow; instead they would surface their boats under spirals of Draks flying with hunting speed and strength.

There would be dead men in that town by now. Amarson snarled. He needed a flier. He had to get into the air; over Riverton, to plan the fight. This new swarm of Draks called for tactics and team work, not single flier pack fights.

A yellow flier wobbled over the jungle and landed crossfield. It was out of line of the hangar, a sure target for a Drak attack. It flicked its tail up and rushed over toward the massed fliers. Amarson's groundsman was waving the pilot in under the protective fire of the Patrolmen and their deadly dart launchers. Amarson saw the flier and he ran out to help unstrap the pilot and feed the new dart belts into the combat flier's wing racks.

He had to get back in the air—quick!

Scientist Lewyll stared at the Draks through the slit windows in his tower wall. They stooped and swirled through the buildings of Riverton. He could see the diving attacks at the docks—and the kills. His hand clenched the top of the polished wooden box that he had hoped would save Riverton from the killing and death he now saw. Inside the box was his deadly nutrient. *Death of Draks* Baron Amarson had called it.

The whole plan was so futile.

Outside, in the sky, he was looking at . . . Death for Rivermen. There was nothing he could do about it. His wide eyes closed wearily.

"Does that box hold your poison spray, Scientist?"

Lewyll whirled at the voice. The priest, Paudre, stood in the door.

"Paudre–Holiness. . ."

"Yes, it is I. I'm no longer sure 'Holiness' is a word that applies to either of us. We have failed, Scientist.

"I walk through Riverton and let the people see the signs of the Two Suns," He crossed his arms over his chest, displaying the water sprayer he held and a sistrum with sun disks on its wires.

"But the people can't look into my heart and see my failure. All they can see are diving Draks.

"So, I came here, where I can share my sense of failure. . . And I find you looking out at the black winged beasts . . . holding the weapon that failed. . .

"Too bad Theiu and your baron are not here. We could all share our failure."

Lewyll glanced at the map. "Amarson has finished his mission by now, Holiness. He is probably fighting Draks."

"No doubt. Your baron has likely stirred them up into this attack . . . angered them. He has driven them into Riverton." Paudre went over to the window slit and looked out.

"So many Draks–killing. Amarson wouldn't be driving them down on us, would he, Lewyll?"

"No. Oh, no! You are wrong, Holiness. The Draks are swarming. That is all. Amarson had nothing to do with that. Neither did my spray."

"No, I suppose not. I can't blame him. The plan was mine as much as yours, or Theiu's. The failure . . . more mine than yours, for I am supposed to be able to show you the Light of the Two Suns.

"Lewyll. Spray the Draks over Riverton. Kill them." Paudre's voice was low, pleading. "They are killing–feeding on our people. Oh, awful, Lewyll–the lesson Amarson said he could teach us. . .

"Spray them, please! In the name of the holy Two Suns, spray them, and save Rivermen."

"I can't, Holiness. The spray doesn't work that way."

"Aiee!" Paudre's voice dropped even lower. He didn't seem to care whether Lewyll heard him or not.

" 'The spray doesn't work' . . . I remember now. So, I was told. We made the plan to kill life, before it had a chance to live, didn't we?"

"The Draks must die!"

"And so we decided that the two suns will never shine on Drak life. We decided? Who? You, Scientist? By what right?

"And I? My doctrine says: All life has the right to the light of both Suns; Father and Younger. This is the law as the World turns. I? Less right than any."

Paudre turned from the window

and walked to look at the big combat map. His voice when he next spoke was pitched in the half-singing mode he used for rituals.

"Tell me, Scientist . . . how would you change *your spray* . . . to make it a spray that denies sunlight to Rivermen? To Rivermen unborn? Heh? Then to the Valley People, perhaps?"

"You are sick! No one would think of such a thing!"

"You thought of it for Draks, Scientist! When there are no more Draks to fight, your Baron Amarson may think of spraying death over Rivermen."

"Impossible. He has honor."

"I can't take that chance. I am the Priest of Riverton. I cannot leave another mistake that will return to kill my people. It is the only way I know." The priest lifted his water sprayer. "By the Light of the Two Suns."

He covered the table and Lewyll with a heavy spray of water. His voice deepened to intone: "In the Light of the Father Sun, in the Light of the Younger Sun; I deliver the Darkness that Follows."

Lewyll watched him lift the sistrum and set it vibrating. He stared down at his damp clothes and arms in horror. The water was filled with tiny white specks. As he watched, the sistrum's sound went up the frequencies and the water began to boil and steam. The sound heated it.

White specks settled on his clothes. The water dried away from them.

"Paudre!" Lewyll screamed. "Sun Fire! No!"

The white specks began to glow and burn. Lewyll screamed as they ate his skin.

Paudre turned his back. The rising glow and the flames of the table; the brilliance of the burning Sun Fire chemical lit his way down the tower stairs. Lewyll's screams followed him out onto the mole.

Outside, the screaming was suddenly louder. Paudre looked up at a diving Drak; screaming down at him. The priest folded his arms and began a prayer. The bright glow of the Sun Fire still spotted his sight. The sound of the scream was still the voice of Lewyll in his ears.

The Drak broke off its killing dive. It beat its wings for altitude.

A pulsing roar tore the screams from Paudre's ears.

A sun-yellow flier slid down the air, close to the water and pulled up into a climb; driving after the Drak.

The flier pilot fired his dart launchers as he lifted and chased the Drak above the mole. He missed his shot, but the spent darts, fired almost straight up, fell back on the mole.

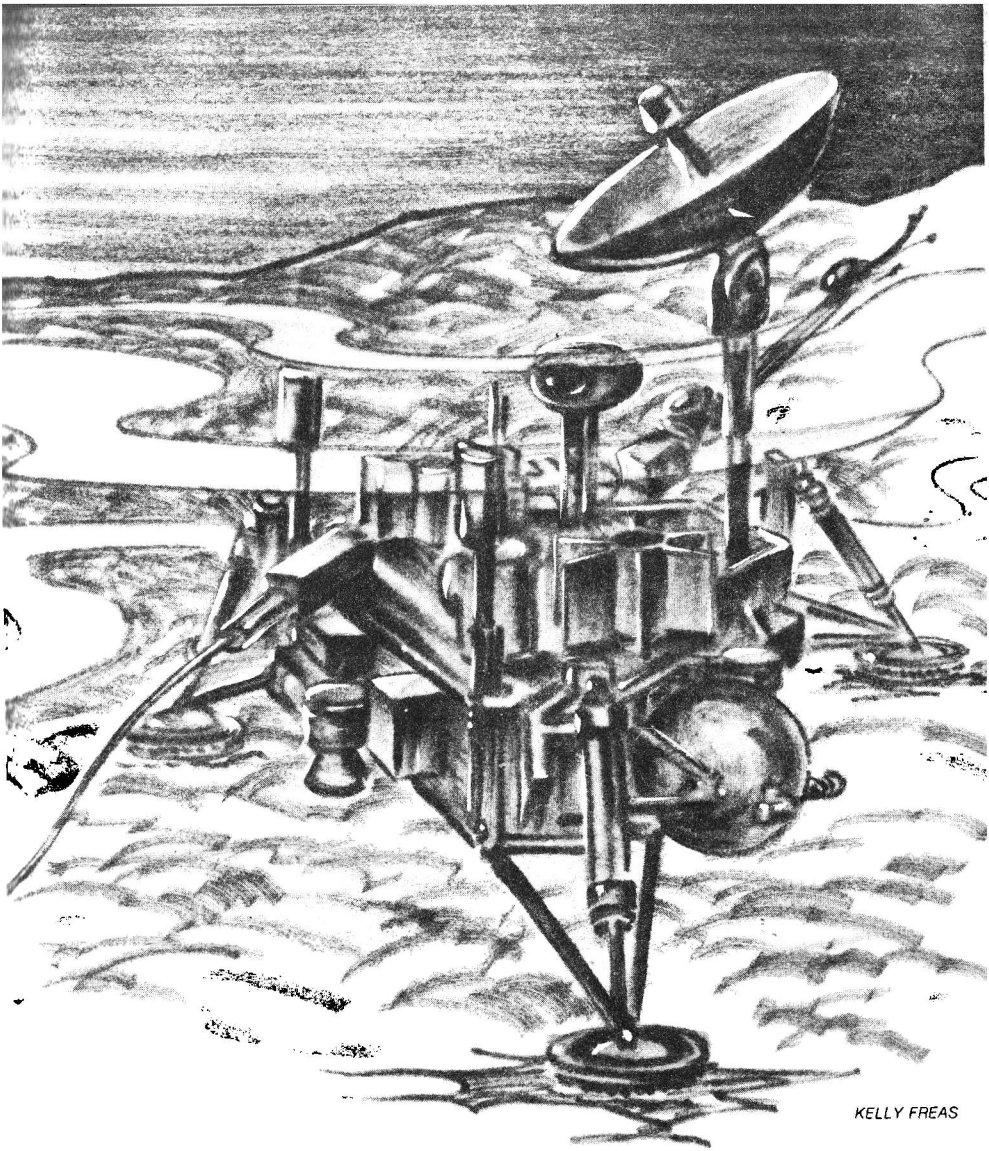
One dart struck Paudre a glance on the side of the head and he fell: Four more pierced his body.

Paudre had a final vision, of the flier rolling into a tight curve, and of a dying Drak, falling from the sky; then the flier blurred into a tiny, yellow Younger Sun. A red glow, as of the Father Sun, swelled behind his eyes and the Darkness followed. ■

lunchbox

Intelligent creatures can recognize the benefits of high technology—even if it's not their own!

HOWARD WALDROP



KELLY FREAS

It came down on a flame toward the gray and red landscape, hissing through the thin air, lower and lower as the dim sun rose up the edge of the planet. The ground below was turning from shadow to sunlight, and the metal eye of the craft reflected the eye and heart of the sun.

It dropped more slowly still, and the pillar under it changed from bright orange to nothingness and shimmer as the propellants burned away and the nitrogen pressure tanks were emptied in the last twenty feet of the drop. It settled with a small thump, and the legs made the machine plumb level inside their hydraulic casings.

The planet was quiet and still.

The sun beaded the horizon in the deathstill frosty calm of dawn.

Man's first claim to daybreak on Mars.

The noise rose from stillness to roar to pandemonium inside the Mission Control Room. Cigars were passed around, papers were thrown into the air, the unloosed tension went from desk to desk. Checklists fell like snow in the cyclone of the room.

Then the men resettled at their consoles, ready for the Big Broadcast of 1977. Above them, television commentators were telling the public that what they had just seen was a celebration by the men at the consoles because the first of the Viking series had landed on the red planet, Mars.

Krvl, resting in their den, heard the scream of a ruined xr. Parts of Krvl roused, other parts remained dormant, others were reproducing in a random manner, ready for the formation of a motherbud later in the day.

Krvl shifted himself sluggishly, aware that something was amiss. Xrs roamed at night, and by the slight pulsing in its head, Krvl knew it was dawnlight—when xrs should be dying. They did not scream when they died. And what but an xr went about at night?

And what, except the Kind, destroyed xrs?

Krvl paused/moved to the chute-tube of the den. It availed themself of an xr pouch and slid out, leaving its reproducing self behind.

Outside, it was a wonderfully murky morning.

The first photographs from Mars showed a hummocked landscape of powdered sand and clay/grit sized particles. The scanning lens mounted atop the module showed the hummocks. The close-up lens in the bottom of the Viking showed the clay-sized particles.

The scanning camera on top turned completely every two minutes. It recorded a scene each twenty degrees of arc and sent them back after two minutes of rumination within the devices that made up the innards of the Viking.

The pictures were marvelously sharp and clear, and showed a rolled

landscape of dunes. Readings gave back a temperature of –27°F but the temperature was slowly rising in the fairly bright morning sunlight.

Krvl seeped across warm dunes. He would have to hurry to gather xrs before they died completely in the hot burning sunlight that would come in an hour. Krvl liked to hunt in the morning better than the evening, though chances of getting a near-live xr were much less. This morning, Krvl also wanted to find the thing that had made the xr scream. He had heard a small sound like it often when he retrieved a half-live xr for his meal from the ice vein that ran through his den. But never from above, in the open, at night, that loud.

He suggled down a dune. Already it was warmer. In thirty minutes the heat would become unbearable. He *would* have to hurry. Krvl liked the summer least of all the times.

He came into view of the xr crawl.

The close-up lens of the Viking began to turn slowly, photographing then relaying pictures back to Earth. First was a photograph showing the third leg of the Viking which showed a discoloration, a darker smudge protruding from beneath the landing leg. When the photograph was relayed a matter of minutes later, the interpreters became tense for the first time. They immediately sent signals to the machine to take a much closer series of pictures of the third leg of the craft.

The scanning camera, meanwhile, showed a patch of darker smudges in a dip between two dunes.

Excitement ran high. The bottom of the Viking opened and a long sticky string uncurled on the ground. The interpreting people got down to work.

They tried to get the long string as near as possible to the third leg of the craft. They tried, but got no closer than four inches.

The string withdrew up into the craft like a long tongue.

The xrs had shifted a lot during the night. Krvl came over the dunes and saw the thick webbing of them strewn over miles and miles of desert.

He opened his pouch and began gathering them up, putting them inside with the small ends up. He would look back ever so often, and those that had not moved their large ends up, he took out and dropped back to the desert. The sun was very very warm now.

He would have to hurry, or they would lose the rebirth fluid into the air through evaporation.

The instruments in the craft showed a temperature at minus eleven degrees Farenheit as the first of the sample gatherers was fired towards the darker smudge between the two dunes. The small rocket was propelled by liquid nitrogen pres-

sure, and as it left, the nitrogen compressor, powered by the same nuclear generator which ran everything on the craft, sucked in more air from outside, to compress and liquefy.

The small rocket arced out, between the dunes, and landed amidst the darker tones of the camera lens. It sat a few moments, the last of the nitrogen bubbling off, and then a small grapple and net affair slid out, scooped, opened and closed. An activator signaled for the craft to start the winch that would draw the collector back.

Krvl straightened at the sound. A high thin pop, and then a thud quite near. He looked in the direction of the sound.

There was a slight hiss. He saw deepfrost form around a depression in the midst of the xr crawl. As he watched, xrs began crawling toward the depression, first a few, then more and more, then a virtual riot of them. And with the sun blazing.

All thoughts of xr gathering were forgotten. This was a new and strange thing. As mysterious as the xr scream early this day.

He/she/it walked toward the moving xrs. Krvl scanned the horizon for other signs of strangeness. Out a ways, between the nearest dunes, he saw a much larger depression, and a solitary, curiously flattened xr. More newness.

He stopped. A group of xrs was being gathered, folded, compacted, crushed into a tight mass before him. The folding stopped. Then the mass moved, without walking, toward the edge of the xr crawl.

Krvl looked and watched and followed, but could not decide what or how this thing happened.

An invisibility. He reasoned.

Krvl pulled out his twelfth and thirteenth Haze eyes.

He stopped at what he saw. His Haze eyes were good only when the air cleared and the Hazelight came down. Using them now, though, he could barely make out the countryside, but was taken aback at the other thing he saw.

A creature sat far off between the two dunes. With one of its feet it was standing atop the crushed xr, and had extended a claw from itself into the xr patch, where the claw had scooped up some of the things and was pulling them back towards itself.

Carefully, Krvl followed the claw as it was pulled back into the Haze creature. It had no business bothering his crawl.

The scanning camera showed the collection rocket being pulled back into the Viking. Then the series of landscapes as the camera rotated. Then the rocket, winched closer, and behind it the drag path where the grapple had slid through the sand.

Then more landscape. Then the rocket, still closer. One of the interpreters asked that the camera be frozen on the winching process next time around; he thought he had seen some interesting phenomena. The

camera came around. The rocket was close, closer. There were marks behind the dragging grapple which did not seem to be made by its passage. Then the rocket was pulled within the innards of the craft. Then there were more markings on the ground.

The interpreter leaped up.

Some of the monitors showed activity within the spacecraft.

The last picture was sideways.

All was black.

Krvl had followed the claw until the creature pulled it inside itself. Then he looked at the Haze creature, sitting very high on its four appendages. It looked at him through its single eye.

Krvl gave it a universal greeting, while he assumed a warning stance. It did not move.

Krvl touched it. Nothing happened. Perhaps it was dormant while digesting its food.

Krvl pulled at its leg, lifting it from the ground.

Immediately the creature hissed, and sent its leg forward to the sand. A shower of dust flew up, and the creature rocked and settled on its legs again in the same relative position.

Krvl was very wary now. He asked it why it had entered his domain without respect. It did not answer. He pulled at its leg again. This time it moved violently, rocked toward him and back, sending up a great geyser of sand.

It would not do, Krvl decided, to have a mindless creature threaten one's food supply.

Krvl took action. The eye was always a good place to start.

On earth, consternation.

That afternoon, a Kind called Mrgk stood respectfully at the edge of Krvl's crawlpatch and asked to come visit.

Krvl was happy to see them again. Mrgk came in and smelled the xr smell, cold and delicate, on his sensors.

"To devour the xr," said Mrgk.

"To devour the xr," answered Krvl. "I have a new thing to show."

"What is it?" asked Mrgk.

"You will have to use your Haze eyes," said Krvl.

The Analytical Laboratory/February 1972

PLACE	TITLE	AUTHOR	POINTS
1.	A Spaceship for the King (Pt.3)	*Jerry Pournelle*	2.11
2.	The Sword of Cain	*Henry Sauter*	2.35
3.	Fido	*William J. Frogge*	3.00
4.	Genesis 500	*Robert F. Young*	3.51
5.	One Man Game	*Joseph Green*	3.74

They went into the den, to the back, near Krvl's xr bin.

"Here," said Krvl.

It lay on its back, legs up.

"This is most strange," Mrgk said. "What can it be?"

"I think it some sort of creature of the Haze," answered Krvl. "I found it raiding my crawl this morninghunt."

As they watched, the creature let out a hissing scream. It's legs thrashed in and out, moving up and down, trying to find footing in the air. Just as suddenly, it quit.

"Can it hurt us?" asked Mrgk.

"I think not," said Krvl. "I blinded it before I brought it back to my humble denning. Or I thought I did. It struggled fiercely much as you just saw, on the way back. I later found a smaller eye on its nether side, which I also removed."

"It has no other appendages?" asked Mrgk. "Four seem such a small number."

"It had." answered Krvl. "Six more clawlike devices, tightly wound inside. I discarded those also, fearing they could be harmful." He indicated a tangled pile of loops and grapples. "I believe it to be fully incapacitated now, though seemingly able to live somewhat, like the xr. It moves from time to time."

"This is a most wondrous creature. We shall have to tell the other Kind."

"I will take it to the next Meet," said Krvl.

"Very strange indeed."

"I have not yet shown the best part," said Krvl modestly. "After rendering it helpless, I cracked its shell. Inside I found a wonderful newness. Note its stomach is very cold?"

Mrgk bent close, saw the deepfrost forming on its insides.

Krvl dropped a stiff xr into the body. In a few seconds, it swelled, grew, moved, began running about, trying to climb out the slick sides.

"Simply marvelous," said Mrgk.

"I think this Haze creature was able to make its stomach very cold, so that it could ingest fully live xrs. Imagine," said Krvl.

"But will it not lose this ability?" asked Mrgk.

"I think not. It remains the same as this morninghunt. It has lost none of its coldness," answered Krvl.

"Then it is a wondrous find. Wondrous. We shall be able to place xrs in it and then ingest them fully live ourselves. Oh, I can imagine the taste already!"

Mrgk paused. "Do you realize every Kind will try to find one of these Haze creatures, so they will be able to rejuvenate their xrs? You'll start a craze, Krvl, a positive craze."

Krvl was pleased. Buds formed quickly on his back.

In front of them, between the four legs, the nuclear generator hummed and the compressor pockpocked, making more liquid nitrogen. The legs suddenly hissed and moved, searching back and forth for footing in the air of the den. ■

CELESTIAL MECHANICS

If you wonder why the astronauts don't whip out their trusty slide rules and quickly compute a new orbit when something goes a little wrong—try this basic course in "Celestial Mechanics and why it drives people nuts." There *is* a solution to the three-body problem . . . only it can't be worked out. To catch up to a ship ahead of you in orbit, you must slow down! Rowland E. Burns is a NASA orbital mechanics mathematician and knows the frustrations of which he speaks.

BY ROWLAND E. BURNS

CELESTIAL MECHANICS

In one of the more perceptive science-fiction stories of recent years Isaac Asimov describes a planet which is associated with a system of six stars. This story, "Nightfall," deals with the collapse of a civilization which occurs once every two thousand and forty-nine years when darkness descends upon a planet which otherwise lives always in light. The fundamental point of this story is the profound interaction between a civilization and the local celestial mechanics of a star system. The psychological, social, and even religious aspects of Asimov's imaginary culture are shown to follow in large measure from celestial mechanics.

Most people would agree that the variations of the seasons, length of the year, weather, and various other manifestations of the geometry of the Earth's path about the sun have had similar effects on our everyday mode of thought. It seems to be less well-known that much of our philosophy, most of macroscopic physics, and all but the most recent of our mathematics have proceeded from the same source.

Specifically, applied mathematics has followed what is generally known as an analytical bent. By this we mean that the end product in the study of a mathematical problem is a formula which relates the variables of the problem, not a numerical answer. It is only quite recently that the advent of large computers has produced the field of numerical methods as being a field which is respectable in its own right. The historical inertia of analytical mathematics is so strong that most new college graduates go forth into the real world with a belief that mathematical problems of the real world can be solved analytically.

The basic impetus behind the surge of analytical mathematics lies in the fortunate complexity of the two-body problem. The two-body problem was first formulated mathematically by Newton after discovery of the inverse square law of gravitation. By way of definition, the two-body problem is the mutual motion of two material objects which are either point masses—a mathematical fiction—or perfect spheres—no less a fiction—which attract each

other with a force proportional to the product of their masses and inversely proportional to the square of the distance between them. This problem was sufficiently difficult that the invention of much of mathematics was necessary to describe the motion, yet sufficiently simple that there was hope for such a solution. Thus, the "fortunate complexity."

In order to better understand the mechanics of a two-body problem, let us imagine the following thought experiment: Imagine, if you will, that you are located in a universe which is quite empty except for a massive perfectly spherical perfectly homogeneous planet and a smaller projectile which fits the same criterion. You, as a massless ghost, are equipped with an equally massless gun and a quantity of massless powder. In the course of the experiment you are to load the projectile—or bullet—into the gun and fire it with varying amounts of powder. The bullet is to be fired while standing—better, lying—on the surface of the planet.

Suppose that the first powder charge is quite small. The bullet will travel a short distance and, due to the attraction of the planet, impact the surface. (Keep in mind that no air exists in the make-believe universe, so no air drag will slow the bullet.) If the bullet is now reloaded into the gun with a larger powder charge, it will travel farther before impact. After each shot, as the bullet speeds away faster and faster, the curvature of the trajectory of the bullet comes closer and closer to matching the curvature of the spherical planet. Finally, at a critical powder loading, the curvature of the trajectory of the bullet exactly matches the curvature of the planet. Impact will never occur; an orbit has been established.

This orbit will be a perfect circle under the idealized conditions that have been postulated here. But, as most people know, other types of orbits are possible. Even under the conditions stated above we can obtain not only circles but ellipses, parabolas, and hyperbolas as well. It is interesting to consider these geometric figures from two points of view. The first point of view is purely geometric and was known long before Kepler discovered the laws of planetary motion. The second point of view is dynamic and dates from Newton.

To proceed with the geometric point of view, we shall temporarily disregard our ideal universe and instead consider an idealized ice cream cone with perfectly smooth sides. In order to proceed with the geometrical discussion it is first necessary to make a few definitions about a cone. The tip of the cone is simply the point and any line through the tip which stays in the surface of the cone is called a generator of the cone. A line which passes through the tip of the cone and bisects the angle at the top of the cone is called the axis of

the cone. These quantities are shown in Figure 1.

If we now take a sharp knife and cut through the cone perpendicular to the axis of the cone, the perimeter of either half of the resulting figures are circles. If we had chosen to cut the cone at some angle other than in a plane perpendicular to the axis of the cone, other figures would have resulted. For example, if we choose to cut the cone at some angle such that the knife blade will emerge from the other side of the cone, an ellipse will result as the perimeter of either of the two pieces that are formed. If the angle of cut had been chosen in such a way that the plane of the cut exactly paralleled the generator of the cone on the opposite side of the cone, the resultant figures would have had perimeters in the shape of parabolas. If the angle of cut is even steeper than that used to shape a parabola, the resultant pieces will have hyperbolas for perimeters.

It is most interesting to note that a considerable degree of freedom exists in the choice of the angle used to generate either the ellipse or the hyperbola. In the case of the circle, or parabola, no such choice exists; one angle, and only one angle, will do the job. This situation has an analogy in the dynamic case which will be pointed out below.

Figure 1 illustrates the various conic sections which result from the cone cutting procedures just discussed.

Having dispensed with the geometric definitions of the conic sections let us proceed to the dynamic aspects of conic orbits by performing additional experiments on the previously discussed imaginary planet.

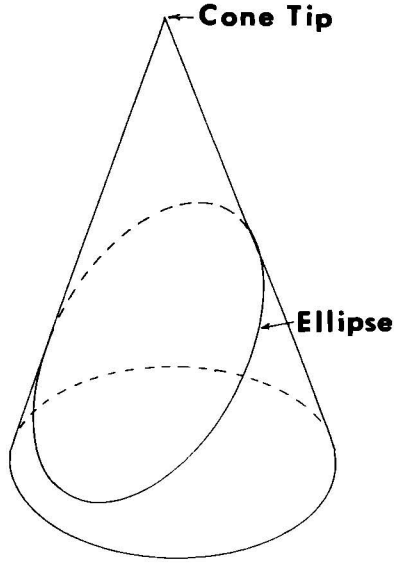


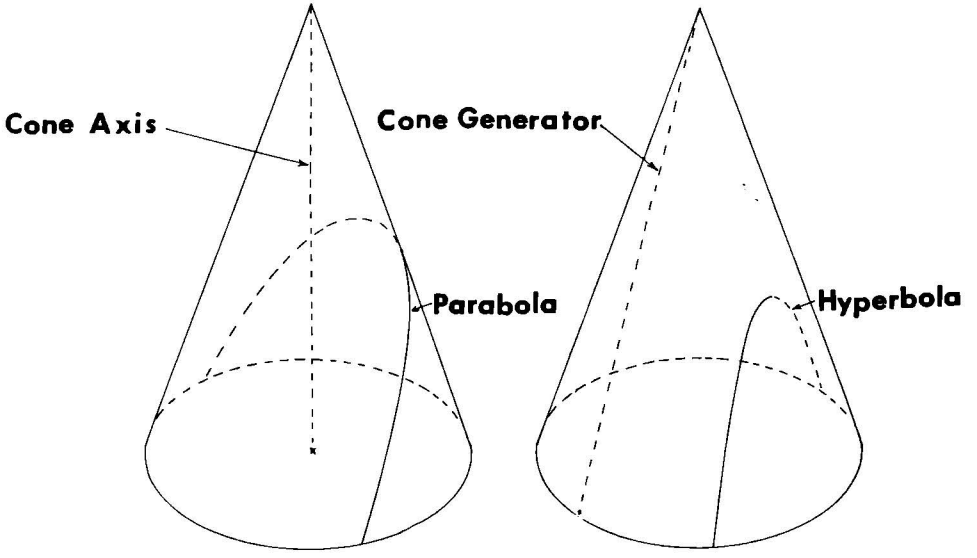
Figure 1

THE CONIC SECTIONS AND DESCRIPTORS

In the initial set of experiments it might have seemed reasonable to record the amount of powder charge which was used and then record the length of time which was required for the projectile to return to the starting point. For the first experiments no real correlation would have been observed since the planet interfered with the projectile and it never returned. Finally, a critical powder load did return the bullet to the firing site and it could be argued that a further increase in powder loading should be expected to decrease the time until return of the bullet just as a car traveling at 70 mph could be expected to circle the globe in less time than one traveling at 50 mph.

'Taint so.

Consider the energy that the bullet possesses when it is fired. Energy is divided, as usual, into two parts. The first part of the energy is called kinetic energy and is measured by the velocity of the bullet. The second part of the energy is called potential energy and is measured by the distance of the bullet from the center of the planet. In the case of the circular orbit which was first generated, the kinetic and potential energies were individually constant since a circular orbit maintains a constant height above the surface of a planet. Once we gain more velocity than the precise value which a circular orbit demands—by increasing the amount of



the powder charge—only the sum of the kinetic and potential energies are constant. The bullet has excess kinetic energy and it begins to immediately convert it into potential energy. Directly opposite the launch site, after traveling through a central angle of 180° the bullet passes through the point farthest from the planetary center and begins to descend. It is now converting potential energy, bought at the expense of kinetic energy, back into kinetic energy. This process continues through all time and we have established a periodic elliptic orbit.

One of the most important points of the preceding discussion is that the velocity which the bullet has at the firing point is *not* retained throughout the orbit. The bullet is fastest at the point nearest the planet and slowest at the point farthest from the planet. Furthermore, it is geometrically obvious that the bullet must traverse a longer path length while in the elliptic orbit than it did in the circular orbit. The combined effects of the lowered speed and longer path length result in a longer time of return with increased initial velocity. This effect is seen to be more pronounced as we continue to increase the initial velocity. The sum total is the paradoxical result that the faster we initially fire the bullet, the longer it will take until the bullet returns!

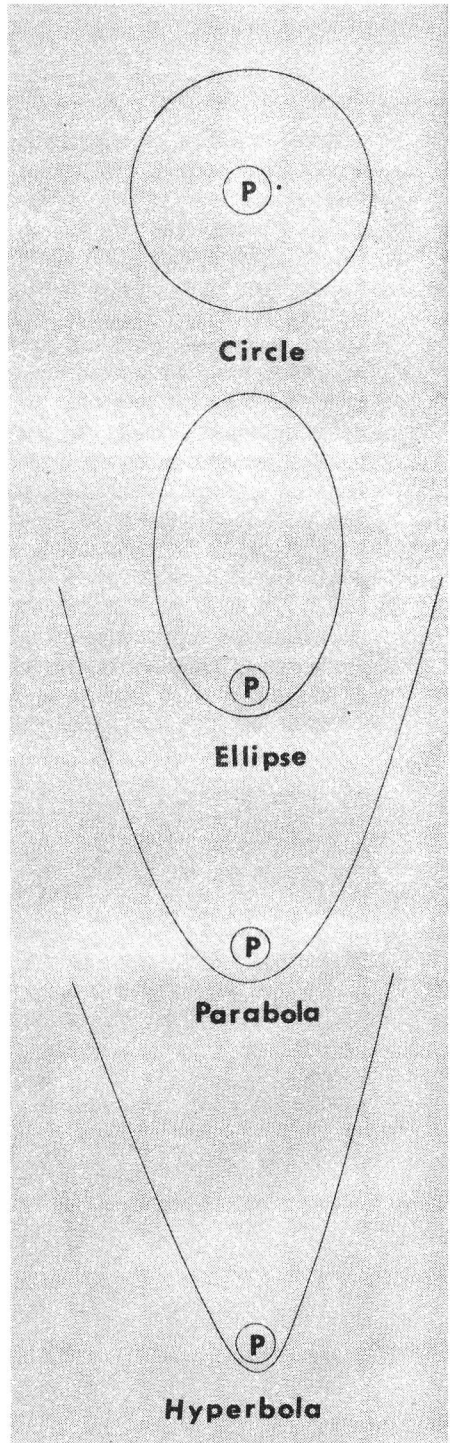


Figure 2 CONIC ORBITS
P = Planet

Just as there was a critical slicing angle that we could not exceed and still obtain an ellipse in the geometric case discussed above, there is a critical powder charge that we cannot exceed and still obtain an ellipse in the dynamic case. If the initial velocity becomes too large we move from the realm of the ellipse to the realm of the parabola. In the case of the ellipse it was pointed out that the velocity at the highest point decreases as the initial velocity increases. It is possible to define a parabola as a figure that has a zero velocity at the highest point . . . but in this case the highest point will be an infinite distance from the center of the planet. At a critical powder loading the time before the bullet returns becomes infinite since the arc length suddenly becomes infinite and, at the apex of the trajectory, the velocity becomes zero.

If the value of the powder charge is increased beyond the value required for a parabolic orbit, a hyperbolic orbit will exist. The hyperbola, like the parabola, is not a closed figure and the bullet will never return, of course.

The velocity at infinity is not zero in the case of a hyperbola, however. In this case even at an infinite distance the velocity still has some non-zero value. (Hyperbolic orbits are often used for interplanetary probes leaving Earth and are sometimes categorized by their "hyperbolic excess velocity." This measures the amount of velocity which the probe would have at infinity, even though it could never arrive at that point.)

It was earlier mentioned that there was an interesting correlation between the exact slicing angle required in the case of generating the circle and parabola in the cone slicing exercise and the dynamic description of our orbits. That correlation is now clear. In the case of these two figures an exact value of the powder charge is required but in the case of the ellipse and hyperbola there is a range of powder charges that will still produce the latter two figures.

Figure 2 illustrates that origin of various conic sections from our imagined experiment.

With a rather few exceptions which will be specifically mentioned, the remainder of this article will be concerned with the ellipse. This is because ellipses are closed figures which account for most real orbits. The open conic sections—the parabola and hyperbola—could be covered but tend to muddy the water by consideration of each case. The circles are special cases of ellipses and most of the comments made about ellipses will apply to that case.

A few definitions about ellipses are in order. One of the more important points is that of the focus. Each ellipse has two foci and one of the more common definitions of the ellipse comes from the property that the sum of the distances from the two foci to any point on the perimeter of the ellipse is a constant.

The attracting planet for any orbit is always located at one focus of the orbital ellipse—which always leaves one empty focus. It does not matter which focus is occupied by the attracting planet, but once we chose such a focus we must keep the planet there.

Another term that is frequently encountered is that of apopoint and peripoint. Apopoint refers to the point of the orbit farthest from the attracting center and peripoint to that point of the orbit closest to the planet. These words are usually encountered with a suffix which additionally indicates a particular planet such as perigee for the Earth, perilune for the Moon, et cetera. The introduction of the generalized suffix-point seems defensible on the grounds of clarity. Furthermore, when satellites are established in orbit about Venus the term periveneral would surely be misinterperted by all but the most dedicated astronomers.

The semi-major axis of the ellipse is one half the sum of the peripoint and apopoint distances. This measures the length of the ellipse along the longest axis of the ellipse. The eccentricity of the ellipse is a measure of the flattening of the ellipse. An ellipse with an eccentricity of zero is perfectly round, i.e., a circle. An ellipse with an eccentricity of 1 is perfectly flat, i.e., a straight line.

Thus far we have considered nothing but the geometrical shape of the orbits which result from a two-body problem, specifically the ellipse. It remains yet to describe how this orbit is located in space by standard astronomical specifications. This description may be given in a number of ways and various workers have had various descriptors which they personally preferred. The set given here is the so-called classical set and has the advantage of being intuitive. The following discussion is illustrated by Figure 3.

Imagine a point fixed anywhere in space. About this point we wish to explicitly define an orbiting body which we assume to be in an elliptic orbit. The first two descriptors which shall be assumed given are the eccentricity of the ellipse and the semi-major axis. Place one focus of this ellipse at the center of the attracting planet. If this is pictured as a geometric construction it is apparent that the ellipse still has a considerable degree of freedom to flop freely about the fixed focal point. We now proceed to specify other parameters to remove this freedom.

Imagine that the planet at one focus of the ellipse is rotating about some fixed axis in space. This defines the equator of the planet and the plane in which the equator lies is convenient as a reference. If we now fix the angle between the orbital plane and the equatorial plane of the planet—the angle is called the orbital inclination—the orbital ellipse has far less freedom to "flop." The inclination is the third of the classical

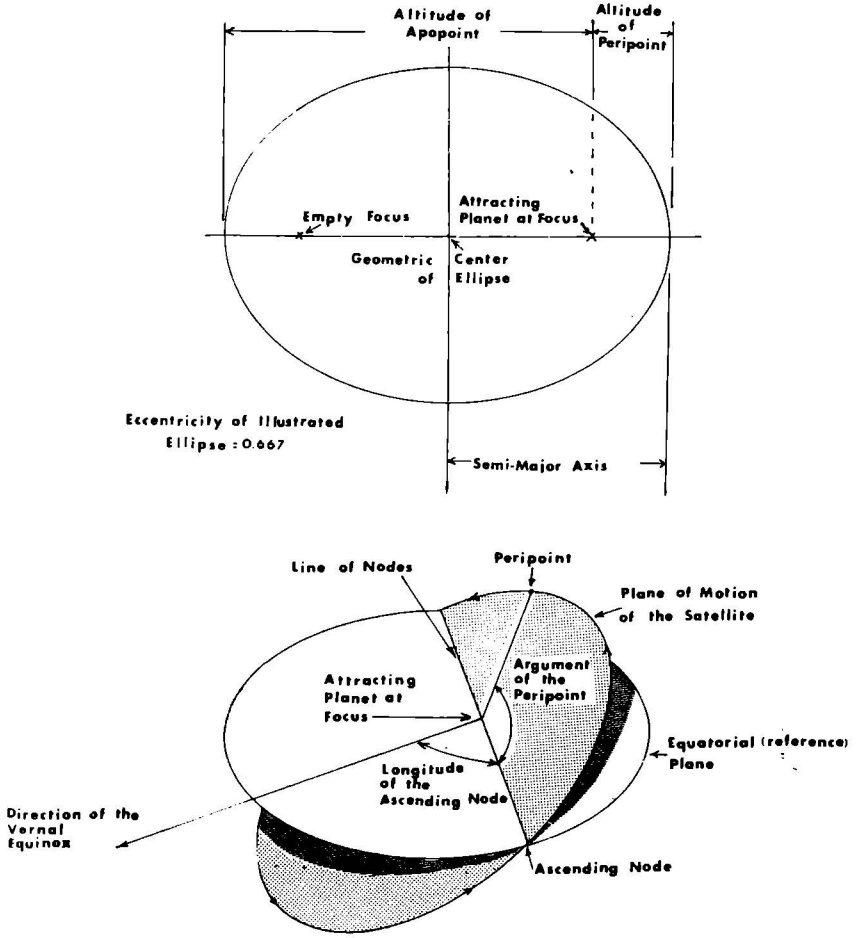


Figure 3 ORBITAL ELEMENTS

orbital elements and has equal standing with the eccentricity and semi-major axis.

Thus far we have not defined the top and bottom of the planet. Define these arbitrarily—imagine that we simply point an "x" at one pole of the planet and call that the top. There are now two points at which the satellite moving in the elliptic path will pierce the equatorial plane of the planet. Call the point at which the satellite moves from below the equatorial plane to above the equatorial plane the ascending node and the point at which the satellite moves from above the equatorial plane to below the equatorial plane the descending node. A line drawn between these two nodal points is called the line of nodes. The line of nodes is not, in itself, an orbital element. A moment's reflection upon our construction to date shows that we have not yet specified the direction in space where this line of nodes must lie. This direction is specified by an angle between the line of nodes and a fixed direction in space such as the vernal equinox. The angle, called the longitude of the eccentric node, is another orbital element.*

The orbital plane is now almost completely oriented. One final degree of freedom that must yet be eliminated is that the orbit can turn about an axis through the focus and perpendicular to the plane of the orbit. To remove the final degree of freedom we specify the angle between the line of nodes and a line drawn from the peripoint to the center of the attracting planet. This angle is called the argument of the peripoint and is the fifth orbital element. Once these five quantities are specified the orbit is uniquely oriented in space.

The usual problem is not just to locate the orbit in space but rather to locate the exact position of a satellite, or planet, in the orbit. In order to locate the exact position of the satellite in the orbit at any given time we must know where it was at some time in the past. For this reason the final orbital element is the time of peripoint passage. Once these quantities are all specified—the semi-major axis, the eccentricity, the orbital inclination, the longitude of the ascending node, the argument of the peripoint, and the time of peripoint passage—then the position of the satellite in the two-body problem is known for all time.

It was earlier mentioned that the classical orbital elements which we have just described are one of the favorite ways of describing an orbit, but they are not the only way. One alternative to this set is simply to specify the three components of position and three components of velocity, again six quantities as before. Each of these two sets of elements

* The standard symbol in the literature for the longitude of the ascending node is Ω. This symbol is a printer's nightmare since it is so rarely used. A few years ago one of the sets of the proceedings of the International Astronautical Congress were delayed over an argument as to whether or not the capital Greek omega could be substituted for this symbol.

have advantages and disadvantages. The classical elements can experience singularities. For example, the argument of the peripoint is not defined if the orbit is circular and thus has no peripoint. The position and velocity designation do not experience singularities but have the disadvantage that they give no intuitive feel for the size and shape of the orbit. Very often this latter designation is useful for computers.

Since the orbit has now been described in general, it is possible to specialize the discussion to two very specific orbits which are of interest. These orbits are the equatorial orbit and the polar orbit. We begin with the equatorial orbit. In both cases we shall further restrict the discussion to circular orbits to simplify the arguments.

At the outset of the discussion it should be remembered that the rotational velocity of the Earth is unrelated to the mass of the Earth. The mass of the Earth and the altitude of the orbit determine the period of the satellite orbit and the fact that the Earth rotates in twenty-four hours in no way depends upon either the mass of the Earth or, of course, the altitude of the satellite orbit. It is thus a pure accident that low orbit satellites—say on the order of 100 miles altitude above the surface of the Earth—complete an orbit in less time than it takes the Earth to rotate about the polar axis. If we now recall that orbits of higher altitude produce longer periods for the satellites which lie in them, it becomes apparent that a satellite with an altitude of 1,000 miles will have a period closer to the rotation period of the Earth than one in orbit at 100 miles. This slowing of the period of the orbit shows that eventually we shall reach an altitude such that the time required for the satellite to circle the Earth is exactly the same as the time that is required for the Earth to rotate about the polar axis. This altitude is 22,300 miles.

It should be noted that a satellite period of twenty-four hours does not depend upon whether or not the orbit is equatorial. It is perfectly possible to launch a satellite into an orbit having an inclination of, say, 30° which has a twenty-four hour period. The sub-satellite point will, however, trace a line on the Earth which is bounded between the north and south latitudes which are numerically equal to the inclination of the orbit. Thus, a satellite is a twenty-four hour period altitude and an inclination of 30° will trace a line from thirty degrees north latitude to thirty degrees south latitude *along a line which is perpendicular to the equator.* In order to establish a satellite which appears to hang motionlessly in the sky it is now only necessary to reduce the inclination to zero—i.e., establish an equatorial orbit.

One final point about geostationary orbits should be made. It was mentioned in the general description of orbits that the center of the at-

tracting planet must lie at the focus of the orbital ellipse—or the center of a circular orbit. It is this reason that makes it impossible to establish an orbit which lies in a plane which is parallel to the equator. Such a plane is exactly what is required to establish a stationary satellite over a nonequatorial site such as Chicago, for example. In passing it can be noted that an equatorial orbit at an altitude of 22,300 miles has such a large "look angle" over the surface of the Earth that even if a satellite could be established in a fixed position over Chicago it would accomplish virtually nothing that could not be accomplished from a presently existing equatorial stationary satellite—unless observation of the polar regions is of prime importance.

The second type of orbit which we will discuss in some detail is that of a polar orbit. A polar orbit, by definition, passes over both poles of a planet, be it Earth or some other planet. Polar orbits are usually used for observation such as close studies of cloud cover and are important because every point of the planet is subject to close surveillance. To understand this point we begin with the assumption that it is easier to observe something when you are close to it than when you are farther away. In other words we want satellite orbits of low altitude. As in the equatorial case a low-orbit satellite means a relatively short period as well as a small look angle. Since the orbit passes over both poles it will cover a narrow strip from the north pole to the south pole then back to the north pole. But during the time that the satellite has completed an orbit and returned to the north pole the Earth has turned about the polar axis a few degrees. The satellite then observes a new strip of terrain on the next orbit. This continues until the entire surface of the Earth has been observed.

It is interesting to contrast the terrain view from a low-altitude equatorial satellite with that of a low-altitude polar satellite. If we consider an equatorial satellite starting at some specific point over the equator such as the Galapagos Islands—it is amazing how few well-known places one finds on the equator—then on the first orbit the satellite will photograph a narrow band about the equator. By the time that we have returned to our starting point over the Galapagos Earth will have rotated about the polar axis . . . but this simply changes the time that we pass the starting point. The terrain viewed on the next orbit will be exactly the same as that passed over on the first orbit.

Thus far we have only established, intuitively, the fact that an orbit can exist, the forms that orbits can take, the parameters used to describe the orbits, and two special cases of orbits. This, in simplest terms, is the area which was of interest to the classical astronomers who were interested in natural bodies such as stars, planets, comets, and natural

satellites. The advent of artificial satellites has introduced the notion of orbit modification which was never even considered in the classical literature.

There are many reasons why it is desirable—and even necessary—to modify satellite orbits. Following launch, the entire Apollo mission is basically a question of orbit modification as is the establishment of an equatorial twenty-four hour satellite. Before proceeding to the actual techniques of orbit modification insofar as flight mechanics is concerned, it is well to remember that the basic tool used in accomplishing such modifications is the rocket motor. A number of different types of motors have been used for orbit modification depending upon the circumstances. The case of "station keeping"—i.e., making sure that small perturbative forces do not destroy an established orbit—is usually handled by small jets of compressed gas. The ion engines, which produce very low thrusts for very long periods of time, have been proposed for some special applications. In this article we shall be concerned with a third type of rocket motor . . . the so-called high-thrust chemical engines which produce spectacularly large orbit changes in very short periods of time.

The fact that these engines produce very large changes in velocity in very short times gives rise to a rather common mathematical approximation known as impulsive orbit transfer. The amount of propellant used in changing the velocity between two orbits is usually not given directly as a measure of how "expensive" the transfer is, since the pounds of propellant necessary to effect the transfer depends upon the type of propellant that is used. Instead, the velocity difference between the orbits is specified and this number, known as "delta V" is independent of the type of rocket used.

It is important at this point to carefully define a word which is often used in a nontechnical sense. We wish to distinguish between the terms "velocity" and "speed" even though they are often used interchangeably in common speech. Technically the two words are quite different. Velocity is a vector, that is, it is specified by both a magnitude and a direction. Speed is a scalar and can be completely specified by a magnitude. Thus we could say that an automobile has a speed of seventy miles per hour but to say that it has a velocity of seventy miles per hour makes no sense. A direction must be added to this second statement and made to read something like "the auto had a velocity of seventy miles per hour heading due north." It is easy to see that two autos which have the same constant velocity can never collide, but two with the same speed could easily destroy each other. It is intuitively apparent that to turn the velocity of an automobile through some given angle requires an expenditure of fuel even though the

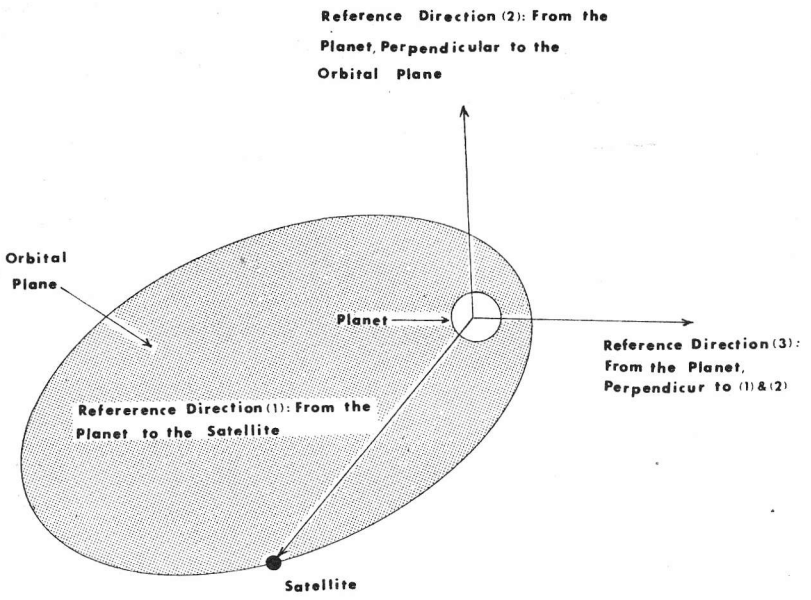


Figure 4 THRUST REFERENCE DIRECTIONS

speed may be the same before and after the turn. A similar case holds in the case of orbital mechanics and just because a satellite has the same speed before and after a maneuver in no way indicates the delta V which has been expended in the transfer.

Having dispensed with preliminary definitions we are now in a position to discuss the fundamental problem of orbital transfer mechanics. We are given an initial set of orbit elements, a desired set of orbit elements, and a rocket engine capable of delivering a certain delta V—which measures the fuel on board. The delta V may be added in any desired number of impulses as long as the total does not exceed the given reserve. We must find the position in space where the rocket engine is to be fired and the direction of firing at each firing point in order to transfer from the initial set of orbit elements to the final set of orbit ele-

ments . . . but we must perform the entire set of maneuvers in such a way that a minimum amount of fuel is expended.

This problem may not appear difficult at first sight but appearances can be deceiving. It is so difficult that no fully general solution has ever appeared. A few special cases have been solved . . . and these may be used as the basis for educated guesses in more complicated cases. The guess must then be checked on a computer for verification. A point to be kept in mind is that the problem stated above is simply the mathematical bare bones of a realistic orbit transfer problem.

In the real case additional effects must be recognized. For example, air drag can severely limit results which are predicted theoretically, and such areas as the van Allen belts must be strictly avoided. An additional complication can come from psychological requirements such as the chase vehicle in a rendezvous situation wishing to keep the target within sight. Mathematics also has the annoying habit of believing literally the problem which is assigned to it. If we design a mathematical system to predict a transfer between orbits which expends the minimum amount of fuel, it may well show us that this minimum occurs using an infinitely long time for the transfer. This possibility often crops up as a part of the solution and it can be expected that both the astronauts and their families might complain. To guard against such nonsense is not simple, however, and it very often becomes a matter of engineering judgment as to just how close to the true minimum fuel expenditure we wish to come.

For the time being we shall exclude such real world effects since we must crawl before we walk. To this end we return to our imaginary planet with ideal properties and the equally ideal bullet. This time we shall add the possibility of impulsive orbit change to the bullet in orbit in order to discuss orbit transfer. At first there will be no consideration of attempts to reach a second vehicle, an operation known as rendezvous. In other words we wish only to achieve the orbit which is different from the initial orbit without consideration of when we achieve the orbit, or where in the orbit we end up.

Before we decide the actual firing direction which will be required to modify one or all of the given orbital elements, it is well to ask which direction of thrust will modify each of the elements individually. It would be nice if each orbital element could be changed by firing in a separate direction and the firing would leave all other elements unchanged but nature is not nearly this kind.

In order to answer the question of "which firing direction changes which orbital element" we must first define reference directions in space. These directions, a set of coordinate axes shown in Figure 4, all originate

at the center of our imaginary planet. The first direction that we shall choose is along the radius vector drawn from the center of the planet to the satellite. The second direction is drawn from the center of the planet in a direction which is perpendicular to the orbital plane. The third direction lies in the plane of the orbit plane and is perpendicular to the first two directions. We shall refer to these directions as reference directions (1), (2), and (3).

The scorecard below will now help to keep up with the game.

From the table we see that firing along the first and third directions will modify the same orbital elements but two orbital elements are uniquely modified by firing along the second reference line. Thus, if an inclination change is desired, we must fire along the second reference line since firing along the first and third reference lines has no effect on this quantity. However, it should be noted that if we do fire in this way the longitude of the ascending node and the argument of peripoint will be simultaneously modified. Of course the reference directions chosen here are quite arbitrary and for any other choice of axes a new table, such as that shown here, must be constructed. Some sets of axes would be more convenient for some problems and much of the work of the orbit transfer problem is the isolation of a judicious choice of axes.

In order to examine an actual minimum fuel orbit transfer we shall consider the first such problem ever

Direction of thrust along reference line	will modify the orbital elements
(1)	eccentricity argument of peripoint semi-major axis time of peripoint passage
(2)	inclination longitude of the ascending node argument of peripoint
(3)	eccentricity argument of peripoint semi-major axis time of peripoint passage.

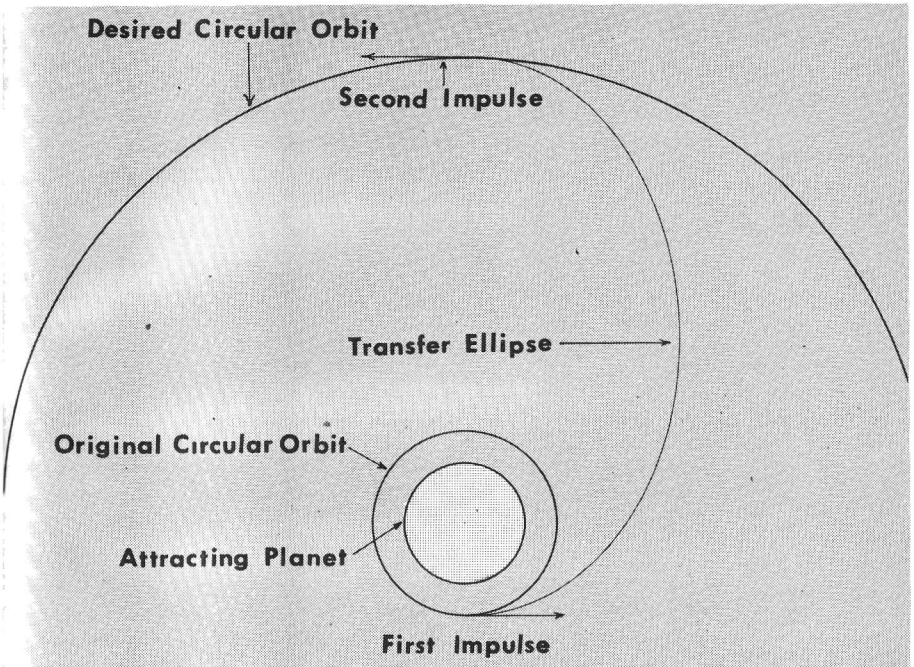


Figure 5 STANDARD HOHMANN TRANSFER

solved. This solution was due to a German engineer named Walter Hohmann and it occurred long before the hardware for a rocket launching ever existed. The transfer maneuver bears his name, the Hohmann transfer. This is shown in Figure 5. The problem is to transfer from a circular orbit about a planet to a second coplanar circular orbit at a higher altitude and minimize the fuel expended in the process. Hohmann showed that the best maneuver that could transfer a vehicle between these two orbits starts by firing along reference line (3), i.e., tangent to the lower circle. This transfers the vehicle to an elliptical orbit which begins coasting upward toward the second circle. The magnitude of the first impulse is chosen to be exactly the value required to produce an ellipse with a apopoint exactly equal to the radius of the second circle. At the time the apopoint distance is achieved a second impulse is added

which raises the velocity at that point of the ellipse to a value necessary to achieve circular velocity. This is the most elementary of the two impulse transfers.

This solution, first published in the early part of this century, was believed to cover all cases of the outlined problem until quite recently. During the late 1950s numerical calculations indicated that the Hohmann transfer is the true minimum fuel expenditure transfer only if certain other conditions are satisfied. This restriction can be summarized as follows; if the ratio of the radii of the final circular orbit to the initial circular orbit exceeds a value of approximately 15.6, then the Hohmann transfer no longer provides the least fuel expenditure. Once the ratio of the radii exceeds this value it is cheaper, fuelwise, to first kick the spacecraft to a distance infinitely far from the attracting center along a parabolic orbit, modify the—zero—velocity at infinity by adding an impulse of zero magnitude, coast back from infinity along a second parabola and add a third impulse at the required circularization altitude. It is interesting to note that a fuel savings results from adding a third impulse even though the results are wildly impractical. In practice the modified Hohmann transfer can be used by coasting to some distance above the target orbit and adding a second impulse of nonzero magnitude then drifting down to the required altitude and adding a third impulse. Even this modified scheme will beat the original Hohmann transfer if the ratio of the radii exceeds the above given value. These modified Hohmann transfers are shown in Figures 6 and 7.

The Hohmann transfers just described are examples of transfers between nonintersecting orbits. It is fairly apparent that transfers between such orbits must necessarily involve two impulses since position does not change during an impulse. If two orbits do intersect—that is, they have at least one point in common—then it is equally obvious that a transfer between them could be accomplished with a single impulse. It is not obvious—and indeed untrue—that a single impulse is always the best way to transfer between intersecting orbits. Whether one impulse, or multiple impulses, can best be used to accomplish an orbital transfer is a very difficult question and individual cases must be examined.

Another case of orbit transfer which is of much importance is that of change of inclination. The inclination is one of the most difficult orbital parameters to modify since the satellite in orbit exhibits some of the characteristics of a huge gyroscope with an equally large angular momentum. The change of inclination involves the rotation of the angular momentum through an angular displacement . . . and that costs in fuel consumption. The problem of inclination modification is so

severe that, if the cost of transporting fuel to the satellite is counted, it is sometimes cheaper to land a payload and relaunch it into the desired new inclination rather than attempt to modify the inclination directly.

Several important mission constraints can be derived from the fact that orbital inclination is so expensive to modify—where expense, as usual, is measured in the coin of the realm, fuel. One of the direct results is that it is impossible to launch reasonably large satellites much out of the plane of the Earth's motion about the sun with today's rockets. The reason for this is that the satellite carries with it much of the velocity of Earth's motion about the sun and this, in effect, fixes the inclination of the orbit to be the same as the inclination of Earth. To launch a probe to some other planet which travels much out of the plane of motion of Earth about the sun—such as Pluto—would be prohibitively expensive—unless we caught the planet while it was at the line of nodes.

One real life case in which inclination modification is absolutely essential is the case of launching an equatorial satellite. The reason that an inclination change is necessary in this case depends upon a quirk of geography and a bit of the mechanics of rocket launching. The quirk of geography is that the United States does not extend southward to the equator. For reasons which are both political and logistic it is desirable to have the rocket-launching site located on home territory. If the United States actually did cross the equator, it would have been important to establish a spaceport at such a point for at least two reasons. One such reason is that the rotational velocity of Earth is a maximum at the equator and a rocket vehicle at liftoff would already have this velocity as a contribution toward the required orbital velocity. But a second—and far more important—reason is that it is possible to launch a satellite into any desired inclination from an equatorial launch site without subsequent orbit modification. (The amount of payload will vary with the required inclination. It will be largest for a due east launch and smallest for a due west launch since in the former case the satellite makes full use of the rotational velocity and in the latter case actually must fight the Earth rotational velocity.)

To see why nonequatorial launch sites cannot efficiently launch equatorial satellites, we consider a specific site such as Cape Kennedy. Kennedy lies at approximately 30° north latitude. If the equatorial orbit is to be directly launched from Kennedy with orbit transfer, then the cutoff point of the rocket engines must necessarily be at a point on the equator. However, this entails traversing an arc of approximately two thousand miles of distance—without yet even worrying about achieving orbital velocity. Such a launch is obviously prohibitive. Thus with our

quirk of geography we are left with the highly expensive problem of inclination modification to achieve the necessary equatorial orbits.

The saving grace comes from the accident that the twenty-four hour satellite orbit is so high—22,300 miles. At this large an altitude the velocity in the orbit is quite low and the velocity vector which must be added to the satellite velocity in order to turn the orbit is small.

This trick of modification of inclination at high altitudes is a special case of a general result from orbit transfer mechanics. It has been shown that if the inclination change is large it is often cheaper to kick the vehicle infinitely far from the attracting center along a parabolic trajectory. At the apopoint, since the velocity is zero, it is possible to rotate the velocity vector by an impulse of zero magnitude, swoop back from infinity and recircularize the orbit. The real life case of the twenty-four hour orbit represents an approximation to this idealized maneuver. It is interesting to compare this case with that of the three impulse Hohmann transfer described earlier.

Two other classes of orbital maneuvers which are more stringent in their requirements than the case of simply matching a desired orbit are interception and rendezvous. Interception is defined as having to match position of one spacecraft with another with no particular worry about a velocity match. Rendezvous involves the matching of both position and velocity and is the most difficult of the orbit transfer problems.

The case of rendezvous has achieved considerable notoriety due to the Apollo program and it is well to examine one case of it in detail. We must assume a specific initial orbit configuration for the pair of vehicles. For convenience we shall label them "chase" and "target" and assume that they are initially in circular orbits with chase in a lower orbit than is target. During the maneuver target will be assumed passive and chase will do all the thrusting. Suppose that chase is in an orbit which is more than ten miles below target. The first maneuver is for chase to perform a Hohmann transfer from whatever circular orbit he initially occupies to an orbit which is again circular but ten miles below target. Since chase is still below target he is gaining on the higher vehicle—a lower altitude involves a greater velocity. Thus the angular separation of the vehicles will gradually diminish until chase passes below target and then the whole process of catching up starts all over again.

At a critical angular separation between the vehicles chase again fires his thruster and moves into a very special elliptic orbit. This ellipse has the property that the apopoint of the ellipse lies as far above target's orbit as the peripoint of the ellipse lies below the circular orbit that chase has just left. Furthermore the ellipse has

the property that the angle traversed between injection into the ellipse and the final rendezvous point should equal one hundred and forty degrees—due to line of sight considerations.

This ellipse should bring chase into the near vicinity of target and a final thrust is used to circularize chase's orbit. This portion of the maneuvering is usually referred to as the "gross" rendezvous. From this point onward seat-of-the-pants flying takes over for docking—if you can count anything involving radar, computers, et cetera, as seat-of-the-pants. The point to make is that within close proximity vehicles will behave in the intuitively obvious manner with respect to each other, just as an astronaut does not need orbital mechanics to pull in a pencil floating about the vehicle cabin.

The reason that intuitive targeting does not apply in the case of gross rendezvous, but does apply in the case of docking, is often a point of confusion to the layman. The reason behind this situation goes back ultimately to the definition of a vector. Suppose that two vehicles are located in the same circular orbit but are separated from each other by an angle of, say, 90°. The gravitational force acting on the vehicles is of equal magnitude in either case—but gravity is a force which means that it is a vector quantity. Since the vehicles are so widely separated the force of gravity, which acts upon one of the vehicles, is *not* the same as the force of gravity, which acts upon the other. As the two vehicles close upon one another the force of gravity upon the two vehicles becomes almost identical and close-range intuitive targeting can take over.

The situation might be thought of as being analogous to the case where a friend stands at the axis of a rapidly spinning merry-go-round and you wish to walk from the rim to meet him. While you are at the rim a force acts upon you which does not act upon him. Although this force decreases as you approach him you must still account for the force until you actually arrive at the axis of rotation. It is apparent in this case that your path from the rim to your friend will not be a straight line as seen from a third man standing on stationary ground. Similarly, the path of rendezvous between two vehicles will not be a straight line.

Thus far it has been continually emphasized that the discussion applies strictly to idealized cases in an imaginary universe. It seems unfair to leave even this brief discussion of celestial mechanics without giving consideration to some of the real world effects that continually confront workers in astronautics even though the resultant whirlwind tour may appear to be a bit of a hodgepodge. Specifically, we shall look briefly at air drag effects, multi-body problems, and nonspherical planetary effects.

To begin with air drag, it is known

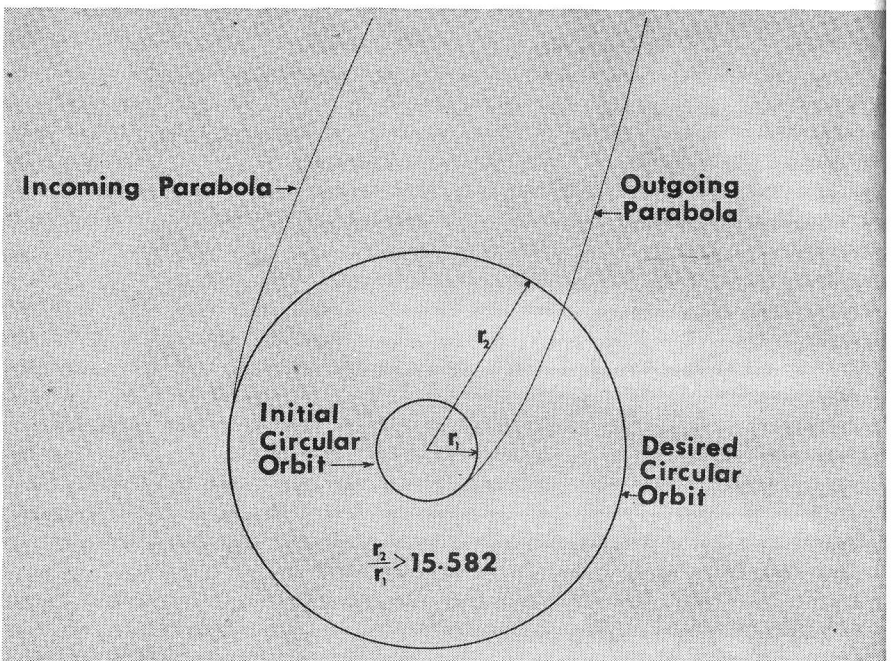


Figure 6 EXTENDED HOHMANN TRANSFER (INFINITE TIME)

that the actual atmosphere of the Earth, for example, extends many hundreds of miles into space and is usually the cause of the demise of most satellites. Air drag is a basically different type of force than is gravity. Gravitational forces are known as conservative forces since energy is conserved by them. This is a generalization of the earlier comment that a satellite in a noncircular orbit continually trades energy between the kinetic and potential forms. Air drag is not a conservative force but rather a dissipative force. Energy lost to air drag cannot be recovered and ends up as increased entropy.

The problems of celestial mechanics which involve only gravity are attractive from a theoretical point of view since the only necessary tool the investigator must possess is ingenuity. Problems involving air drag are far more complex and must be largely empirical, at least at our present state of knowledge. The approximate equations which yield pressure, temperature, and density as functions of altitude are not in the least aesthetic to a theoretician. Due

to the complexity of the system almost any meaningful calculation involving drag must resort to numerical analysis rather than hope for an analytic solution.

One of the results of air drag which is sometimes referenced in the literature is the so-called "satellite paradox." The phenomenon is really rather easily explained and is hardly deserving of the title "paradox." The original observation was that as a satellite lost energy due to air drag it attained increased velocity. The velocity increase, as pointed out several times, comes from the fact that the radius of the orbit is decreasing which results in a shorter period. If the total energy of the satellite—kinetic plus potential—is considered it will be seen that the total energy decreases due to the drag.

Another aspect of the real world that has not been considered as yet is the influence of other massive bodies on the two-body problem. Examples of this case are quite easy to construct. For example as a satellite moves in orbit about the Earth the gravity attraction of the Moon, the Sun, Altair, and, in short, every other body of the universe perturbs the motion away from the ideal two-body case. As a second idealization to the physical case the three-body problem was posed. This problem is to describe the motion of three massive bodies—in an otherwise empty universe—which attract each other according to Newton's law of universal gravitation. Virtually every great mathematician from Newton on has made contributions to this problem but it was not solved until Sundmann gave the solution in 1907—a fact which is apparently unknown to most people.

To understand the difficulty involved in the solution of the three problems, let us begin by recalling that Newton's second law of motion—which is the basis of all classical mechanics—relates the acceleration experienced by a body to the mass of the body and the forces acting upon it. In the present case the forces are simply those of gravity and at first sight the three-body problem may not appear more difficult than the two-body problem. Now the question arises as to what is meant by a solution. The desired end point of the analysis is an equation, or set of equations, which allow us to predict the position and velocity of the body once the time is specified. Very often much of the necessary information comes from what are called conservation laws and a number of conservation laws are known for the three-body problem.

The first such conservation law tells us that the energy of the system is conserved since the forces are conservative. Furthermore the angular momentum of the system about the center of mass must remain constant. The linear momentum of the center of mass must, likewise, remain constant and this final fact additionally allows us to predict where in space the center of mass will lie at any

given time. Since there is one scalar conservation law—energy—and three vectorial conservation laws, we have a total of ten pieces of information that can be of value. But the total required is eighteen since we have three bodies, each of which must be specified by three velocity components and three position coordinates. Thus a total of eight additional pieces of information is necessary to solve the three-body problem.

Things began to look fairly hopeless with respect to the possibility of obtaining a solution when an investigator named Bruns showed that no more purely algebraic relationships—which would be additional laws of conservation—could ever be obtained. This theorem relegated many of the ongoing studies concerning the three-body problem to that limbo occupied by efforts to trisect the angle and square the circle.

Enter Sundmann. Sundmann in no way negated the theorem of Bruns, but rather circumvented it by using nonalgebraic functions. In order to solve the problem it was necessary for Sundmann to introduce certain functions that were very exotic and could be described only as the sum of an infinite number of terms—a common practice in mathematics. In order to use such a series it is absolutely necessary that the series approach some limit value as more and more terms are added; that is, it must converge. Sundmann investigated the convergence of his series and demonstrated that they must converge—but *he did not investigate how fast they converged.* This was not an error on his part since there are no usable tests in mathematics that yield the rate of convergence of a series, but it was fatal nonetheless. Numerical calculations involving the Sundmann solution showed that the rate at which the series converged was so slow that no practical importance could ever be attached to the solution.

It is tempting at this point to consider the feeling that Sundmann had when the numerical analysts pointed out the fatal flaw. He had obtained the solution to a problem which stopped Newton, Gauss, Euler, and Poincare only to have it pulled from him at the last instant. Let us hope that he took comfort in the solution, be it practical or impractical.

Long before the work of Sundmann other attacks on the three-body problem were in progress. The most notable of these is the restricted problem of three bodies. This was originally introduced as a simplification of the three-body problem but turned out to be a brand-new can of worms. The basic ground rules of the problem are to assume that two of the bodies are quite large and the third is extremely small. The two large bodies are required to move about their common center of mass in circular orbits while the third wanders about under their gravitational attraction. The

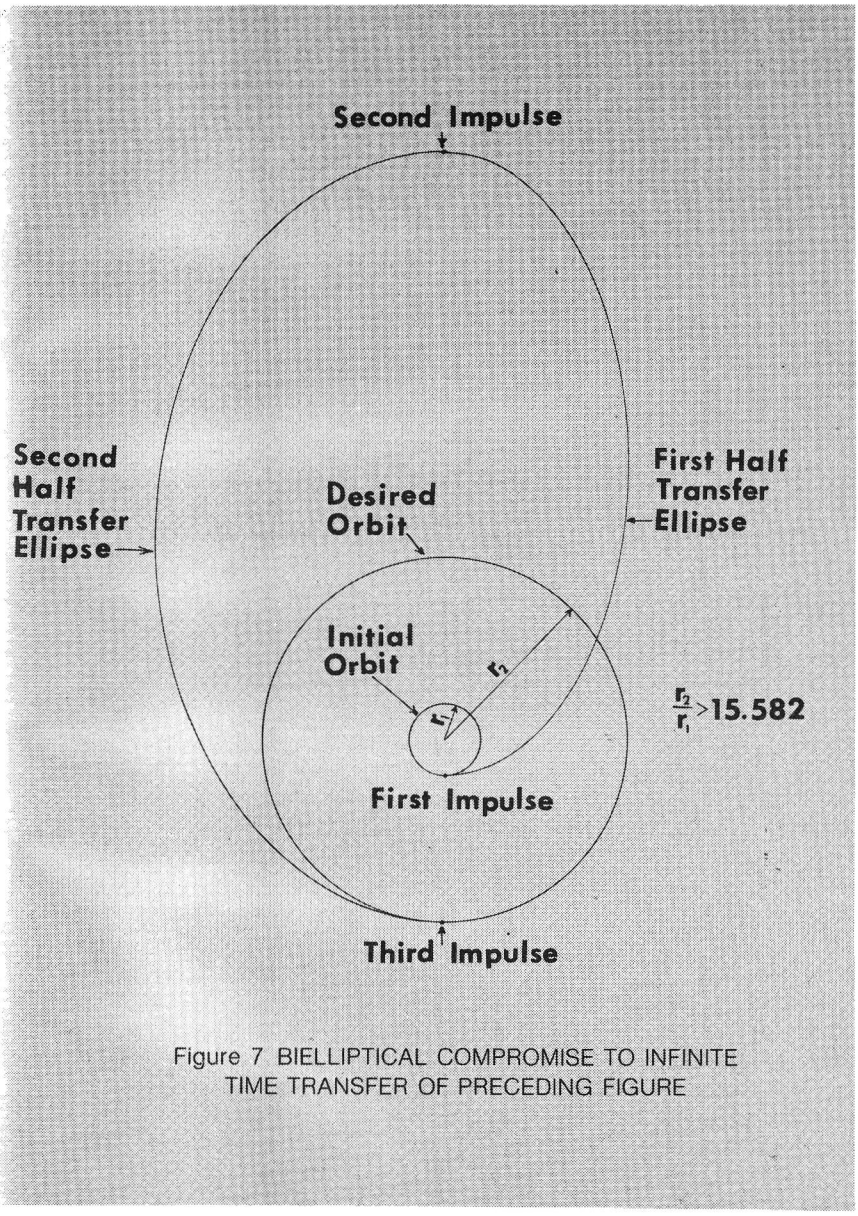


Figure 7 BIELLIPTICAL COMPROMISE TO INFINITE TIME TRANSFER OF PRECEDING FIGURE

problem is to predict the position and velocity of the very small body as a function of time.

Since the third body was so small that it did not affect the motion of the two larger bodies the law of *mutual* gravitational attraction was violated. Physics revenge from this affront is that none of the quantities conserved in the three-body problem, such as energy and momentum, are conserved. Over the years it has become apparent that the restricted problem of three bodies is at least as difficult as the full blown three-body problem; recently it was demonstrated that the Sundmann solution is completely inapplicable to the restricted case.

Euler, probably one of the greatest of the great mathematicians, was determined to find a problem more complex than the two-body problem that could be solved. To this end he further simplified the restricted problem by requiring that the two massive bodies no longer rotated about each other but rather were fixed in space. This problem, of course, bears the title of "Euler's problem of two fixed centers" and it is solvable in terms of only slightly exotic functions.

Since the restricted problem is made to order for Moon probes it seemed that Euler's problem would be a good working approximation to a Moon probe motion but this was not found to be the case by early workers in the astronautics industry. It has been found that, if we wish to launch a probe toward the Moon, it is a better approximation to completely disregard the Moon and use a two-body approximation than it is to assume that the Moon is on station but motionless. This result can be predicted once it is known, hindsight being 20/20.

To justify the case let us begin with the observation that the units and dimensions that mankind has developed are purely arbitrary; in problems of celestial mechanics it is often convenient to use units and dimensions which are inherent to the problem. To apply this to the motion of the Moon probe we begin by measuring distance in units of the distance from the Earth to the Moon, and time in units of the time that is required for the Moon to make one complete circuit about the Earth—that is the lunar month.

The third applicable quantity that is available to us is the unit of mass and we choose this unit such that the sum of the masses of the Earth and the Moon are equal to 1.

In the system of units which we have chosen the problem is now simplified. The time that it takes the Moon to complete one orbit about the Earth is 1, which is not a small quantity. On the other hand the Earth possesses 80/81 of the mass of the Earth-Moon system while the Moon possesses only 1/81 of the combined mass. It seems apparent that we can disregard the small quantity 1/81 and make only a slight error.

Another major problem area in the calculation of celestial mechanics is that the attracting planets are not spheres. Before describing this further it is well to keep things in perspective by pointing out that the Earth is much closer to being a sphere than is the average bowling ball. But even these small deviations from a spherical shape are enough to cause easily observable perturbations in the orbit of a satellite.

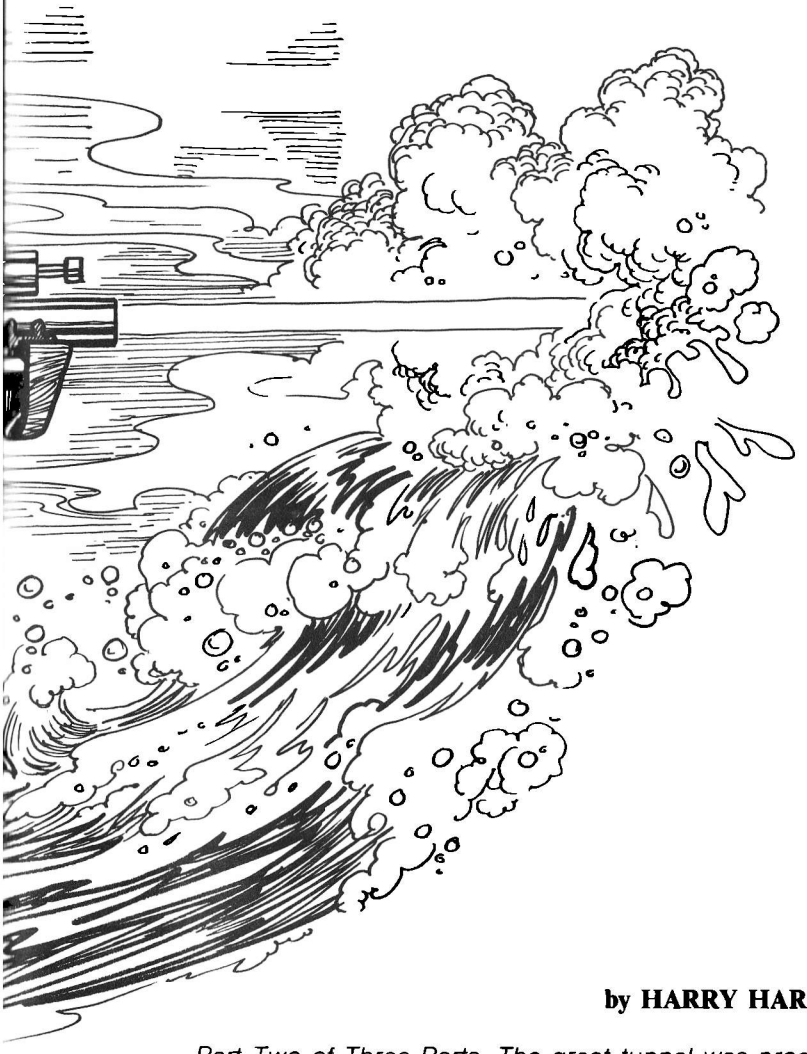
Fortunately there Earth's equator is quite circular so we must be more concerned with deviations from sphericity along lines of latitude than we are along lines of longitude. (This is not the case with lunar satellites since the equator of the Moon is not close to circular.) Before the advent of geodetic satellites not much was known about the actual shape of the Earth. The shape was written in terms of an infinite series of terms and, since the Earth obviously has a finite gravitational field, it was assumed that each succeeding term would be much smaller than the preceding term in order that the sum of the series would be finite. Measurements from satellites have produced the disturbing result that the terms are not growing smaller. The resulting dilemma, known as the King-Hele catastrophe, has not been resolved.

The major contributor to the mathematical description of the Earth's gravitational field is the zeroth term of the series mentioned above. This term simply tells us that as a first guess Earth is a sphere. The second term—which is much smaller than the zeroth—distorts the Earth to an oblate spheroid—which is flattened at the poles. It is of interest to note that the first two terms of this series are exactly equivalent to the field observed if we study Euler's problem of two fixed centers but choose the distance between the two bodies to be an imaginary number! This problem was first solved several hundred years ago and then rediscovered in the 1930s—a case which is not uncommon in celestial mechanics. Almost any modern worker in celestial mechanics today at one time or another will make a discovery which he later finds is a special case of a problem treated by a long dead genius.

Another case of this sort is the pear shaped Earth which made a splash in the newspapers a while back. The pear shaped Earth is treated by the old master, Tisserand, in a multi-volume work entitled *"Mecanique Celeste,"* published in 1889.

The treatment of additional perturbations such as radiation pressure, outgassing of vehicles, et cetera, could be extended almost indefinitely. The interesting topic of the motion of a rocket vehicle when the burning time is not short—as it was in our impulsive approximation—is so extensive that it includes normal celestial mechanics as a special case and cannot be considered here. ■

KELLY FREAS



a transatlantic tunnel, hurrah!

by **HARRY HARRISON**

Part Two of Three Parts. The great tunnel was progressing across the floor of the ocean, but its enemies were still very hard at work to stop it. Augustine Washington has to risk his life again as he crossed the mighty Atlantic in a daring new way that no man had tried before.

SYNOPSIS

The time is now, the year 1972, but this is not the familiar world that we know. It is a parallel world, a "what if?" world. The golden days of the British Empire seem destined to continue forever. Europe is a collection of squabbling monarchies and New York is the major city in the American colonies. After the Battle of Lexington—which the British won—General George Washington was shot as a traitor. His descendant, AUGUSTINE WASHINGTON, has a secret ambition to clear his ancestor's name, an ambition he never forgets as he works on the construction of the Transatlantic Tunnel.

The genius behind the design and construction of the tunnel is SIR ISAMBARD BRASSEY-BRUNEL.

WASHINGTON, although a fine engineer in his own right, is proud to work for SIR ISAMBARD. But the tunnel is in financial trouble, more backing is needed and the American colonies are looked to to supply the money. With this in mind WASHINGTON is placed in complete charge of the American end of the tunnel construction, a position which makes him more SIR ISAMBARD'S equal than employee. SIR ISAMBARD is greatly put out by this and refuses WASHINGTON access to his home and, at the same time, sees to it that the engagement between his daughter, IRIS, and WASHINGTON is broken.

Undaunted, WASHINGTON goes right to work, and flies to the American colonies in the giant coal-fired airplane, the Queen Elizabeth. *While in flight there is an assassination attempt on his life which he foils, killing one of his attackers in the bargain. Apparently great forces are working against the tunnel and he must be on his guard.*

In New York, despite opposition, he is put in charge of the tunnel. The work will go on! Despite assassins, rich Tories who hate the traitorous name of Washington, money and design problems—and the tragedy of his personal life. This, the greatest physical feat mankind has ever attempted, will be done.

A tunnel will be built under the waters of the Atlantic Ocean, linking London and New York City by rail.

Part 2

VII

The silence in the little cabin was almost absolute and were it not for the constructions and devices of man it would have been, for here at thirty fathoms of depth in the Atlantic there was no sound. On the ocean's surface above the waves might crash and roar and ships' foghorns moan as the vessels groped their way through the almost constant fogs of the Grand Banks off Newfoundland, and nearer the surface pelagic life made its own moans as it was consumed; the shrimp clicked, the dolphin beeped, the fish burbled. Not so

at the level where the tiny submarine sped; here was the eternal quiet of the deep. Stillness outside and almost as still within. There was only the distant hum of the electric motors that drove them through the water, the sibilant whisper of the air vents and, surprisingly the loudest, the *tack-tack-tack* of the jackdaw clock fixed to the bulkhead above the pilot. There had been no conversation for some minutes and in that vacuum the clock sounded the louder. The pilot saw his passenger's glance move to it and he smiled.

"You'll be noticing the clock then, Captain," said he, not without a certain amount of pride.

"I do indeed," said Washington, failing to add that it was impossible not to notice the obtruding thing. "I assume it is an original?"

"Not only an original but it is close on being *the* original, one of the very first ones made, that's what it is. My grandfather it was who built the first jackdaw clock after seeing one of them things from the Black Forest when he was in a hock shop on O'Connell Street. Cuckoo clock it was, he said, and it fascinated him, what with him being a clockmaker himself and all of that. When he came home to Cashel he tried to build one but not being overfond of cuckoos himself—great ugly thing laying eggs in others' nests and such incivility—he put in a jackdaw and a bit of ruined tower that being where jackdaws are found in any case and there it was. He made first one and then another and they caught on with the English tourists out to look at the Castle and the Rock and before you could say Brian O'Lynn an entire new industry was founded and to this day you'll see a statue of him in the square there in Cashel."

As though to add emphasis to this panegyric the clock struck the hour and the jackdaw emerged through the portal of the ruined abbey and hoarsely shouted *CAWR, CAWR* before retreating.

"Is it two already?" asked Washington, looking at his watch which was in rough agreement with the jackdaw who had retired to his dark cell for another hour. "Are we going as fast as we can?"

"Full revs, Captain, *Nautilus* is doing her best." The pilot pushed the speed lever harder against its stop as though to prove his point. "In any case there's the site now."

O'Toole turned off the outside lights so they could see farther through the darkness of the sea. Above them there was a filtered greenness that vanished as the depth increased so that below there was only unrelieved blackness. Yet when the glow of the beams had died away something could be seen down there in abyss, light where only night had ruled since the world was born. One light was visible, then another and another until a cluster of submerged stars greeted them as they dropped lower, welcoming them to a hive of industry alien to the ancient peace of the ocean floor.

First of all the eye was captured by a hulking, squat, ugly, alien, angular, boomed, buttressed and barbizaned machine that clutched the ocean floor. It had the girder and rivet look of a sturdy bridge for well over ninety-five percent of its construction was open to the ocean, at a pressure equilibrium with the sea around it. The frame was open and the reaching arms were open, while the tractor treads were jointed plates that ran on sturdy cast-iron wheels. It took a keen eye to note the swollen bulges behind the treads that contained the electric motors to power them, though the rotund shape of the nuclear reactor, swung like a melon behind the great machine, was certainly easy enough to see. Other motors in pods turned the gear wheels and cables while the most important pod of all made a rounded excrescence on the front of the entire structure. This was the control room and living quarters of the crew, pressurized, comfortable and habitable, and so self-contained that the men could live here for months on end without returning to the world above the waves that was their natural habitat. Yet so large was the great supporting device that even these stately quarters were no larger in proportion than an egg would be balanced on the handlebars of a bicycle, which, in some ways, the structures did resemble.

This hulking machine, entitled the Challenger Mark IV Dredger by its manufacturers, was nonetheless called *Creepy* by all who came into contact with it, undoubtedly because of its maximum speed of about one mile an hour. *Creepy* was neither creeping nor operating at the present time which was all for the best since otherwise vision would have been completely impossible, for while at work it threw up an obscuring cloud in the water denser than the finest inky defense of the largest squid alive. Its booms would then swing out and the rotating cutters, each as large as an omnibus, would crash into the ocean floor, while about them compressed streams of water tore at the silt and sand deposits of this bed. Under the attack of the water and the cutting blades the eternal floor of the ocean would be stirred and lifted—into the mouths of suction dredgers that sucked at this slurry, raised and carried it far to the side where it was spewed forth in a growing mound.

All of this agitation raised a cloud of fine particles in the water that completely obscured vision and was penetrable only by the additional application of scientific knowledge. Sound waves will travel through water, opaque or no, and the returned echoes of the sonar scanner built up a picture on the screen of events ahead in the newly dug trench. But *Creepy*'s work was done for the moment, its motors silent, its digging apparatus raised when it had backed away from the new trench.

Other machines now took their place upon the ocean floor. There

was an ugly device with a funnel-like proboscus that spat gravel into the ditch, but this had finished as well and also backed away and the silt raised by its disturbance quickly settled. Now the final work had begun, the reason for all this subaqueous excavation. Floating downwards towards the newly-dug trench and the bed of gravel on which it was to rest was the ponderous and massive form of a preformed tunnel section. Tons of concrete and steel reinforcing rods had gone into the construction of this hundred foot section, while coat after coat of resistant epoxies covered it on the outside. Preformed and prestressed it awaited only a safe arrival to continue the ever-lengthening tunnel.

Thick cables rose from the embedded rings to the even larger flotation tank that rode above it, for it had no buoyancy of its own. The tubes that would be the operating part of the tunnel were open to the sea at both ends. Massive and unyielding it hung there, now drifting forward slowly under the buzzing pressure of four small submarines, sister vessels to the one that Washington was riding in. They exchanged signals, stopping and starting, then drifting sideways, until they were over the correct spot in the trench. Then water was admitted to the ballast tanks of the float so it dropped down slowly, setting the structure to rest on its prepared bed. With massive precision the self-aligning joint between the sections performed its function so that when the new section came to rest it was joined to and continuous with the last.

The subs buzzed down and the manipulating apparatus on their bows clamped hydraulic jacks over the flanges and squeezed slowly to make the two as one. Only when the rubber seals had been collapsed as far as their stops did they halt and hold fast while the locking plates were fixed in place. On the bottom other crawling machines were already waiting to put the sealing forms around the junction so the special tremie, underwater setting concrete, could be poured around the ends to join them indivisibly.

All was in order, everything as it should be, the machines below going about their tasks as industriously as ants around a nest. Yet this very orderliness was what drew Gus's thoughts to the object off to one side, the broken thing, the near catastrophe that for a brief while had threatened the entire project.

A tunnel section. Humped and crushed with one end buried deep in the silt of the ocean's floor.

Had it been only twenty-four hours since the accident? One day. No more. Men now alive would never forget the moments when the supporting cable broke and the section had started its tumbling fall towards the tunnel and *Creepy* close below it. One submarine, one man, had been at the right spot at the right

time and had done what needed to be done. One tiny machine, propeller spinning, had stayed in position, pushing with all its power so that the fall had shifted from a straight line and had moved ever so slightly to one side, enough to clear the tunnel and the machines below. But machine and man had paid the price for so boldly pitting themselves against the mass of that construction, for when the tunnel section had struck and broken it had risen up like an avenging hammer and struck the mote that presumed to fight against it. One man had died; many had been saved. The name of Aloysius O'Brian would be inscribed on the slate of honor. The first death and as honorable a one as a man could want, if a man could be said to want death at all. Washington breathed heavily at the thought, because there would be other deaths, many deaths, before this tunnel was completed. The pilot saw the direction of his passenger's gaze and read his thoughts as easily as though they had been spoken aloud.

"And a good man, Aloysius was, even if he came from Waterford. The Irish make good submariners and no empty boast is that and if ever anyone should doubt that you just tell them about himself out there with a thousand ton tombstone and what he did. But don't fret yourself, Captain. The other section is on the way, the replacement for that one, hours away but moving steadily, the thing will be done."

"May it be the truth, O'Toole, the very truth."

The next section had already appeared and was visible in the lights below and Gus knew that the final ones were waiting out there in the darkness, with the ultimate one coming as fast as the tugs could pull. Under his directions the sub moved along the length of the trench the short distance to the two completed sections of tunnel that projected from the caisson that would some day be the Grand Banks Station. The ocean here was no more than eleven fathoms deep which made the dumping of the rubble for the station that much easier. The artificial island rose up to the surface before them, an island growing all the time as barge after barge of stone and sand was added to it. Gus looked at his watch and pointed ahead.

"Take us up," he ordered.

A floating dock was secured here and they rose next to it and there was the thud of the magnetic grapple striking the hull as they were hauled into position. O'Toole worked the controls that opened the hatches above and the fresh, damp ocean air struck moistly against Gus's face as he climbed to the deck. The sun had set unremarked while he had been below the ocean's surface and the fog, temporarily held at bay by the warming rays, was returning in all haste as though to make up for time lost. Streamers of it rolled across the dock, bearing with them a sudden chill in the northern September eve-

ning. A ladder had been lowered to the submarine and Gus climbed towards the sailor waiting above who saluted him as he stepped from it.

"Captain's compliments, sir, and he says the ship is waiting and we'll cast off as soon as you're aboard."

Gus followed the man, yawning as he did for it had been a long day, beginning well before dawn, and it was the latest of an endless series of similar days stretching into the past longer than he could remember. When he looked in the mirror to shave he was sometimes startled at the stranger who looked back at him, a man with an unhealthy pallor from being too long away from the sun, dark-burnt circles under the eyes from being too often away from his bed, touches of gray around the temples from too much responsibility too long borne. But no regrets ever, for what he was doing was worth doing, the game worth the candle. His only regret even now was that although he had a full night ahead of him when he could sleep, this night would be spent aboard *H.M.S. Boadicea* known affectionately to her crew as Old Bonebreaker for the quality of her passage over troubled waters.

She was a hovercraft, the newest addition to the Royal American Coast Guard, capable of fifty knots over even the most towering seas, or sand, or swamp, or solid ground for that matter, the revenue agent's delight, the smuggler's dread; at top speed she rode like a springless lorry on a washboard road so was not the vessel of choice when one wanted a good night's sleep. But speed was the point of this trip, not sleep, and speed was what this unusual vehicle could certainly guarantee.

Captain Stokes himself was waiting at the top of the gangplank and his welcoming smile was sincere as he shook Washington's hand.

"A pleasure to have you aboard, Captain Washington," spoken quietly. "Cast off those lines," exploded out like the shell from a gun towards the ratings on deck. "Reports say a moderate swell so we should be able to maintain fifty-five knots for most of the night. If the seas stay that smooth, our ETA at Bridgehampton will be dawn. Reporter chap coming along for the ride, no way to stop him, hope you don't mind."

"Not at all, Captain. Publicity has been the making of this tunnel, so when the press wants to see me I am available."

The reporter stood up when they entered the officers' mess, a sturdy, sandy man in a checked suit wearing a bowler, the traditional hat of all newsmen. He was one of the new breed of electronic reporters, the recording equipment slung on his back like a pack, with the microphone peeping over one shoulder, the lens of the camera over the other. "Biamonte of the New York *Times*, Captain Washington. And I'm pool man, too, drawer of the lucky straw.

Since only one reporter could come on this voyage I'm AP, UP, Reuters, *Daily News*, the lot. I have a few questions—"

"Which I will be more than happy to answer in a few moments. But I have never been aboard a hovercraft before and I would like to watch her when she pulls out."

Scarcely a second was being wasted on the departure. The two great propellers mounted on towers in the stern were already beginning to turn over as the lines that secured *Boadicea* to the dock were being cast off. The thrust propellers for the surface effect must have been turned on at the same time for the great craft shifted and stirred, then, strangest sensation of all, began to lift straight up into the air. Higher and higher, six, eight, ten feet it lifted until it was literally riding on a cushion of air and had no contact with the water at all. The thrust propellers were now just silvery disks, disks that could pivot back or forth on top of their mounts, and swing about they did until they faced crosswise rather than fore and aft and under their pressure the craft floated easily away from the dock. They turned again, thrusting now at full speed and bit by bit the modern *Boadicea* became a lady conqueror of the waves riding up

and over them, faster and faster, rushing south into the night. But the hammering and shaking increased as she did, so that the plates rattled in the racks and the charts in their cupboards and Gus gratefully sought the softening comfort of the sofa.

Biamonte sat across from him and touched buttons on his hand controller. "Are we going to win, Captain Washington, that is the question that is on everyone's lips today? Shall we win?"

"It has never been a question of winning or losing. Circumstances were almost completely governed by chance so that the American section of tunnel is reaching completion to the shelf station just about the same time as the Engligh section to their station on the Great Sole Bank. There never was a race. The situations are different, even the distances involved are different."

"They certainly are and that is what makes this race, that you won't call a race, so exciting. The American tunnel is three times as long as the English . . ."

"Not quite three times."

"But still a good deal longer, you'll have to admit, and to build our tunnel in the same length of time as theirs is in itself a victory and a source of pride to all Americans. It will be an even greater victory if you can make a trip through the entire length of the American tunnel and then reach London in time to be aboard the first train to pass through the English tunnel. That train will be leaving Paddington Station in less than thirty hours. Do you still think you will be aboard it?"

"I have every expectation."

The hovercraft had reached its maximum speed now and was hammering along like a demented railway carriage, leaping from wave to wave. Biamonte swallowed and loosened his collar as a fine beading of perspiration appeared on his brow; for those of delicate tummies the hovercraft is not a recommended form of transportation. But, sick or well, he was still a reporter and he pressed on.

"Does not the fact that one segment of the tunnel was destroyed interfere with your chances of winning?"

"I wish you would not refer to winning or losing since I feel it does not apply. In answer to your question, no, it has not altered the situation appreciably. Extra sections were constructed, reserve sections, in case faults developed in any of the others during construction. The final section is on its way now and will be placed during the night."

"Would you care to comment upon the fact that Mr. J. E. Hoover, of the Long Island region branch of the Colonial Bureau of Investigation, thinks that sabotage may be involved with the broken cable and that he has a man in custody?"

"I have no comment since I know no more about it than you do."

Gus kept all emotion from his

voice, giving no hint that this was not the first case of attempted sabotage to the project. The reporter was now turning an interesting shade of green and noticed nothing. Yet he persevered with his questions despite a growing glassiness of the eye and a certain hoarseness of voice.

"Since the accident the bookmakers' odds have fallen from five to three in your favor to even money. Does the immense amounts wagered upon your reaching London in time bother you at all?"

"Not in the slightest. Gambling is not one of my vices."

"Would you tell me what your vices are?"

"Not answering that sort of question is one of them."

They both smiled at this light exchange, though Biamonte's smile had a certain fixed, or frozen, quality. He definitely was green now and had some small difficulty speaking as *Boadicea* charged the briny hills with undiminished energy.

"More seriously then . . . would you explain . . . the importance of these stations . . . in the ocean . . . for the tunnel."

"Certainly. If you had before you a three-dimensional map of the world with all the waters of the oceans stripped away, you would see that the seas bordering the British Isles and North America are quite shallow, relatively speaking. Here we have the continental shelf, shoal water, stretching along our coast up to Canada and out past the island of Newfoundland to the Grand Banks that border the abyssal plain. An underwater cliff begins here steep, sharp and deep, dropping more abruptly than any mountain range on earth. You saw the artificial island that is the beginning of the Grand Banks Station. It stands in sixty-six feet of water. Beyond this the bottom drops sharply down to over fifteen thousand feet, three miles in depth. The British Point 200 in the Great Sole Bank stands in forty-two feet of water, also at the edge of a three-mile drop. These two stations mark the limits of our shallow water operations, and beyond them we will have to use different types of tunnels and different types of trains. Therefore, train junctions must be built as well as . . ."

He did not finish because the reporter was no longer there. With a strangled gasp he had clutched at his mouth and rushed from the room. It was something of a wonder to Gus, who had a cast-iron constitution when it came to things of this sort, why people behaved like this, though he knew some did. But the interruption was timely since it gave him an opportunity to get some rest. He found the captain on the bridge and after a brief but interesting talk concerning the technologies of this new-fangled craft the captain offered his own quarters for the use of his visitor. The bed was most comfortable and Gus fell at once into a deep though not undisturbed sleep. Complete relaxation was not pos-

sible and his eyes were already open when the messboy brought in a cup-like container with a spout in its top.

"Coffee, sir, fresh from the thermos, sugar and cream like I hope you like. Just suck on the top there, splashproof valve, easy enough to work once you catch on."

It was, and the coffee was good. After a wash and a quick shave Gus felt immensely better as he climbed back to the bridge. Astern the sea was washed with golden light as dawn approached, while ahead dark night still reigned though the stars were going and the low outline of Long Island could be clearly seen. The lighthouse on Montauk Point flashed welcome and within a few minutes its form could be clearly seen against the lightening sky. The captain, who had not quit his bridge the entire night, bid Washington a good morning then passed him a piece of paper.

"This was received by radio a few minutes ago." Gus opened it and read.

CAPT. G. WASHINGTON ABOARD HMS BOADICEA. FINAL SECTION INSTALLED SEALING CONTINUED AS PLANNED. EOC EIGHT FEET GOWAN WILL UNIFY ALL IN THE GREEN. SAPPER

"I am afraid the radio operator was quite mystified," said Captain Stokes. "But he had the message repeated and says this is correct."

"It certainly is, and the news could not be better. All of the sections of the tunnel are in place and are being sealed together for a water-tight bond. As you undoubtedly know, other sections of the tunnel were extended back from the Grand Banks Station to meet the ones coming the other way. Surveying is not easy on the ocean floor, plus the fact that we wanted some leeway when the two tunnels met. While we can manufacture sections of tunnel underwater, we cannot shorten sections already fabricated. Our error of closure was eight feet, almost exactly what we estimated it would be. Right now mud is being poured between the ends and this will be stabilized with the Gowan units, they will freeze it solid with liquid nitrogen so we can bore through. Everything is going as planned."

Gus had not realized that the others on the bridge, the steersman, sailors and officers, all of them, had been listening as he spoke, but he was made aware of this as a cheer broke out from them.

"Silence!" the captain roared. "You act like a herd of raw boots, not seamen." Yet he was smiling as he said it for he shared their enthusiasm. "You are destroying the morale of my ship, Captain Washington, but just this once I do not mind. Though we are Royal Coast Guard, and as loyal to the Queen as any others, we are still Americans. What you have done, are doing, with your tunnel, has done more to unify us and remind us of our American heritage

than anything I can remember. This is a great day and we are behind you one hundred percent."

Gus seized his hand, firmly. "I shall never forget those words, Captain, for they mean more to me than any prizes or awards. What I do I do for this country, to unite it. I ask no more."

Then they were entering the outer harbor at Bridgehampton, slowing so the spray no longer rose in great sheets around them. This sleepy little town near the tip of Long Island had changed radically in the years since the tunnel had begun, for here was the American terminus of the great project. A few white frame houses of the original inhabitants remained along the shore, but most had been swallowed in the docks, ramps, boatworks, assembly plants, storehouses, marshaling yards, offices, barracks, buildings, boom and bustle that had overwhelmed the town. *Boadicea* pointed towards the beach and slid over the surf and up onto the sand where it finally settled to rest. As soon as the storm of blowing particles had ceased a police car raced across the hard-packed surface and slid to a stop. The driver opened the door and saluted as Washington came down the ramp.

"I was told to meet you, sir. The special train is waiting."

As indeed it was, as well as a cheering crowd of early risers, or rather nonrisers and nonsleepers most of whom must have spent the coolish night here in vigil, warming themselves around now cold bonfires, rousing up to listen to every word of Washington's progress as it was passed down from the tunnel headquarters. They were on his side and he was their hero so the general joy and noise rose to a fever pitch when he appeared, while the mob seethed and churned like a soup pot on the boil as everyone wanted to get closer at the same time.

A platform had been erected, draped with flags and bunting, where a red-faced band sat and trumpeted loud but unheard music that was drowned completely by the thunderous ovation. Everyone there wanted to greet Washington, shake his hand, touch his clothing, have some contact with this man upon this day. The police could not have prevented them, but a gang of navvies could and did; they surrounded him with the solidness of their bodies and boots and tramped a path towards the waiting train. On the way they passed the stand which Washington mounted, to shake hands quickly with the silkhatted dignitaries there and to wave to the crowd. They cheered even more loudly then fell almost silent so his words reached all.

"Thank you. This is America's day. I'm going now."

Concise but correct and then he was on his way again to the train where a strong bronze hand reached down to half lift him into the single coach behind the electric engine. No

sooner had his feet touched the step than the train began to move, picking up speed quickly, rattling through the points and rushing at the black opening framed by the proud words, *Transatlantic Tunnel.*

Gus had no sooner seated himself than that same elevating bronze hand became a bearing hand and produced a bottle of beer which it presented, open and frothing, to him. Since beef and beer are the lifeblood of the navvies he had long since accustomed himself to this diet, at any hour of the day and night, so that he now seized the bottle as though he normally broke his fast with this malt beverage, as indeed he had many times, and raised it to his lips. The owner of this same bronze hand had another bottle ready which he also lifted and half drained at a swallow, then sighed with pleasure.

Sapper Cornplanter, of the Oneida tribe of the Iroquois nation, head ganger of the tunnel, loyal friend. He was close to seven feet of copper-skinned bone and sinew and muscle, black haired, black of eye, slow to anger but when angry a juggernaut of justice with fists the size of Virginia hams and hard as granite A gold circlet with an elk's tooth pendant from it hung from his right ear and he twisted it between his fingers now as he thought, as was his habit when deep concentration was needed. The twisted elk's tooth by some internal magic twisted up his thoughts into a workable bundle and when they were nicely tightened and manageable he produced the result.

"You're cutting this whole operation mighty fine, Captain."

"A conclusion I had reached independently, Sapper. Do you have any reason to think that I won't make it?"

"Nothing—except the fact that you have no leeway, no fat in the schedule at all in case of the unforeseen and I might remind you that the unforeseen is something tunnelers always have to take into consideration. The tunnel sections are all in place and the tremie seals between the joints poured, everything is going as well as might be expected. The last five tunnel sections are still filled with water since we need some hours for the joints to seal. On your orders. Want me to phone ahead and have them drained?"

"Absolutely not since we need as much time as possible for the setting. Just make sure the equipment is ready so we can get right at it. Now what about my connection at the station?"

"The RAF helithopter is already there, fueled and standing by. As well as the Wellington in Gander. They will get you through just as long as the Great Spirit showers his blessings, but there is a chance that He will shower more than blessings. There is a weather low out in the Atlantic, force nine winds and snow, moving in the direction of Newfoundland, and it looks like heap big trouble."

"May I get there first!"

"I'll drink to that." And he was as good as his word, producing two more bottles of Sitting Bull beer from the case beneath his seat.

With ever increasing speed the train drove deeper into that black tunnel under the Atlantic, retracing the course beneath the sea that the hovercraft had so recently taken above it. But here, far away from the weather and the irregularities of wind and wave, over a roadbed made smooth by the technical expertise of man, far greater speeds could be reached than could ever be possible on the ocean above. Within minutes the train was hurtling through the darkness at twice the speed ever attained on the outward trip so that after a few more beers, a few more hours, a hearty meal of beef and potatoes from an extemporized kitchen—a blow torch and an iron pot—they began to slow for the final stop.

Final it was, for the driver, knowing the urgency, had in his enthusiasm, stopped with his front wheels scant inches from the end of the track. In seconds Washington and Sapper had jumped down and clambored into the electric van for the short journey to the workface. Lights whisked by overhead in a blur while up ahead the sealed end of the tunnel rushed towards them.

"Better put these boots on," Sapper said, handing over a hip-high pair. "It is going to get wetter before it gets drier."

Washington pulled the boots on as they were stopping, and when he jumped down from the van Sapper was already at the unusual device that stood to one side of the tunnel. While he adjusted the various levers and dials upon it the van hummed into reverse and rushed away. Gus joined the small group of navvies there who greeted him warmly and whom he answerd in turn, calling each of them by name. Sapper shouted to them for aid and they rolled the machine closer to the tunnel wall and arranged the thick electric cables back out of the way.

"Ready whenever you say, Captain."

"Fire it."

When the head ganger pulled down the master switch a thin beam of burning ruby light lashed from the laser and struck high up on the rusted steel panel that sealed the tunnel's end. That this was no ordinary manner of light was manifest when the metal began to glow and melt and run.

"Stand to one side," Washington ordered. "The tunnel ahead is sealed off from the ocean but it is still full of water under tremendous pressure. When the laser holes through we are going to have . . ."

The reality of the experience drowned out the descriptive words as the intense beam of coherent light penetrated the thick steel of the shield and on the instant a jet of water no thicker than a man's finger shot out, hissing like a hundred de-

mons, as solid as a bar of steel, under such great pressure that it burst straight back down the tunnel a hundred feet before it turned to spray and fell.

In the meantime Sapper had not been idle and his beam was now cutting out a circle of metal high up on the top of the shield, a circle that was never completed because the pressure on the other side was so great that the disk of solid steel was bent forward and out to release a column of water that roared deafeningly in their ears as it hurtled by. Now the tunnel was chilled and dampened by the spray of the frigid water and a vaporous haze obscured their vision. But the burning beam of light cut on, making an oblong opening in the center of the shield that extended downward as the water level lowered.

When the halfway mark was reached Washington got on the phone and radio link to the men at the Grand Banks Station end of the tunnel. Though they were no more than a tenth of a mile ahead there was no way to speak directly to them; his voice went by telephone back to Bridgehampton, from there by radio link across the ocean.

"Open her up," Washington ordered. "The water is low enough now and everything is holding."

"Too much for the pumps to handle," Sapper said as he looked down gloomily at the dark water rising around their ankles, for the water here had to be pumped back eighty miles to the nearest artificial island with a ventilation tower.

"We won't drown," was the only answer he received and he twisted his elk's tooth in the earring as he thought about it. But at the same time he worked the laser until he had driven the opening down to the level of the rising water around them, where the beam spluttered and hissed. Only then did he enlarge the opening so a man could fit through.

"It won't get any lower for a while," said Gus, looking at the chill water that reached almost to his waist. "Let us go."

In a single file they clambered through, with Washington leading, and forced their way against the swirling water beyond. An instant later they were soaked to the skin and in two instants chilled to the bone, yet there was not one mutter of complaint. They shone their bright electric torches about as they walked and the only conversation was technical comment about the state of the tunnel. The joints were sealed and not leaking, the work was almost done, the first section of the tunnel almost completed. All that lay in their way was eight feet of frozen mud that formed the great plug that sealed the end of this tunnel and joined it to the sections beyond.

All of the navvies carried shovels and now there was a use for them, for when the mud had been pumped in from the outside it had flowed

part way back down the tube and was not congealed. They tackled this with a will, arms moving like pistons, working in absolute silence, and before this resolute attack the wet earth was eaten away, tossed to one side, penetrated. Their shovels could not dent the frosty frozen surface of the sealing plug but, even as they reached it, a continuous grinding could be heard—and then a burst of sound and a spatter of fragments as a shiny drill tip came thrusting out of the hard surface.

"Holed through!" Sapper called out and added an exuberant warcry that the others echoed. When the drill was withdrawn Gus clambered up to the hole and shouted through it, could see the light at the far end, and when he pressed his ear to the opening he could hear the answering voices.

"Holed through," he echoed and there was a light in his eyes that had not been there before. Now the navvies stood about, leaning on their shovels and chattering like washerwomen as the machines and men on the other side enlarged the opening from a few inches to a foot to two feet.

"Good enough," Sapper shouted through the tunnel in the frozen mud. "Let's have a line through here."

A moment later the rope end was pushed through and seized and tied into a sturdy loop. Washington dropped it over his shoulders and settled it well under his arms, then bent to put his head into the opening. The faces at the other end saw this and cheered again and even while cheering pulled steadily and firmly on the rope so he slid forward bumping and catching and sliding until he emerged at the other end, out of breath and red-faced—but there. More hands seized him and practically lifted him onto the waiting car that instantly jumped forward. He wrestled free of the rope as they stopped then sprang for the elevator. It rose as he put foot to it, rattling up the shaft to emerge in the watery afternoon sunshine of the Grand Banks. Still more than a little out of breath he ran across to the level spot before the offices, brushing the dirt from him as he went, to the strange craft that was awaiting his arrival.

It is one thing to gather intelligence from the printed word and the reproduced photograph, to be deluded into the knowledge that one is acquainted with an object one has never seen in three-dimensional reality, yet it is another thing altogether to see the object itself in all the rotundity of its existence and realize at once that there is a universe of difference between the two. Gus had read enough to labor under the delusion that he knew what there was to know about a helithopter so that the reality that he was wrong caused him to start and almost stumble.

He slowed his run to a fast walk then and approached the great ma-

chine with more than a little awe manifest in his expression.

In the first place the machine was far bigger than he imagined, as large as a two-decker London omnibus standing on end. Egg shaped, oh definitely, as ovular as any natural product of the hen, perched on its big end with the smaller high in the air above, squatting on three long curved legs that sprang out of the body and that could be returned in flight to cunningly artificed niches carved from the sides. The upper third of the egg was transparent and from the very apex of this crystal canopy there jutted up a steel shaft that supported two immense four-bladed propellers separated, one above the other, by a bulge in the shaft. Gus had barely a moment to absorb these details before a door sprang open in the dome and a rope ladder unrolled and rattled down at his feet, a head appeared in the opening and a cheery voice called out.

"If you'll join me, sir, we'll be leaving."

There was a lilt to the words that spoke of Merioneth or Caernarvon, and when Gus had clambered up to the entrance he was not surprised to see the dark hair and slight form of an R.A.F. officer who introduced himself as Lieutenant Jones.

"You sit there, sir; those straps for strapping in, sir."

While he spoke, and even before Gus had dropped into the second chair in the tiny chamber, Jones's fingers were flitting over the controls putting into operation this great flying engine. There was a hissing rumble from somewhere beneath their feet, a sound that grew rapidly to a cavernous roar and, as it did so, the long-bladed rotors above their heads stirred to life and began to rotate in opposite directions. Soon they were just great shimmering disks and as they bit into the air the helithopter stirred and shook itself like a waking beast—then leaped straight up into the air. A touch on a button retracted their landing legs while the tiny artificial island dropped away beneath them and vanished, until nothing except ocean could be seen in all directions.

"Being an engineer yourself, Captain Washington, you can appreciate a machine such as this one. A turbine, she has, that puts out two thousand horsepower to turn the contra-rotating rotors for a maximum forward speed of two hundred seventeen miles in the hour. Navigation is by radio beam and right now we are locked onto the Gander signal and all I need do is keep that needle on that point and we'll be going there directly."

"Your fuel?"

"Butane gas, in the liquid form, very calorific."

"Indeed it is."

Within a matter of minutes the coast of Newfoundland Island was in sight and the city of St. John's moved smoothly by beneath them. Their route took them along the coast and

over the countless bays that fringed the shore. Jones looked out at the landscape then back to his controls and his hand reached out to touch a switch.

"Number One tank almost empty so I'll switch to Number Two."

He threw the switch and the turbine rumbled and promptly died.

"Now that is not the normal thing I'm sure," said he with a slight frown. "But not to worry. I can switch to tank Number Three."

Which he did and still the engine remained silent and they began to fall.

"Well, well, tank Four." Which proved to be as ineffective in propelling the ship as had its earlier mates. "But we cannot crash, bach, there is that. We windmill down to a soft landing."

"Wet landing," Gus said pointing out at the ocean.

"A well made point. But there should be enough fuel left in tank One to enable us to reach the shore."

The flying officer seemed cheered by these final words because they were the first true prediction he had made in some time, for when he switched back to the first tank the turbine rumbled to life instantly and the helithoper surged with power. As he curved their course towards the shore he tapped, each in its turn; the dials set above the switch, then shook his head.

"They all read full, I cannot understand it."

"Might I suggest you radio the base at Gander about our situation."

"A fine idea, sir, would I could. No radio. Experimental ship you know. But there, beyond that field, a farmhouse sure, perhaps a telephone, contact reestablished."

As though to defy his words the turbine coughed and stopped again and their forward flight changed to an easy descent. Jones hurriedly lowered the landing legs and they had no sooner locked into position than the craft touched the ground in the center of a plowed field. Instants later the pilot had thrown open a door in the floor and had dived down into the maze of machinery below.

"That is very interesting," he said, spanner in hand and banging on the cylindrical tanks below him. "They are empty, all of them."

"Interesting indeed, and I shall report their condition if I can find a telephone at that farmhouse."

The hatch release was easy to locate and Gus pushed it open and threw the rope ladder out and was on it and down it even before the lower end had touched the ground. At a quick trot he crossed the field, angling towards the patch of woods behind which the farmhouse was located, running as quickly as he could across the stubble, running his thoughts no less quickly over the hours remaining before the train left London, the darkening sky above a dire portent of their vanishing number. Nine a.m. the train departed,

nine in the morning and here he was on the other side of the Atlantic the evening before, running, which was not the most efficient form of ocean crossing imaginable. For the very first time he felt that he might not make it in time, that all the effort had been in vain—but still he kept on running. *Giving up* were two words he simply did not know.

A farm track, a wooden fence and finally, reluctantly, the trees thinned out to permit a wood framed farmhouse to come into view. The door was closed, no one in sight, the shutters drawn. Deserted? It could not be. With raised fist he hammered loudly on the door, again and again, and almost abandoned hope before there was the rattle of a moving bolt and it opened a crack to reveal a suspicious eye set in an even more suspicious face and, if a beard can be said to be suspicious, wrapped around about by a full and suspicious graying beard.

"Aye?" a suspicious voice muttered, nothing more.

"My name is Washington, sir, and I am in some distress. My flying vehicle has been forced down in your field and I would like very much to make a call with your telephone, for which you will be reimbursed."

"No telephone." The door closed far quicker than it had opened and Washington instantly pounded upon it until it reluctantly opened for a second time.

"Perhaps you could tell me where the nearest neighbor with a phone—"

"No neighbors."

"Or the nearest town where a phone—"

"No towns."

"Then perhaps you could allow me into your house so we could discuss where I could find a telephone," Washinton roared in a voice accustomed to giving orders over the loudest of background clamor. Where good manners had not prevailed this issuing of a command had, for the door opened wider, though still reluctantly, and he stamped after the owner into the house. They entered a modest kitchen, lit by glowing yellow lights, and Washington strode back and forth the length of it, his hands clasped tightly behind his back, while he attempted to discover from the reluctant rustic what his next step would be. A good five minutes of questioning managed to worm out the tightly held information that nothing could possibly be done in any reasonable length of time. The nearest town, far distant, the neighbors, nonexistent, transportation in fine, only equine.

"Nothing can be done then. I have lost."

With these sad words Gus smacked his fist into his palm with great force, then held his wristwatch towards the lamp so he could tell the time. Six in the evening. He should have been at the air base by now, boarding the Super Wellington for the jet flight to England, instead he

was in this primitive kitchen. Six, now, eleven at night in London and the train departed at nine in the morning. The light hissed and flickered slightly and the hands on the watch irrevocably told the lateness of the hour. The light flickered again and Gus slowly raised his vision to the shade, the transparent globe, the glowing hot mantle within.

"What . . . kind . . . of . . . light . . . is . . . this—?" he asked with grim hesitation.

"Gas," was the reluctant answer.

"What kind of gas?"

"In a tank. The truck comes to fill it."

The light of hope was rekindled in Gus's eyes as he spun about to face the man again. "Propane? Could it be propane? Have you heard that word, sir?"

Squirming to hold in the fact, the farmer finally had to release it. "Something like that."

"It is that, because that is the only sort of liquid gas that can be used in the north because butane will not vaporize at lower temperatures. There is hope yet. I wish to purchase that tank of gas and rent your farm wagon and horse to transport it for me. What do you say to that, sir?"

"No."

"I will pay you one hundred dollars for it."

"Maybe."

"I will pay you two hundred dollars."

"Let me see it."

Gus had his wallet out on the instant and the bank notes smacking on the table. The head and the beard shook in a very definite and negative *no.*

"Colonial money. I don't take it. Canadian greenbacks or sterling, either."

"I have neither."

"I ain't selling."

Gus would not give in, not surrender to this backwoods agrarian; the man who had triumphed over the ocean would not admit defeat at the hands of a pastoral peasant.

"We will swap then."

"Whatcher got?"

"This." He had his watch off in an instant and dangling tantalizingly before the other's eyes. "A two-hundred and thirty-seven dollar waterproof watch with four hands and seven buttons."

"Got a watch."

"Not a shockproof, self-winding, day-of-the-week-and-month-revealing watch that tells the time when this button is pressed," a tiny bell struck six times, "and contains an infinitesimal radio permanently tuned to the government weather station that gives a report when this one is pressed."

". . . Small craft warnings out, snow and winds of gale velocity . . ."

A report he would just as well not have heard. Standing there, the watch of many qualities extended in silence until, with the utmost reluctance, a work-gnarled hand came up

and, with the greatest trepidation, touched it.

"It's a deal."

Then physical work, a harsh anodyne to the frustration of impotent waiting, struggling with the ponderous tank by the light of a paraffin lantern, loading it into the farm cart, harnessing the reluctant beast, driving it down the track, pushing mightily to get it over the ruts in the field towards the lighted helithopter where Jones's head popped out of the open hatch when he was hailed.

"Found the trouble, sir, and strange it is since I filled the tanks myself. They are empty and the indicators somehow broken so they read only full. It could only be—"

"Sabotage. But I have the answer here. Propane, and may there be enough of it to reach the base at Gander."

It was the work of seconds to remove the access ports and reveal the hulking forms of the helithopter's fuel tanks. Jones spat on his palms and reached for his toolbox.

"We'll have to have these out since there is no way to transfer the fuel. If you will tackle the fittings above, Captain, I'll tackle the clamps and we'll have them pulled before you can say Rhosllanerchrugog."

They worked with a will, metal struck metal and there was no further sound other than an occasional muffled curse when a wrench slipped and drew blood from barked knuckles. The tanks were freed and toppled out to the ground, after which with an even greater effort, they managed to raise the replacement tank into their vacated position.

"A lorry will return your tank and remove these," Jones said and received a reluctant nod in return.

Straps had to be arranged to secure the new tank in position, and there was some difficulty in attaching the fitting to its valve, but within the hour the job was done and the last connection tightened, the plates lifted back into place. The wind had accelerated while they worked and now the first flakes of snow sped by in the lantern's light. Gus saw them but said nothing; the pilot was working as fast as he could; but he did glance at his wrist before he remembered his watch was no longer there. Surely there was still time. The new jet Wellingtons were rumored to do over six hundred miles an hour. There *must* still be time. Then the job was done, the last fastener fastened, the last test completed.

They climbed the ladder and rolled it up and at the touch of the switch the great engine stirred and roared to life once more. Jones turned on the landing lights and in that fierce glare they saw the snow, thicker now, the frightened horse kicking up its heels against the wagon then stampeding out of sight with the shouting farmer in hot pursuit while the rotors spun, faster and faster until they were up, up and away into the blinding storm.

"Instruments all the way," said

Jones with calm assurance. "There's nothing over five hundred feet high between us and the field so I'll hold her at a thousand, no need to waste fuel going higher. Follow the beam and keep an eye on the altimeter and that's all there is to it."

That was not all there was to it for the weather worsened with every mile they flew until the great mass of the helithopter was tossed and spun about like a child's kite. Only the ready skill and lightning reflexes of the pilot held them on course while, despite his outward calm, the dampening of his shirt collar indicated the severity of the task. Gus said nothing, but held tight to the seat and looked out at the swirling snow as it blew through the golden cone of their lights and tried not to think about the minutes quickly slipping by. There was still time, there had to be time.

"Now look at that, just look at that!" Jones called out cheerily as he spared an instant to point to their radio beacon where the needle was spinning in mad circles.

"Broken!"

"Not half likely—it just means that we are over the beacon, over the field. Hold tight for we are going down."

And down they did go, plummeting towards the unseen ground below while the altimeter unwound and the snow rushed by.

"Do you see anything, Captain Washington?"

"Snow, just snow and blackness. Wait . . . a moment . . . there! Off to port, lights of some kind, and more below us."

"Gander. And there come the lads to hold her down and just in time. Sit tight for this is not ideal weahter to maneuver."

But he did it. A fall, some quick work with the controls and throttle to check them, slow, drop again, until with a jar and a thud they were grounded and the engine died as the throttle was closed.

"I'll never forget what you have done, Jones," said Gus as he warmly shook the other's hand.

"Just part of the ordinary R.A.F. service, Captain. A pleasure to have you with me. You'll win this yet."

But would he? After a quick rush through the blizzard to the haven of the heated building and hurried introductions by the officers there, Gus became aware of a general unease coupled with the specific disability of anyone to meet his eye.

"Is there something wrong?" he asked the Wing Commander in charge of the base.

"I am afraid there is, sir. I would be hesitant about taking off an aircraft in a storm like this, but it could be done, and the runways could be cleared of snow now, no trouble there. But I am afraid that the wind, gusting over a hundred miles an hour at times, has lifted and dropped the Wellington and damaged her landing gear. Repairs are being made but I do not think they will be done before midnight at the earliest.

We could still reach London in time, but if the storm continues unabated, and Met office says it will, all the runways will be sealed by then. It is the horns of the dilemma, sir, for which I beg your profound pardon."

Gus said something in return, he was not sure what, then accepted with thanks a steaming mug of tea. He looked into it and saw failure and drank deep of the bitterness of despair. The fliers sensed his mood and busied themselves at other tasks to leave him in solitude. It was so damnably frustrating! So close, so much effort, so much rising over circumstance and fighting adversity, to be stopped at the last moment like this. The forces of nature had balked him where sabotage had not. These bitter thoughts possessed him so that he was scarcely aware of the room around him and the officer who stood in front of him remained there for some minutes before his physical presence made itself known. Washington raised a face stamped with defeat until he became aware of the other man and smoothed his features so his feelings did not show.

"I am Clarke, sir, Captain Clarke. Forgive me for intruding with what may be, could be considered as, a suggestion."

He was a thin man, slightly balding, wearing gold-rimmed glasses and seemed most sincere. His voice still held the softness and rolled R's of his Devonshire youth though there was nothing of the rustic about him now.

"Please speak, Captain Clarke, for any suggestion is more than welcome."

"If I might show you, it would perhaps be simpler. If you would follow me."

They went through a series of connecting passageways to another building, for snow and blizzards were not unknown here at the best of times and this device enabled free passage whatever the weather. They were now in a laboratory of some sort with wires and electric apparatus on benches, all dominated by a mass of dark-cased machinery that covered one wall. Through glass windows set in the mahogany front of the impressive machine, brass gears could be seen, as well as rods that turned and spun. Clarke patted the smooth wood with undisguised affection.

"A Brabbage engine, one of the largest and most complex ever made."

"Beautiful indeed!" Gus answered in sincere appreciation, forgetting for the moment his great unhappiness. "I have never seen one this size before. I suppose you have a large memory store?"

"More than adequate for our needs as you can see." He opened a door with a flourish to disclose serried banks of slowly turning silver disks, all of them perforated with large numbers of small holes. Metal fingers riding on rods brushed the surfaces of the disks, bobbing and

clicking when they encountered the openings. There was a continual soft metallic chatter going on, along with some hissing and an occasional clatter. From this welter of sound Clarke must have detected an inconsistency because he cocked his head to one side, listening, then threw open the next panel and seized an oil can from the bench behind them. "A fine device, although it does need upkeep." He dropped oil on the bearings of a cam follower where it rode up and down on the smoothly formed and complex shape of a brass analog cam. "They are making wholly electric Brabbage engines now, calling them computers as if that made a difference, they are much smaller but still filled with bugs. Give me good solid metal anytime, although we do have trouble with backlash in the gear trains."

"It is all very interesting . . ."

"Please excuse me, Washington, no excuse really, bit carried away, dreadfully sorry." He dropped the oil can, flustered, picked it up again, restored it to the bench, closed the panels and pointed to a door across the room. "If you please, now you've seen the Brabbage, right through here. This may interest you more."

It did indeed, for beyond the door was a great hangar, in the center of which stood the tall, spearlike form of a rocket. Fifty feet or more it reached up, six feet thick at the base, finned and sleek and stern, all of a color, blue-black and striking.

"*Black Knight,* our best and most powerful rocket. Completely reliable with a most efficient liquid fuel engine that burns kerosene mixed with peroxide. Very delicate controls. Sends back a radio signal as it goes along that is monitored by the Brabbage engine we have just seen, so that course adjustments can be made in flight. Using this we have been most successful in an experimental program that may soon become a standard practice. Rocket mail, the Post Office is interested as you can well imagine, between here and Croydon. They have one of the electric computers there, pick up the signal as *Black Knight* comes over the Atlantic and guide her in, cut engines and all that, bring her down by parachute . . ." His voice ground to a halt as Washington turned slowly to stare at him, fix him with a terrible gaze. When he spoke again it was hurriedly, stumbling at times. "No, hear me out please, experimental program, nothing more. Worked every time so far, mail got through, but who knows. Tremendous acceleration. Kill a person dead perhaps. But other experiments, sent a chimp last time, Daisy, sweet thing, in the Regent's Park Zoo right now, never seemed to phase her, ate a whole hand of bananas when they took her out."

"If you are saying what I think you are saying, Clarke, why then I am your man. If you would like a volunteer to cross the ocean in your piece of fireworks, then I have volunteered. But only if it gets me there

a transatlantic tunnel, hurrah!

by nine in the morning. Will it?"

And indeed that was what the Devonshire engineer had in mind and the more he explained the more convinced Gus was that victory might still be snatched from the already closing jaws of defeat. The other engineers and the base commander were called in and they conferred, London was contacted on the radio telephone and more conferring was done until, in the end, there were none to say nay and the yea-speakers were overwhelming in numbers and there was no choice but to do this new and wonderful thing.

It was a labor to finish in the few hours that remained, but labor they did. Outside the arctic storm howled and beat in impotent rage against the buildings while inside they worked on the device that would vanquish the storm, vanquish time and space and distance to send a man from the new world to the old in a matter of some few minutes. The rocket was fueled and readied and all of its complex circuitry tested while, high above, the mechanics labored to install the rubberized lining and to pump in all the gallons of water that would be needed.

"That is the secret," Clarke explained, eyes glistening with enthusiasm behind the smudged lenses of his glasses. "Amniotic fluid, a secret known to nature and there for the taking had we but the sense to know where to look. But we have at last looked and seen and utilized this se-

cret. As you know 1-G is the force of gravity, gravity as we know it on the surface of the Earth. Acceleration and gravity seem to be identical, or at least that's what that German chap Einstein who used to be at Oxford says, identical. We accelerate and feel 2-G's and are uncomfortable, 3-G's and we suffer, 5-G's, 6-G's strange things happen, death and heart failure and blackouts, very nasty. But, suspended in a liquid medium, we have had test subjects, simians for the most part, subjected to 50-G's and they survived in fine fettle. So that is what we are doing now. A space-going womb, ha-ha, you might call it."

"Submerged all the way? I hope I won't have to hold my breath?"

"That would be impossible . . . Oh, pulling my leg, Captain Washington? Oh dear yes! No, indeed, quite comfortable. The water may be chill but you will be wearing a wet suit with an oxygen mask. Quite comfortable indeed."

Comfortable was not exactly the correct word, Gus thought as helping hands slipped him into the space-going bath. He dropped below the surface and fastened the snaps to his belt as he had been instructed while he breathed slowly and carefully through the mask. It was all quite interesting though there was a moment of disquiet when the distorted faces and hands above him vanished and the nose cone slid into place with a resounding clang. The water carried all the sounds and he could hear the clanking and grinding of metal as the bolts were secured. Then silence.

This was the worst part, the waiting in the darkness and solitude. Alone, alone as he had never been before in his life, perched atop this column with its cargo of highly combustible fuel. Waiting. He could visualize the roof opening up above the rollers, the preflight checkoff, the switches thrown. He had been told this would take a few minutes but had not realized that his time perception would be thrown off to such a degree. Had minutes passed—or hours? Had there been a failure, an accident? Could he escape from here or would he die in a boiling pot atop a fiery column? His imagination steamed along in high gear and had he been able to speak he would have shouted aloud so great was the tension at this moment.

And then a sound, a whine and a scream like the souls in the pit in eternal agony. He felt the hair on his neck stir before he realized that it was just the high-speed pumps going into operation, forcing the fuel into the combustion chamber. The flight was beginning! And at the instant he realized that there was a distant rumble and roar that grew fantastically until it beat at his ears so he had to cover them with his hands while something unseen jumped on his chest and battered him down. Blast off!

For a long and unmeasurable time the pressure continued—then suddenly ceased as the engines shut

down. The rocket was coasting. In those eternity-long minutes while the engines were working they had burned their way up through the storm and penetrated the atmosphere above and the stratosphere above that until now they were beyond the last traces of airy envelope of the Earth and arcing through the vacuum of space. The Atlantic was a hundred, two hundred miles below them and ahead was England. And the waiting computer at the airport in Croydon, that sleepy little suburb of London, an electric Brabbage engine that was not as reliable as the mechanical one and he hoped that, at least this once, the enthusiastic Captain Clarke would prove to be wrong about the reliability of that machine.

Yet as they coasted his heartbeat slowed and he felt a measure of peace and even good cheer. Fail or succeed, this was a voyage that would be remembered, almost a modern version of that romantic novel by the Frenchman about a voyage around the world in eighty days using all forms of transportation. Well here he was, utilizing some forms of transportation that the redoubtable M. Verne had never dreamed existed. This game was certainly worth the candle. It was in this reposed state of mind that he felt the engine re-ignite and so composed was he that he smiled at the thought. Dropping now, over Surrey and down, steering, pointing, falling and at the last moment the crack of the released parachute. There was a sudden jar that might well have been that parachute opening and soon after another and what he was sure was a cessation of motion. Had he arrived?

Evidence came swiftly. There was a clank and a bump, then another one, and once again the grinding of metal. In a moment the nose cone above him vanished from sight and blurred faces appeared in its place against the brilliant blue of the sky. Of course! He had flown into daylight in the swiftness of his voyage. He rose up and pushed his face above the surface of the water and tore off the mask and smelled the sweetness of the warm air. A smiling face, bad teeth in that wide grin and a spanner in the matching hand, looked down, while next to this face a sterner one below a blue official cap and a square of cardboard next to that.

"Her Majesty's Customs, sir. You have seen this card which lists contraband and dutiable items. Do you have anything to declare?"

"Nothing. I have no baggage."

Strong hands helped him out to the top of the wheeled platform that rested against the tall rocket. A view of white concrete, green trees beyond, a waiting group of men, distant cheers. He turned to the Customs officer.

"Might I ask you the time?"

"Just gone a quarter to nine, sir."

Was there time? How far to the station in London? Ten, twelve miles

at least. Pushing away the helping hands he scrambled to the ladder and half slid to the ground, stumbling at the bottom and turning to see a familiar bulky form before him.

"Fighting Jack!"

"Himself. Now hurry and you like t'make it yet. There are clothes in here." He thrust a paper parcel into Gus's hands while hurrying him forward at the same time towards an unusual vehicle that was backing towards them.

"That there driver is Lightning Luigi Lambretta who is a good driver, even though a Wog. Now get in and away with you."

"A pleasure to meet you, signore," the driver said as Gus dropped into the empty cockpit and felt the seat slam into his back the instant he was down. "This car the winner of the Mille Miglia, so not to worry. *Due cento,* two hundred of your horsepowers, like the wind we shall go. Steam-powered turbine, fueled with gasoline and using Freon as the vaporizing fluid. The *polizia* out and roads cleared all the way to Putney Bridge and beyond. A nice day for the drive."

They roared, they raced, they dived down the road with a squeal of complaining rubber as they sideslipped and skidded broadside into the London Road at over a hundred miles an hour. Quick glimpses of bobbies holding back the crowds, flags waved, a holiday air to everything. Squirming in the tiny seat Gus managed to slip out of the wet suit and the slipstream grabbed it and whisked it from sight. He was more careful as he opened the parcel and drew out small-clothes, shirt, tie, lounge suit and sturdy boots below all this. It was an exhausting effort to get them on, but don them he did and even knotted his tie fairly adequately.

"The time?" he shouted.

"One minute past the nine."

"Then I have failed . . ."

"Not yet, signore." Roaring at one hundred thirty-five miles an hour onto Putney Bridge. "Things are arranged, I have talked by the phone, all of England is on your side, the Queen herself. She was delayed leaving Buckingham Palace, marvelous woman, and now she proceeds most sedately by the horse and carriage to the station. All is not lost yet."

Would he succeed? Would failure follow this heroic effort? It was now in the hands of the gods and it was to be hoped that they were smiling. Brake, accelerate, squeal of rubber, broadside through the narrow streets, a twist of the wheel to save the life of a stray dog, around another corner and there was the station. Down the ramp towards the platform, the State Coach to one side, empty.

The train, pulling out.

"Never fear, dottore. Lightning Luigi will not fail you!"

Laughing wildly and twisting

his fierce mustachios with one hand the intrepid driver hurtled his blood-red machine at the platform while the officials and bystanders scattered, raced up to the train, alongside of it, easing over until his offside wheel was only inches from the platform edge, matching his speed to that of the train and holding it steady and even close to the open door.

"If you would please to disembark, signore, the end of the platform fast approaches."

In the instant Gus was standing on the seat, standing on the rounded top of the racing car and bracing himself with a hand on the driver's head, reaching out for the extended hand from the train, grabbing it, leaping, looking back horrified as the driver stood on his brakes and slid and twisted and slammed into the pillars at the station's end. But he was waving and shouting happily from the smoking wreck.

"This way, sir," said the porter. "Your seat has been reserved."

VIII

Green England hurtled by outside, fields and streams like speeding patchwork quilts, blue rivers that swept under their wheels, black bridges and gray stone villages nestled around church spires, also in motion, also whisking by to quickly vanish along with the waving crowds in the fields and the rearing horses and barking dogs. It seemed that the entire countryside was unrolling for the benefit of the lucky travelers in this mighty train this fortunate day, for so smooth was the ride that the passengers aboard the *Flying Cornishman* felt that they were indeed standing still and the whole of England was spinning by beneath them for their edification alone.

They were indeed a blessed few who had secured passage in this inaugural run of the tunnel train, nonstop London to Point 200, the artificial island far out in the Atlantic Ocean, west of Ireland, and over a hundred miles from the nearest shore. The Queen was aboard, and Prince Philip, while the Prince of Wales also had returned by special train from Moscow where he was on a state visit to make the trip. There was a sprinkling of the nobility and the Proper Names, but not as many as might be expected at the Derby or a fashionable opening, for this was science's day, the triumph of technology, so that the members of the Royal Academy outnumbered those of the House of Lords. The company directors were there as well as the largest financial backers, and a well-known actress whose liaison with one of these backers explained her presence.

There was champagne, bottles of it, cases of it, oh dear—a refrigerated room full of it, courtesy of The Transatlantic Tunnel Company who had bought almost the entire stock of an excellent 1965 from a lesser known but superior chateau. This golden liquid flowed like a river of

beneficence through the corridors and compartments where glasses were lifted and toasts drunk to the glory of this hour, the superiority of British engineering, the strength of the pound, the stability of the Empire, the peace of the world, the greatness of this day.

Aboard as well, in sorely diminished ranks, was the press, thinned down by the exigencies of seating space, swollen again by the need for complete world coverage for this historical event. One cameraman was filming everything for the entire world to see at the same time on their television sets, though of course B.B.C. viewers would see it first, while the world papers would have to be satisfied with what the gentleman from Reuters told them, other than the French that is, who would read what was written by a small dark gentleman, pushed to the rear by his bulkier Anglo-Saxon colleagues, who was aboard though by bribery for which at least one head would roll in Transatlantic House. Of course the gentleman from *The Times* was there, since the kind attentions of the Thunderer of Printing House Square were much sought after, and a few other leading journals including, with much reluctance and persistent insistence since this was going to be a *transatlantic* tunnel, the square-shouldered bulk of the New York *Times'* man.

They all wanted to talk to Washington at once, because he was the most singular piece of news aboard for the readers around the world who had been following every thrilling and heart-stopping detail of his journey. Now, on the last leg, with the finish line but a few hours away, they wanted him to describe all of the earlier stages down to the smallest detail. Between sips of champagne he answered them, reliving the heartstopping moments aboard the helithopter and the rocket, the mad ride to London, the last moment arrival. He was informed in turn that the driver, Lambretta, had received only minor bruises and regretted nothing, was, in fact, enthused that one of the more popular dailies had already purchased his personal story for a price reputed to be in five figures.

Every foot of the journey to Penzance, Gus was interviewed, and he was rescued only by the fact that the journalists had to file their stories. Since they would have tied up completely the only telephone and telegraph link from the train they had been forbidden access to them, with the exception of the gentleman from *The Times* who had been permitted to file one brief report, so arrangements had been made to put off a bag in Penzance. The great canvas sack, boldly labeled PRESS, was quickly filled with the reports and stories and the can of film put in on top. Other arrangements of an ingenious nature had been made as well so that the various reporters now dispersed to complete the work. Fast cars were waiting by certain fields,

displaying flags of particular colors, ready to pick up dropped containers, one motorcyclist on a racing machine paralleled the train briefly on a stretch of road and was seen to end up in a pond still clutching a hoop and attached package he had seized, while more than one net-armed and speedy boat waited in waters the train would cross.

Free of his interviewers for the moment, Gus found his compartment and his allotted seat, which he now saw for the first time, and accepted the congratulations and another glass of champagne from the other passengers there. At this point he escaped their attention for the train was slowing as they passed through Penzance where the waiting thousands cheered uproariously and waved their Union Jacks with such animation that they fluttered like gaudy birds. The Press bag was thrown to the platform and the attendant telegraph men, the train picked up speed again, through the city and towards the dark mouth of the tunnel, passing the sidings where the other trains waited, packed with humanity, to follow after the inaugural run. Faster and faster it went to dive with a roar into the black opening, accompanied by excited female shrieks at the sudden night.

Gus, who had been in a tunnel before, closed his eyes when they entered and when the others had exhausted the pleasures of gazing out at nothing and turned back he was well and soundly asleep. They appreciated his fatigue after the voyage he had just accomplished and lowered their voices accordingly so that he slept the sleep of the just, and they only roused him when the announcement was made that they were just ten minutes from arrival at Point 200.

An air of electric excitement overwhelmed the travelers and even the most cynical and worldly-wise were possessed by it, peering out at the darkness, getting up and sitting down again, and generally displaying an eagerness they would normally have scorned. Slower and slower the great train went until a grayness could be seen ahead and then, startling and sudden, a burst of brilliant sunlight as they emerged from the tunnel into the open air. Through the empty train yard and over the points they rumbled to the station where the waiting band struck up the lively tune of *"A Transatlantic Tunnel, Hurrah!,"* the song specially commissioned for this occasion from Sir Bruce Montgomery and now having its debut performance.

Wide and clean and spacious this station was, and seemingly empty of life until the passengers poured from the train, oohing and ahhing at the appointments. For the top of the station, high above, was constructed entirely of large panes of glass through which blue sky and soaring gulls could be seen. This was supported by cast-iron columns enameled white

and decorated at the junctions and on the capitals by iron fish and squid and whales cunningly cast into the fabric of the supports themselves. These configurations were finished in blue, and this color scheme of white and blue was carried on throughout the great station giving it an airy and light feeling out of all proportion to its size.

The passengers held back respectfully as the red carpet was brought up and unrolled and the Queen and her party descended. There was the quick flashing of lights from the photographers and then they had gone and the others followed.

No one, no matter how stern of demeanor or inflexible of expression, but failed to hesitate for a moment and to draw in a gasp of breath upon emerging from the station between the alabaster columns that supported the portico. For here was a vista that was breath-catching and inspiring, a wholly new thing come into the world. Broad white steps descended to a promenade that glistened and shone with the multihued splendor of the inlaid mosaics, arches and waves and wriggling bands of color not unlike those of the promenade at Copacabana Bay which undoubtedly had no small influence upon their design.

Just beyond this was a field, a rolling meadow of the trimmest and greenest grass that sloped down gently to the deep blue of the ocean beyond that was now breaking with small waves upon the shore. No flotsam or refuse marred the purity of this ocean so far from any shore, no land was visible at any distance in any direction where only the white wings of the yachts scudding across the surface broke the perfect emptiness. Once the visitor descended these steps there were greater wonders to come, for this promenade followed the shore of this new island and with every step forward there was something incredible to see.

First a great hotel stretching long wings into a flower-filled garden below and rising in matched, blue-domed towers high into the air. On the terrace here the orchestra played a dance tune to tempt passersby to the linened tables where black garbed waiters stood ready to pour tea. There was a holiday air about this spot and along the promenade, a holiday holding its breath in the wings and waiting to arrive, for all of this was ready and had never been used before, brought in by sea and constructed here in all optimism that custom would follow when the tunnel was opened. Restaurants and dance halls, and tucked away behind the elegant establishments, little lanes that led to fun fairs and roundabouts and ferris wheels, coconut shies and public houses; something for everyone. Further along were the beaches of white sand that glistened welcome and soon the first bathers could be seen, stepping hesitantly into the water then shouting in amazement for here, in the

middle of the Gulf Stream, the water was warm and salubrious as it never was at Brighton or Blackpool.

Behind the beaches rose the turrets and towers of Butlin's 200 Holiday Camp waiting impatiently for all who had booked in, the loudspeakers already calling the first arrivals to the heady pleasures of group amusements. And more and more, until the eyes of the strollers were filled with the color and panoply. Farther on, around the island, there was the yacht basin, already jolly with the jostling boats that had sailed here for this grand opening day, and still farther along a tree-crowned hill where the promenade ended in an outdoor bowl where a Greek drama, ideal for this pastoral setting, was about to begin. All was pleasure to the eye and so it had been designed, for the hill shielded from view the other half of the island where the industrial park, railway sidings, and commercial docks were located. Great things were planned for Point 200 and the transatlantic tunnel and the investors had flocked to its proffered charms. It was indeed a wonderful day.

Washington enjoyed the stroll and the sight of the colorful activity just as well as did the shopkeeper from Hove or the lord from his castle, walking and mingling with them along the way. Tired finally he repaired to the great hotel, The Transatlantic Towers, where a room had been reserved for him. His bag, sent on ahead weeks ago, had been opened and unpacked, while the table was banked with flowers and congratulatory telegrams. He read a few then put them aside, feeling let down after the fury of the preceding hours, sipped from the champagne provided by the management and went to his bath. Soon after, feeling refreshed and in better sorts, he donned a lightweight silk tropical suit, more fitting for this clime than his tweeds, and was just fixing his cravat when the telephone chimed. He took it from the drawer, put the microphone on the table before him and the receiver to his ear and threw the small switch which activated it. The familiar voice of Drigg, Lord Cornwallis's secretary, spoke, congratulating him on his voyage and extending the marquis's invitation that he join them on the terrace at his convenience.

"I will be there shortly," Gus said, disconnecting the instrument, putting a flower in his buttonhole, and drinking one last glass of champagne in preparation for the encounter.

It was a small and elite group that was gathered there on the secluded balcony overlooking the sea, taking the late afternoon sun and basking in the balmiest of breezes. A sideboard spread with regimented bottles enabled them to help themselves to whatever drink they chose without a waiter to interrupt their privacy. If a pang of hunger should stir them, a great crystal bowl of Beluga caviar rested in cracked ice for their edifi-

cation. Above the sideboard there hung in stately display a detailed map of the North Atlantic with the route of their tunneling ventures scribed upon it. From time to time one or the other of the men would look at it and usually smile at that heartening sight.

Sir Isambard Brassey-Brunel sat with coat open and his waistcoat half unbuttoned, an unusual relaxing of sartorial standards for him, and sniffed from time to time at the sweetness of the sea breeze and taking small sips from his glass of Perrier water. Across from him Lord Cornwallis relaxed with a slightly more fortifying drink of Hennessy Seven Star of an unbelievable vintage, varying his attention between this and a Jamaican cigar of impressive length and girth and superior whiteness of ash.

Sir Winthrop Rockefeller considered the hour too early for such spirituous beverages so sipped instead from a glass of claret with the bottle placed handily beside it. All three men were composed and given almost entirely to small talk, basking in the relief of a job well done before turning their energies to the next task ahead. For all of the news was good, they had nothing to fault, it was indeed a splendid day.

When Augustine Washington was shown in they rose by common consent and the handclasps that were exchanged were those of mutual acclaim. They did congratulate the young engineer on the success of his voyage that so dramatized the opening of this new age of tunnel travel, and he in turn thanked the financiers for making everything possible, and the older engineer for the design and labor that had enabled the tunnel to be done at all. Sir Isambard nodded at this tribute, aware of what was his rightful due and, after they had seated themselves and Gus had accepted a glass of wine from Sir Winthrop's bottle, composed himself to speak about a matter he had long considered.

"Washington, we have been estranged long enough. Our personal differences have not prevented us from doing our best for the company, but I do feel that the past is now so much water over the dam and it is time to let bygones be bygones. Rockefeller here is chairman of the American Board again and I want to state before these gentlemen that you have done an excellent job with the American tunnel." He sipped from his glass for a few moments while the two other gentlemen cried *hear, hear!* with great enthusiasm, then resumed. "When I am wrong I freely admit it, and now I admit that the technique of preforming and sinking tunnel sections is not as dangerous as normally assumed and is indeed faster as you have proven. It has been utilized in completion of the tunnel we passed through today as proof of this assumption. It is my hope that we shall be able to work together more closely in the future and, in addition,

you will find yourself welcome in my house once more."

This latter bit of information took Gus by surprise for he started from his chair, then sank back again, and a slight pallor touched his skin, proof that this casual piece of social intelligence caused more stir in his constitution than the most severe of the hazards through which he had so recently passed. However he took some of the wine and when he spoke next he appeared as composed as ever.

"I accept this news and this invitation with the most profound thanks, sir, because, as you must know, I still consider you the leading engineer and builder of our age and it is my pleasure to work under you. It will also be my pleasure to call at your home. And your daughter is at home, I presume . . ."

"Iris is well, and she accompanied me on this trip, and I presume will make you welcome as well, but I do not discuss this sort of thing with her. Now to other and new business. Though today is a success, tomorrow will surely come with its problems and we must prepare for it. The two units of the tunnel now completed are important and will, if the figures I have seen are correct prognostications, earn money in their own right. Point 200 will soon grow to a major and most modern port where goods bound for England can be offloaded and sent ahead by train, quickly and surely, thus avoiding the Channel traffic and the outmoded facilities of the Port of London. I believe we have witnessed its other success today as a spa and resort. On the far side of the Atlantic the Grand Banks Station will perform like functions, in addition to which the fishing fleets will unload their catches there for rapid transport of fresh fish to the colonies. All well and good but we must press on and justify the name of this company. We must cross the Atlantic. The preliminary surveys and reports are done, now is the time to finalize and put them into action."

There were warm shouts of agreement at this, for they were all as eager as he to see this mighty project through to completion. Financing, of course, would be the next consideration and the two chairmen of the transatlantic Boards of Directors rose and spoke in turn about the state of their treasuries. In fine they were healthy as bull pups. The recent improvement in the States of their national economies, that might very well be traced to the tunnel operations, had left considerable profits in a number of hands and eager money was waiting to be invested. That the nods of agreement were not quadrilateral was not noticed in the warmth of their enthusiasm; there seemed nothing standing in their way.

But Gus grimly fingered the stem of his glass, looking up betimes at the map on the wall, then down at the surface of his wine as though some important revelation was

drowned in its depths. He seemed at internal battle within himself, as indeed he was, for a door had opened again this day that had been closed for many a year and for this he would be eternally grateful. But what he had to say might very well close that door again—yet he could not leave this place without speaking, for it was scientific fact that he must mention.

And so the war of heart and head was fought within and, silent as this battle was, it was more terrible and devastating than any conflict of shell or bomb. In the end he came to a conclusion for he drew himself up, drained the prognosticatory glass of wine, and waited for an opportunity to speak. This came soon enough as the financial details were resolved and the engineering programs came to the fore. He gained the floor and crossed to the map where he traced the proposed course of the tunnel with a steady finger.

"Gentlemen, you all realize that the longest and most arduous portion of our labor now lies before us. Sir Isambard has proposed a radical form of transportation in these sections of our tunnel and research has proven that his genius was correct. The evacuated linear electric line will add a new dimension to transportation in the future."

"Forgive my interruption," said Cornwallis, "but I'm not quite sure that *I* understand the operation of this thing and I would be deeply grateful if you could explain it in some manner that would enable me to grasp it. Though I can wend my way through the intricacies of international finance I must admit that my head grows thick at the mention of electrons and allied objects."

"Nonsense, Charles, I've told you a dozen times how the blasted thing works," Sir Isambard broke in, quite warmly. "Let's get on with the affairs at hand."

"Please, an explanation first, if you don't mind," said Sir Winthrop, with some gratitude. "I am happy to see I am not alone in my ignorance, which was causing me some concern. If you would, Washington."

Sir Isambard subsided, grumbling at this outrageous waste of time, draining a reckless draft of his spring water, so annoyed was he. Gus took this as assent and explained.

"The theories behind the proposals are quite complex, but there is no need to go into that since the results can be simply understood. Think of the tunnel, if you will, as an immense length of pipe, solid and integral. There is air in this pipe at the same pressure as most air upon the surface of this world, that is in the neighborhood of some fifteen pounds to the square inch. This air serves only one function, that of permitting the passengers in the trains to breathe, an important fact to the passengers but of no importance to the engineering of the tunnel. These few pounds of pressure add nothing to the structural strength of the tun-

nel walls to keep out the immense pressures of the ocean above, and from the engineering point of view the air is, in fact, a handicap because it limits and retards the speed of the trains. Remove the air, an easy thing to do, and the trains would go faster while using less power."

"But the people, sir, our passengers, they must breathe!"

"And breathe they will—for the trains will be sealed and pressurized just like high-altitude aircraft. With the air removed we can now consider higher speeds than were ever possible before. Why there is no reason why our trains cannot go eight, nine hundred—even a thousand miles an hour."

"Wheels and bearings will not sustain such speeds."

"Perfectly correct, Sir Winthrop, which leads us to the next stage. A train with no wheels. This train will literally float in the air as powerful magnets in the train are repelled by equally powerful magnets in the track. We have all seen how one magnet will support another in midair upon its repelling field, and thusly will our train ride in its evacuated tunnel. But what will move our train? And here is the genius of Sir Isambard's answer.

"The train will move by means of a linear traction engine. I shall not explain this complex invention, but suffice to say it is like an electric motor turned inside out with one part of the motor aboard the train and the other stretched on the roadbed the length of the tunnel with no physical connection needed, or wanted, between them. In addition, most of the train's speed will be derived by its dropping off the edge of the continental shelf and falling the three miles down to the abyssal plain on the ocean's bottom. And there you have it, gentlemen, a sealed train in an evacuated tube, floating in mid tunnel and touching nothing physical, even molecules of air, being started on its way by gravity and continuing by electricity. A form of transportation as modern as the entire concept of the tunnel itself."

There were sighs of relief from the financiers and a few questions to clear up certain points so that when Gus continued he had the informed and knowledgeable attention of his small audience.

"As has been demonstrated we now have our means of transportation and the preforming technique to lay the tunnel. The final step, before detailed surveying and construction begins, is the selection of the route to be followed. Because of the complex nature of the ocean's floor, great care must be taken at this point, for the bottom of the Atlantic is no sandy lagoon that may be slashed directly across. Hardly! What we have here is a varied landscape more complex and drastic than the one we know on the drier surfaces of our globe. There are, of course, the abyssal plains that form the bottom, lying at an average

depth of sixteen thousand feet below the ocean's surface, but other features must be taken into consideration.

"Down the center of the ocean runs the Mid-Atlantic Ridge, a great mountain chain that is in reality a double row of mountains with the gorge of the Rift Valley between them. These mountain ranges and the Rift Valley are crossed at right angles by immense canyons called fracture zones that resemble wrinkles in the Earth's hide. Other features also concern us, the Mid-Ocean Canyon, like an underwater riverbed on the ocean's floor, seamounts and islands and trenches—that is, extraordinarily deep gulfs—such as this one, on the map here, that is over five miles in depth.

"And there are more factors to consider, underwater earthquakes and vulcanism which are concentrated in specific areas for the most part, the very high temperatures of the sea bottom near the Rift Valley as well as the fact that the sea bottom here is moving as the continents drift apart at the rate of about two inches a year. It appears, and the geologists confirm the suspicion, that new matter rises from the Earth's interior in the Rift Valley and spreads outwards at that steady rate. All problems, gentlemen, but none of them problems that cannot be surmounted.

"You will note the proposed route on this map which avoids these enumerated obstacles. If we begin here at Point 200 on the edge of the Continental Shelf, our tunnel proceeds roughly north northwest along the fracture zone we call 41-G that joins the end of the Mid-Atlantic Ridge and the offset Reykjanes Ridge south of Iceland. By doing this we avoid the peril of crossing the Rift Valley which ceases to exist at this point. Now, further west, we emerge from the fracture zone and turn south, skirting the Mid-Ocean Canyon and swinging around the heights of the Milne Seamount until we reach the Sohm Abyssal Plain. At this point the tunnel will turn almost due north to rise up the Laurentian Cone to meet the tunnel already laid on the Continental Shelf at the Grand Banks Station. Now this route might be said to have a few faults."

There was a rumble like a distant storm from Sir Isambard's direction that Gus chose to ignore as he continued.

"Since the ocean bed is so warm in the fracture zone special tunnel sections will be laid on the bed itself, not in a trench, and constructed in such a manner that water will circulate through cavities in them to keep them cool. However the major criticism might be that, in order to avoid all the geological details, the tunnel will be twice as long as it would be if it went in a direct manner, therefore twice as costly."

"Good God, man," Sir Isambard exploded. "We have been over this before and you know we can't go

directly across the infernal ocean. So what are you suggesting?"

There was a hushed silence as Gus took a sheet of paper from his pocket and unfolded it; gulls could be heard crying outside and the strains of the orchestra playing in the distance, but all was listening quiet on the balcony.

"That is just what I am suggesting," said Gus, with a positive sureness. "And I intend to show you how. I propose that the tunnel go due *south* from Point 200, over the flat bed of the Biscay Abyssal Plain to a base in the archipelago of the Azores, where it will meet the other leg of the tunnel that has come almost due east from the Grand Banks along the Oceanographer Fracture Zone. This route is less than half the length of the one under consideration now and, in addition, will provide an unexpected benefit. Cargo can be unloaded in the Azores base to be loaded on ships for Africa and the Continent, thereby shortening the voyage greatly. Plus the fact that another leg of the tunnel can eventually be considered from the Azores to Spain that will make a train connection between the Continent and the Americas. If this is done the results will be simply amazing.

"It will then be possible for a passenger to board a train at the Pacific port of Provideniya at the end of the Trans-Siberian Railroad and thence to proceed by train across Siberia, Russia and Europe, under the Atlantic, across America and connect with the Trans-Canada Railroad to Alaska there to finish his journey once more on the shores of the Pacific. After a journey around at least ninety-nine percent of the Earth's circumference at this point."

At this juncture there were shouted questions and eager enthusiasm for more information about this novel idea until Sir Isambard hammered with his fist for silence.

"A mad dream, nothing more. Or rather it would be possible were it not for the aforementioned Mid-Atlantic Ridge with the Rift Valley which, I believe, is at least one mile wide and a number of miles deep at this point. It cannot be crossed. The plan is discarded."

"Not so. The valley can be crossed and I have the plan for that procedure in my hand. It will be crossed, gentlemen, by an underwater bridge."

Into the following silence Sir Isambard's snort of contempt burst like a trumpet peal. "Nonsense, sir! Poppycock and nonsense! A bridge cannot be built a *mile long* that will support the weight of the tunnel sections at this depth."

"You are correct, sir, it cannot. That is why this bridge will have *negative* buoyancy, a thing our tunnel sections have in any case until we weight them down, so it will float over the canyon, secured in place by heavy cables."

This time the silence was absolute as Gus snapped open his plan and

put it before them, explaining how the bridge would be made and how, since it floated, it could absorb the two-inch-a-year movement of its opposite ends, and all the other details of his new proposal. For every question asked he had an answer and it soon became obvious that, unless unknown factors were thought up, this plan was far superior to the earlier one in every way.

Long before this became clear to the others it was realized by Sir Isambard who parted the table and stood, arms folded, staring out at the setting sun. When the others had exhausted their words and enthusiasm and stopped for breath he turned and fixed Gus with a gaze the coldness of which outdid the most frigid blast of arctic night.

"You have done this deliberately, Washington, produced your plan to supersede mine in an attempt to obtain some gain."

"Never sir! You have my word . . ."

"There is no doubt this design, or a variation of it, will be adopted," the redoubtable man continued, unheeding of the interruption. "The tunnel will be built to the Azores and you will get the credit I am sure. Since I put the good of the tunnel above my own ambition I will continue working as I have done in the past. But for you, sir, personally, sir, I have little regard. Please be informed that you will no longer be a welcome guest in my house."

Gus was nodding even before the other had finished, for it had been foreordained.

"I was sure of that from the beginning," said he, a weight of unspoken feelings in these simple words. "I have nothing but good feelings for you, sir, nor do I intend to do you injury in any way. I wish that you would believe me when I say that I have put the good of the tunnel ahead of any personal advancement for myself. Therefore, in the light of your remarks, I have no choice other than to resign from my position in the Transatlantic Tunnel Company and leave their employ. If my presence is a disconcerting one and interferes with the completion of this great work, then I will remove that presence."

His remarks, though spoken in a quiet voice, brought a stunned silence to the others in the room, though only for a few moments to Sir Isambard.

"Resignation accepted. You may leave."

This further paralyzed the verbal apparatus of the two men of finance so that Gus had actually risen from his chair and was on his way to the door before Lord Cornwallis could speak.

"Washington, a moment if you please. We must not be unilateral, matter of precedence, full consideration, blast me, I am not sure what to make of all this." With an effort he assembled his fractured thoughts and sought for some form of compromise even at this last moment.

"We have heard your suggestion and must consider it, since, Sir Isambard, with all due respect, you cannot speak for all the members of both Boards or even for myself or Winthrop. What I would suggest, what I do suggest, sir, is that we here consider what must be done and will then inform you of any decisions reached. If you would tell us where you could be reached at the end of our conference, Captain Washington?"

"I will be in my room."

"Very good. We will contact you as soon as there are any results to our deliberations."

Gus left then and the heavy door closed behind him with a powerful clack of the latch and a certain positive finality.

IX

On all sides cheer and goodwill abounded; tastefully clad couples and groups talked animatedly, friends called to one another with hearty voices, bellboys darted through the press in the lobby with messages and telegrams undoubtedly all of a happy, wholesome nature, and such a flood of good spirits encompassed them all that it must surely have lapped up and out of the windows and across the pavement bringing smiles as it went and causing even the gulls on the balustrades to cry with joy. Yet through this ocean of cheer one dark vessel plunged, a man with an aura of great unhappiness about him, cut off and alone, architect of all these glories, and now, in the hour of triumph, set apart from all those who enjoyed the fruits of his labors.

Washington was too depressed to be depressed, too numb for feelings, even miserable ones. He walked steadily and calmly with a grave exterior which in no way indicated the depths of unplumbed unhappiness within him, for the tunnel had become his life and without it he felt an empty shell. He was tempted to be bitter towards himself, yet if he had it to do over again he knew he would do the same. The improved route must be used. If saving the tunnel meant a loss in his personal life, then it must be done. Occupied like this, in the darkest of dark studies, he plowed through the crowd to a berth before the lift doors and waited for them to open. and open they did, quickly enough, for this lift was powered by hydraulics with a piston sunk into a cylinder deep in the ground, and he stepped aside so the single occupant could emerge, face to face with him, a chance of fate, a roll of some celestial die that determined that the occupant should be none other than the lady so recently mentioned, Sir Isambard's daughter Iris.

"Iris," said he, and could say no more for to his eyes her face and elegantly garbed form were enclosed in a golden nimbus that made detailed vision difficult.

"You're looking older, Gus," said

she with the eminently more practical vision of a woman. "Though I must say that touch of gray to your hair does add something." But, practical as she was, it could not be denied that, sure as her voice had been when she started to speak, there was a certain indeterminate waver to it before she had done. At this all conversation ceased and they stood, simply looking at each other for long moments until the boy who operated the lift piped up.

"Lift going up, your honor, all floors if you please."

With this they stepped aside so others could enter and in that bustle of humanity they were as alone as they might be in a rushing sea. She was as radiant as she ever had been, Gus realized, more beautiful if that were possible with the new grace of maturity. His eyes moved of their own accord down her left arm to her hand and fingers, but there any revelatory vision was blocked by the kid-skin gloves she wore. But she was well aware of his gaze and its import and she smiled in answer.

"No ring, Gus. I still live with my father, very quietly."

"I have just left him and we have talked. We had most friendly words and then, I am afraid, most harsh ones."

"My father in all truth."

"The friendly ones encompassed an invitation to make myself a guest at his home again. The harsh ones . . ."

"You shall tell me of them later, for just the first will do for now." With simple foresight she knew that this moment, brief as it might be, must be clutched at and abstracted from the flow of time. What came after would arrive speedily enough, but the passport to social intercourse granted by her father had to be seized and utilized. "Is there no place we can sit for a few moments?"

"I know the very spot," answered Gus, knowing nothing of the sort, but also now aware that here was an opportunity that might be grasped and, therefore, clutching at it with both hands. He excused himself for the moment and addressed one of the functionaries of the establishment who was stationed nearby, and if a sum of money changed hands this was to hurry the arrangements, which it apparently did, for they were led without further ado to a secluded alcove at the rear of one of the dining rooms where an attendant waiter vanished as soon he had taken their order and filled it with unusual speed. No tea this time, as on their last meeting, for Iris had reached her majority in the meanwhile and was one of the new brand of liberated women who drank in public places. She had a Tio Pepe sherry while he perforce had a double brandy.

"To your good health, Iris."

"And to yours, which needs it more since you seem to treat health and life with a very cavalier attitude."

"This last trip? It was necessary and there was little risk."

"Risk enough to one who sits in the quiet of a London room and waits for the reports."

"You are still concerned about me?"

"I still love you."

The words were spoken with such sincerity and truth that they bridged the gap of years as though these years had never existed, they had never been parted. His hand found hers, eagerly waiting, and pressed it beneath the table.

"And I have never stopped loving you, not one moment of the time. May the waiting be ended now. I still carry your ring, here, and have always hoped that I could return it to you some day."

"And can you now?"

The loosening of his touch, the moving away of his hand from hers told her more surely than any words could what was to be.

"I can, only if you will break with your father."

"The harsh words you spoke of. Yes, I suppose you must repeat them now, though I wish to heaven I did not have to hear them." With this she drained her glass and her cheeks glowed with the drink and the power of her feelings. Gus admired her in silence before he spoke again, knowing there was none like her on the face of the globe, knowing he would never love another.

"I have proposed certain changes in the tunnel that will modify and even alter drastically parts of your father's plan. We are of different opinions regarding the changes. He feels, and perhaps it is true, that my modifications of his work are a personal attack and after offering me the courtesy of his home he has withdrawn it. That's where matters now stand." No power on Earth could have dragged from him the admission at this point that he had also resigned from the tunnel, since this would be crude playing upon her sympathies.

"They stand there indeed and stand very crookedly I must say. Ring for another drink, if you please, because it is not every girl who sees her dreams restored and dashed again all in the space of a few brief minutes."

When she had her sherry and had touched it to her lips he spoke the question that meant the most to him.

"Must they be dashed? You are past twenty-one now and your own person. Would you marry me despite your father's displeasure?"

"Dear Gus, I would if but I could. But I must stay by him."

"But *why?* Can you give me any reason?"

"Yes, one, and I tell you only because you should know that I do this not from any lack of love for you, but because I have a certain duty. My mother is dead, as you know, my two brothers engineers like yourself and always far away. I am the only one he has. What I say now is in strictest confidence, known only to

myself and his physician, some trusted servants. My father is not a well man. Oh, I know he bombasts and roars and carries on as he always did, but the years have exacted their toll. He has had a heart attack, a serious one, so serious he lay between life and death for days. Now I must look after him and smooth everything in his way that I can because the physician says the next one will be fatal, he is almost certain of that. If I left him, went against his will, I would be killing him as surely as if I pulled a trigger."

After that there was nothing that could be added. They sat in silence for a few moments, then she rose and he stood as well. She kissed him on the cheek softly and he returned this distant embrace which is all they would allow themselves, knowing the wellsprings of emotions that they would tap with anything more. They said good-bye and she left and he watched her go until she vanished from sight behind the gilt pillars, then he resumed his seat and the swift destruction of his glass of brandy which burned so warmly, the only warmth in a world of cold, that he ordered another to follow it, then the bottle for the table so the waiter would not have to run back and forth so often.

Yet as much as he drank he was immune to drink. The level in the bottle lowered until it faced extinction and still its potent medicine never touched the chill core within him. His work had vanished, the one he loved had gone, there remained only an encompassing despair. He sat in this manner for a great length of time until he became aware of the waiter standing at his shoulder holding out a portable telephone instrument while a mechanic connected it to a concealed fitting in the wall.

"You are wanted on the line, Captain Washington," said he.

Cornwallis came on, his voice loud and booming.

"Washington, is that you? What a relief, we have been trying to contact you now for hours."

"Yes?"

"Well, tried to contact you as I said. Had quite a time here I can assure you, Sir Isambard is a difficult man as you well know. But he came around in the end. He puts the tunnel ahead of all other considerations as do we all. As I hope you do, too, Washington."

"Sir!"

"Of course you agree. In which case we are asking you to withdraw your resignation and carry on with us. We need you, man! Sir Isambard will build the Point 200 to the Azores leg, the easier one, and will let you do the American section with your infernal tunnel-bridge across the Rift Valley. Will you do it? Will you stay with us?"

The silence lengthened and Cornwallis's anxious breathing could be heard on the line. Despite the brandy he had drunk Gus was sober

on the instant, and when he answered there was only firmness in his voice.

X

Far out to sea thunder rumbled like great wooden kegs rolling over cobbles, and jagged flares of lightning lit up the banks of dark clouds with an ominous glow, creating for a moment an unreal landscape of fiery black meadows in the sky, a country of the damned hanging over the slate-gray sea. The first fat drops of rain flew ahead of the storm and splattered on the stone of the dockside while the gusts of wind sent up a shaking rustle and a clatter from the tall palm trees that stood in ranks along the shore. The tugs entering the harbor hooted hurried signals one to the other with white puffs of steam from their whistles, the steam silently visible to the watchers on shore long seconds before the mournful moan of the whistle could be heard.

They had reason to hurry for already the approaching storm was raising the waves and breaking streamers of white spray from their tops. Yet they still must make haste slowly for the great whale of a tunnel section they had in tow resisted any hurried motions with its multi-hundred tonned mass. Its humped back was just awash so that the rising seas broke over it, giving it the appearance of some surfacing sea monster, gray and ominous. Finally, with careful attention and much frantic hooting, it was brought into safe harbor behind the sea walls and secured to the waiting buoys there.

From his vantage point on the raised platform of the Control Office, Gus had a clear view of the harbor and work yards, train yards and barns, junctions and tracks, cranes and constructions, slipways and storehouses; a varied industrial landscape that was all under his control, where thousands of men labored at his bidding. It was a familiar scene now, yet he never tired of it. The radio at his elbow reported the successful tying up of the tunnel section at the same moment his eye saw the rising column of steam, the long blast that meant the tow was completed and the lines could be cast off. With this finished he lowered the powerful binoculars and wiped at his fatigued eyes, then looked around at the boom and bustle that was his life.

Riveting guns hammered and metal clanged on metal, cables squealed as great traction engines moved ponderous weights, small whistles toot-tooted as the puffing yard donkeys scurried back and forth through the maze of tracks, shunting the goods wagons about, great cranes swung as they lifted cargo from ships' holds. The raindrops came closer and closer until they were upon him and now he was grateful for their cool touch upon his bronzed skin, for it had been a hot and close day.

Though his shirt, with the sleeves

rolled up, and his puttees were made of the thinnest cotton khaki twill, the heat had still been insufferable, so that the rain was a welcome change. He even took off his topee and turned his face up to the sky so the drops splashed pleasantly upon him. Only when the shower became a torrent did he seek shelter in the office and take up a towel to dry himself. The office staff continued with their assigned tasks, except for the head ganger, Sapper Cornplanter, who now approached carrying an immense sheaf of papers.

"I have all the work reports and time sheets for all the gangs, time and hours, days sick, everything. Heap big waste of time."

"I am forced to admit that I share your lack of enthusiasm—but what must be done, must be done." He looked at his watch and came to a quick decision. "Have a messenger take them to my hotel and leave them at the desk so I can work on them tonight. New York is concerned about the rising unit costs and the secret of the higher expenses may well be here. I'll go over them this evening and see if I can prize out the nugget of truth from this dross of statistics. In fact I shall leave now before the shift ends so I won't be trampled underfoot."

"Making tunnels is thirsty work in this climate. Navvies need plenty beer, wine, red-eye to keep going."

"A point I'll not argue. You know where I'll be and what to do."

The quick storm had almost passed as he picked his way across the yards, the last drops clattering on his topee. He needed his knee-high engineer's boots here for the mud was constantly churned up by the heavy lorries. Reaching Avenida Atlantica, the wide street that ran along the shore, he strolled down it, blending with the heterogeneous crowd that was now making its appearance after the warm afternoon siesta. He enjoyed this time of day, this parade of people from every walk of life, from almost every corner of the world, for it was his tunnel that had turned the sleepy little sub-tropical city of Angra do Heroismo, on the island of Terceira in the Azores, into the bustling, brawling, international port it had become.

Of course the off-shift navvies were there, from both sides of the Atlantic, handsome in their scarves and colorful waistcoats, high boots and great hats, pushing their way through the pack and giving ground to no man. The olive-skinned islanders seemed in a minority here, but they did not complain because prosperity was now their lot, a prosperity never known before when fish were the only profit they took from the sea, not tunnelers' wages. Once the cash crops of pineapples and bananas, oranges, tobacco and tea were sold on a perilous world market. Now these products were consumed locally with great enthusiasm, so that little or none had to be shipped abroad.

Nor were the navvies the only cus-

tomers of local goods, for where the tunnel went and the money from the men's pay packets, there went as well men and—alas!—women who had designs upon that money, whose only ambition in life was to transfer as much of it as possible from the purses of the honest working men to depths of their own sordid wallets. Gamblers there were in the crowd, sleek men with dark clothes, neat moustaches and white hands—and ready derringers about their persons to confront any man so rash as to dispute the honesty of a deal or the fall of a pair of dice. Money lenders there were, who had ready cash at any time for any man gainfully employed, who exacted such immense sums in interest, three and four hundred percent not being uncommon, that the biblical injunctions against usury easily could be understood.

Merchants came, too, not men of established business who displayed their wares in public and stated their price clearly, but gray men with folding boxes and velvet bags in secret pockets, who produced rings and watches, diamonds and rubies at ridiculously low prices, inferring, or whispering, that the goods were *lava*, hot that is, stolen that is, though it would take an insane thief to steal such poor wares, for the rings turned green, the watches stopped ticking when the roaches inside them died, the diamonds and rubies fell to smithereens of glass if dropped.

And there were women, oh yes, hapless creatures of the night, betrayed, stolen, enslaved, entrapped, doomed to a life of hell that does not bear describing on the printed page lest the ink that forms the words grows warm, then scorching hot enough to burn the letters from the paper, for the eye of the gentle reader dare not behold the facts of such as these and the trade they plied.

All these were upon the sidewalks this afternoon, and more as well; Moorish traders come with dhows from Africa and Iberia bringing food, for the few islands of the archipelago could not produce enough for the great numbers of men based here, dark-skinned, hawk-nosed men in white burnooses who paced the pavement with firm tread, hands resting on cruel knives, interested in this strange outpost of the alien Christian. An occasional frock-coated man of business could be seen, for much business was conducted here, proceeding incognito in his uniform clothes so the observer could not tell if he were French or Prussian, Russian or Pole, Dane or Dutch. And more, and more they passed in an ever changing, never changing, flood of humanity.

Gus always enjoyed the show and when he came to his favorite establishment, the Tampico, he turned in and sat at a table on the porch, just a few feet above the street, resting his arm on the thick brass rail that surrounded it, waving to the bowing owner and smiling at the rushing

waiter who was bringing a chilled bottle of the local wine he favored, *vinho de cheiro,* a delicately scented, sweetly flavored wine that had the taste and smell of roses. He sipped at this and felt at peace. The work went well, there was nothing to complain about. But as he watched the crowd he was aware, out of the corner of his eye, of someone sitting at the next table, back to him, moving very close. That this arrangement was not accidental was made manifest when the man, for it was a man, spoke in a low voice that only Gus could hear.

"Your navvies good workers, Meestair Washington, work very hard and need to eat very much. Feed them you must, beeg meals, beeg money. I joost happen to have many tons of canned hams, such good hams you would not believe and I have a sample here in pocket to prove you." Something slapped the table wetly and Gus could not help noticing the piece of meat on a cloth napkin that had suddenly appeared at his elbow. He ignored it as well as he had ignored its owner, yet the man persisted. "See how fine, my, good pig from the mountains of the Balkans, eat, eat, you will enjoy. I have these hams to sell for special price for you, oh good price and under the table for you a certain commission, gold most suitable, *yike!"*

The speaker had terminated his conversation in this unusual manner because Sapper Cornplanter had appeared silently behind him and had lifted him suddenly by trouser seat and nape of neck and had hurled him bodily into the street where he instantly vanished. With his fingertips Gus sent the portion of meat after its master where it disappeared into the maw of one of the long-legged island dogs who roamed the pavement.

"More tons of concrete cut with sand?" Sapper asked, still standing but pouring himself a glass of wine for his services.

"Not this time. From the little I heard before you terminated the conversation it was either a stolen shipment of meat, or tainted, or some such. They never stop trying, do they?"

Sapper grunted a monosyllabic answer and faded from sight inside the café. Gus sipped at his wine. The entrepreneurs would never believe that he could not be bribed, it was their lifetime of experience that everyone had their price, everyone was accessible, so they persisted in trying with him. He had long since stopped trying to talk to them so arranged that one of his men was always nearby when he was in public and that a certain gesture of his hand, apparently meaningless in itself, carried the information that once again a conversation never begun was due to be terminated.

He forgot about this matter at once, so common had it become, and had more wine while the gentle tropical evening drew on apace. When he was refreshed and cooled he made his leisurely way through the

still streaming crowd to the Terra Nostra Hotel where he kept a room at the best hotel on the island, which was by no means an extravagant claim, as well as being hideously overcrowded as were all hotels and restaurants since the tunnel had located here. The manager, bowing with pleasure, for his custom was greatly respected, handed over the package the messenger had brought, and Gus went up to his room to do some work on the papers before partaking of the late dinner so favored by the islanders.

When he unlocked the door he saw that the room was dark, that the chambermaid had neglected once again to turn on the light. This was a normal occurrence and he thought little of it as he closed the door and groped for the switch and threw it. Nothing happened. The electricity must be off again, he thought, the coal-fired generating plant was hideously inefficient. Yet the lights had been on in the lobby. Puzzling over this, he had just turned back to the door when the sudden glare of an electric torch burned into his eyes, the first intimation he had had that he was not alone in the room. Whoever his secret visitor might be, he was certainly here for no good end, that was Gus's instant thought, and he turned to hurl himself at the light source. He was stayed from attacking by the silent appearance of a man's hand in the beam, a hand clutching a nickel-plated and very efficient-looking revolver.

"You are here to rob me?" said Gus, coolly.

"Not exactly," the secret visitor answered in what were obviously American tones. "Let us say I wished first to see who you were, then to make sure you were alone, and lastly the gun, if you will excuse its presence, to ensure you did nothing hasty in this darkened room as, I believe, you were starting to do."

"Here is my wallet, take it and leave. I have nothing else of value to you in the room."

"Thank you, no," said the voice in the darkness, a hint of laughter to the words. "You misconstrue my presence." There was a rattle and a clatter at the lighting fixture, though the torch stayed steadily on Gus all the time, and the lights finally came on.

The nocturnal visitor was a man in his middle thirties garbed in the almost traditional dress of the American tourist abroad: colorful, beaded Indian shirt, peaked fisherman's cap with a green plastic visor that was studded all over with badges and patches indicating places he had been, knee-length shorts, and sturdy, hobnailed boots. Around his neck was slung his camera and ancillary photographic apparatus and from his belt there hung the required wire recorder that lectured him day and night on what he was seeing. His face was cheerful enough when he smiled, as he was doing now, but it hinted that in repose the icy blue eyes were stern, the wide jaw set, the

broken, hooked, sharp nose might resemble the predatory bill of a hawk.

Gus examined the man slowly and carefully, standing motionless under the ready threat of the revolver, looking for an opportunity to turn the tables. That this would not be necessary was proven an instant later when the stranger touched the bottom of his wire recorder so that the case fell open and a secret compartment was disclosed. Into this opening he pushed the gun while, at the same time, he removed a smaller object. The leather case sealed again with a click as, still smiling, he passed over the extracted metal shield.

"A pleasure to make your acquaintance, Captain Washington. My name is Richard Tracy and I am manager of the New York office of Pinkerton's. That is my shield you have in your hand and I was instructed, as further identification, to give you this note."

The sturdy envelope was closed with sealing wax, with Sir Winthrop's seal upon it, and showed no signs of being tampered with. Inside was a brief note in Rockefeller's own hand which Gus recognized at once. The message was succinct.

This will introduce R. Tracy, Esq., whom I have retained privately. He is to be trusted absolutely in the matter to hand. W. Rockefeller.

"Do you know the contents of this letter?"

"Just the gist of it, that I am conducting an investigation and only you are to know about it. I was advised to inform you that Sir Winthrop has engaged me personally, out of his own private funds, and that you are the only other person who knows of my existence."

"I suppose you wouldn't care to tell me just what it is you are investigating?"

"Just getting to that, sir. Sabotage it is, a very nasty business indeed. I can cite instances you know of, and still more that you don't."

"Such as the mysterious lack of fuel in the helithopter in Canada?"

"True enough. And the cut cable on the tunnel section of the last part to the Grand Banks Station, the collapsing shed in the rail yard, and many others. I have been here on the island for a little time now and have made an investigation in depth. There is a strong organization that is actively operating against the success of this tunnel. They are well financed and ruthless and will stop at nothing."

"But, who is doing this—and why?"

"At this stage I could only guess, and guessing is a thing I prefer not to do, being a man of facts and facts alone. Perhaps that is one of the things we will soon discover, for I have approached you now for your aid. I and my operatives have been investigating here for some months . . ."

"I had no idea!"

"Nor should you have, for my

men are of the best. You have seen some of them working on the tunnel, I'll wager, because I have managed to get them into a number of places. And now one of them, he is called Billygoat because he is as ugly and nasty as one, has been approached by the saboteurs and has agreed to aid them. That is where I need your help. You must supply me with a place to commit willful and expensive sabotage so that Billygoat will be admitted to their ranks. Once I know who they are we can swoop and grab the lot."

"It will take some thinking, but I know we can come up with something. I'll talk to—"

"No one, sir, no one if you will, for I value my life dearly."

"I miss your meaning."

"I will be frank. Other investigators have been hired in the past and they either failed in their tasks or were found dead under mysterious circumstances. Sir Winthrop believes, and I agree heartily, that someone within the company is in league with the saboteurs."

"It cannot be!"

"But it is. Someone with much special knowledge, perhaps more than one person. Until we find out we take no chances, that is the reason why I came to your room in this strange manner. Other than yourself and Sir Winthrop, no one knows I am on the job."

"Surely I can tell—"

"No one! It must be that way."

It was agreed; no one else was to know. A system of passwords and means of contact were agreed upon, and an exuberant kind of sabotage worked out. When all was done the secret investigator flipped open what appeared to be an identification bracelet on his wrist, but which proved to be a two-way radio with which he spoke to a confederate who disclosed that the room was not being watched. Armed with this knowledge he turned off the lights and slipped out the door to vanish as mysteriously as he had appeared.

Though Gus worked late upon his papers and should have had all of his attention there, his thoughts kept returning to the mysterious saboteurs. Who were they—and who inside the company was part of the plan?

He found it hard to sleep when finally he retired, for his thoughts went around and around this bone of knowledge and worried at it unceasingly.

TO BE CONCLUDED

DEFINITIONS:

If it stinks or pops, it's chemistry.
If it bites or scratches, it's biology.
If it doesn't work, it's physics.

the observer

To make a workable data-gathering system, you must understand what kind of information is being sought, why it's being sought, and—ultimately—who is the seeker.

CLIFFORD D. SIMAK

KELLY FREAS

It existed. Whether it has slept and wakened, or been turned on, or if this might be the first instant of its creation, it had no way of knowing. There was no memory of other time, or place.

Words came to fit where it found itself. Words emerging out of nowhere, symbols quite unbidden—awakened or turned on or first appearing, as it had itself.

It was in a place of red and yellow. The land was red. The sky was yellow. A brightness stood straight above the red land in the yellow sky. Liquid ran gurgling down a channel in the land.

In a little time it knew more, had a better understanding. It knew the brightness was a sun. It knew the running liquid was a brook. It thought of the liquid as a compound, but it wasn't water. Life forms sprang from the redness of the soil. Their stems were green. They had purple fruits at the top of them.

It had the names now, identifying symbols it could use—life, liquid, land, sky, red, yellow, purple, green, sun, bright, water. Each instant it had more words, more names, more terms. And it could see, although seeing might not be the proper term, for it had no eyes. Nor legs. Nor arms. Not body.

It had no eyes and seemed to have no body, either. It had no idea of position—standing up or lying down or sitting. It could look anywhere it wished without turning its head, since it hadn't any head. Although, strangely, it did seem to occupy a specific position in relation to the landscape.

It looked straight up into the sky at the brightness of the sun and could look directly at the brightness since it was seeing without eyes, without frail organic structures that might be harmed by brilliance.

The sun was a B8 star, five times more massive than the Sun, and it lay 3.76 A.U. distant from this planet.

Sun, capitalized? A.U.? Five? 3.76? Planet?

Sometime in the past—when past, where past, what past—it had known the terms, a sun that was capitalized, water that ran in brooks, the idea of a body and of eyes. Or had it known them? Had it ever had a past in which it could have known them? Or were they simply terms that were being fed into it from another source, to be utilized as the need arose, tools—and there was yet another term—to be used in interpreting this place where it found itself? Interpreting this place for what? For itself? That was ridiculous, for it did not need to know, did not even care to know.

Knowing, how did it know? How did it know the sun was a B8 star, and what was a B8 star? How know its distance, its diameter, its mass just by looking at it? How know a star, for it had never seen a star before?

Then, even thinking this, it knew it had. It had known many suns, a long string of suns across the galaxy and it

had looked at each of them and known its spectral type, its distance and diameter, its mass, its very composition, its age and probable length of remaining life, stable or variable, its spectral lines, any small peculiarities that might set it apart from other stars. Red giants, supergiants, white dwarfs, even one black dwarf. But mostly main sequence stars and the planets that went with them, for it made few stops at stars that had no planets.

Perhaps nothing had even seen more suns than it. Or knew more of suns than it.

And the purpose of all this? It tried to think of purpose, but there seemed no purpose. The purpose utterly escaped it. If there were, in fact, a purpose.

It stopped looking at the sun and looked at the rest of it, at all of it at once, at all the planetary surface in its sight—as if, it thought, it had eyes all around its nonexistent head. Why did it, it wondered, keep dwelling on this idea of a head and eyes? Had it, at one time perhaps, have had a head and eyes? Was the ideal of head and eyes an old residual, perhaps a primitive, memory that persistently refused to go away, but that for some reason must linger and thrust itself forward at the slightest opportunity?

It tried to think it out, to reach back and grasp the idea or the memory and drag it squalling from its hole. And failed.

It concentrated on the surface. It was located—if located was the word—on a steep hillside with massive rock outcroppings. The hill shut off the view of one portion of the surface, but the rest lay bare before it to the horizon line.

The rest of the surface was level, except for one place, far distant, where what appeared to be a circular prominence arose. The top of the prominence was jagged and the sides were furrowed and it looked very like an ancient crater.

But the rest was level and through it ran several little streams of something that was liquid but was not water. The sparse vegetation stood up on its dark green stems, surmounted by its purple fruit and now it was apparent that there were several kinds of vegetation. The purple fruit vegetation at first had seemed to be the only vegetation because it was more abundant, and certainly more spectacular.

The soil seemed to be little more than sand. It put out a hand—no, not a hand, for it had no hand—but it thought of its action as putting out a hand. It put out a hand and thrust the fingers deep into the soil and the data on the soil came flowing into it. Sand. Almost pure sand. Silicon, some iron, some aluminum, traces of oxygen, hydrogen, potassium, magnesium. Almost no acidity. There were figures, percentages, but it hardly noticed. They simply passed along.

The atmosphere was deadly.

Deadly to what? The radiation lancing in from the B-type star was deadly and again, deadly to what?

What do I have to know, it wondered. And there was another word it had not used before. I. Me. Myself. An entity. A self. A single thing, standing all alone, no part of another. A personality.

What am I? it asked. Where am I? And why? Why must I go on collecting all this data? What care I for soil, or radiation, or the atmosphere? Why should I have to know what kind of star is standing overhead? I have no body that can be affected by any of it. I seem to have no form, I only have a being. A disembodied entity. A nebulous I.

It desisted for a time, unmoving, doing nothing, collecting no more data, only looking at the red and yellow of the planet, the purple of the flowers.

Then, after a time, it took up its work again. It touched the rocky outcrops on the hillside, found the planes that lay between the layers, seeped into the rock, following the cleavages.

Limestone. Massive, hard limestone. Put down millennia ago at the bottom of the sea.

It paused for a moment, vaguely disturbed, then recognized the cause of its disturbance. Fossils!

Why should fossils disturb it, it asked itself and then suddenly it knew with something that amounted to excitement, or as close as it could come to what might be excitement. These were not the fossils of plants, primordial ancestors to those purple plants growing on the present surface. These were animals—well-organized forms of life, sophisticated in their structure, well up the evolutionary ladder.

So few of the other planets had any life at all, the few that did more often than not had only the simplest of vegetable life or, perhaps, tiny organisms on the borderline, things that might be slightly more than vegetable, but not yet animal. I should have known, it thought. The purple plants should have alerted me. For they are highly organized; they are not simple plants. On this planet, despite its deadly atmosphere and its deadly radiation and its liquid that is not water, evolutionary forces still had been at work.

It traced one particular fossil. Not large. A chitin covering, apparently, but still it had a skeleton of sorts. It had a head, a body, legs. It had a flattened tail for swimming in whatever evil chemical brew the ocean might have been. It had jaws for seizing and for holding. It had eyes, a great many more eyes, perhaps, than it had any need of. There were faint tracings of an alimentary canal, fragments of nerves here and there that were still preserved, or at least the canals in which they ran had been preserved.

And it thought of that faint, misty time when he—

He? First an I. And then a he.

Two identities—or rather two terms of identity.

No longer an it, but an I and he.

He lay thin and spread out along the tight seams of the limestone and knew the fossils and pondered on the he. Especially that one particular fossil and that other misty time in which the first fossil had been found, the first time he had ever known there was such a thing as fossil. He recalled the finding of it and recalled its name as well. It had been called a trilobite. Someone had told him the name, but he could not remember who it might have been. A place so faint in time, so far in space, that all he had left of it was a fossil called a trilobite.

But there had been another time and another place and he was not new—he had not in that first instant of awareness been turned on, or newly hatched, or born. He had a history. There had been times of other awarenesses and he had held identity in those other times. Not new, he thought, but old. A creature with a past.

The thought of eyes, of body, or arms and legs—could all of them be memories from that other time or times? Could there have been a time when he did have a head and eyes, a body?

Or could he be mistaken? Could all of this be a phantom memory fashioned out of some happening, or event, or some combination of happenings and events that had occurred to some other being? Was it, perhaps, a misplaced memory, not of himself, but of something else? If the memory should prove to be his own, what had happened to him—what changes had been made?

He forgot the limestone and the fossils. He lay spread out in the fissures of the rock and stayed quiet and limp, hoping that out of the limpness and the quietness he might devise an answer. A partial answer came, an infuriating answer, unspecific and tantalizing. Not one place, but many; not one time, but many times. Not on one planet, but on many planets spaced over many light-years.

If all of this were true, he thought, there must be purpose in it. Otherwise, why the many planets and the data on those planets? And this was a new, unbidden thought—the data on the planets. Why the data? For what purpose was it gathered? Certainly not for himself, for he did not need the data, had no use for it. Could it be that he was only the gatherer, the harvester, the storer and communicator of the data that he gathered?

If not for himself, for whom? He waited for the answer to come welling up, for the memory to reassert itself and in time he realized that he had gone groping back as far as he could go.

Slowly he withdrew from the rock, once more was upon the hillside above the red land beneath the yellow sky.

A portion of the nearby surface moved and as it moved, he saw that it was not a portion of the surface, but a creature that had a coloration which made it seem to be a part of the planet's surface. It moved quickly, as if a shadow had brushed along and blurred the surface. It moved in short and flowing motions and when it stopped its motion it became a part of the surface, blending into it.

It was watching him, he knew, looking him over, although what there was to see of him he could not imagine. Sensitive, perhaps, to another personality, to another thing that shared with it that strange and undefinable quality which made up life. A force field, he wondered—was that what he was, a disembodied intelligence carried in a force field?

He stayed still so the thing could look him over. It moved in its short, flowing dashes, all around him. It left a furrowed track behind it, it kicked up little spurts of sand as it made its dashes. It moved in closer.

And he had it. He held it motionless, wrapped up as if he held it in many hands. He examined it, not closely, not analytically, but only enough so he could tell what kind of thing it was. Protoplasmic and heavily shielded against the radiations, even designed, perhaps—although he could not be sure—to take advantage of the energy contained in the radiation. An organism, more than likely, that could not exist without the radiations, that needed them as other creatures might need warmth, or food, or oxygen. Intelligent and laced with a multitude of emotions—not, perhaps, the kind of intelligence that could build a complex culture, but a high level of animal intelligence. Perhaps still evolving in its intelligence. Give it a few more million years and it might contrive a culture.

He turned it loose. It flowed away, moving rapidly, straight away from him. He lost sight of it, but still could follow its movement for a time by its unreeling track and the spurts of sand it kicked into the air.

There was much work to do. An atmospheric profile, an analysis of the soil and of the microorganisms that it might contain, a determination of the liquid in the brook, an examination of the plant life, a geological survey, measurement of the magnetic field, the intensity of the radiation. But first there should be a general survey of the planet to determine what sort of place it was, a pinpointing of those areas that might be of economic interest.

And there it was again, another word he had not had before. Economic.

He searched inside himself, inside the theoretical intelligence enclosed within the hypothetical force field, for the purpose that was hinted in that single word. When he found it, it stood out sharp and clear—the one thing he had found that was sharp and clear. What was here that could

be used and what would be the cost of obtaining it? A treasure hunt, he thought. That was the purpose of him. It was clear immediately that he, himself, had no use for treasure of any kind at all. There must be someone else who would have a use for it. Although when he thought of treasure a pleasurable thrill went through him.

What might there be in it for him, he wondered, this location of a treasure? What had been the profit to him in the finding of all those other treasures on all those other planets—although, come to think of it, there had not been treasure on every one of them. And on some of the others where there'd been, it had been meaningless, for planetary conditions had been such that it could not be got at. Many of the planets, he recalled, far too many of them, were such that only a thing such as himself would dare even to approach them.

There had been attempts, he remembered now, to recall him from some of the planets when it had become apparent they had no economic worth and that to further explore them would be a waste of time. He had resisted those attempts; he had ignored the summons to return to wherever it was he went when he did return. Because, in his simplistic ethic, when there was a job to do he did it and he did not quit until the job was done. Having started something, he was incapable of leaving off until it had been finished. It was a part of him, this single-minded stubbornness; it was a characteristic that was necessary to do the work he did.

If they had it one way, they could not have it two. He either was, or wasn't. He did the job, or didn't. He was so made that he had an interest in each problem that was presented him and would not leave off until he'd wrung the problem dry. They had to go along with that and they knew it now; they no longer bothered trying to recall him from a nonproductive planet.

They? he asked himself and remembered faintly other creatures such as he had been. They had indoctrinated him, they had made him what he was and they used him as they used the priceless planets he had found, but he did not mind the using, for it was a life and the only life he had. It either had been this life, or no life at all. He tried to recall circumstances, but something moved to block the recall. Exactly as he never could recall in all entirety, but only in fragments, the other planets he had visited. That, he thought at the time, might be a great mistake, for experience he had gathered on the other planets might have been valuable as guide lines on the one to which he currently had been sent. But for some reason, they did not allow it, but did their imperfect best to wipe from his memory all past experiences before he was sent out again. To keep him clear, they said; to guard him from confusion; to send a bright new mind, freed of all encumbrances, out to each new

planet. That was why, he knew, he always arrived upon each planet groping for a meaning and purpose, with the feeling of being newly born to this particular planet and to nowhere else.

He did not mind. It still was a life and he saw a lot of places—very different places—and saw them, no matter what conditions might obtain, in perfect safety. For there was nothing that could touch him—tooth, or claw, or poison, no matter what the atmosphere, no matter what the gravity, no matter what the radiation, there was nothing that could touch him. There was nothing of him to be touched. He walked—no, not walked, but moved—in utter nonchalance through all the hells the galaxy could muster.

A second sun was rising, a great swollen, brick-red star pushing its way above the horizon, with the first one just beginning to slide toward the west—as a matter of convenience, he thought of the big red one as rising in the east.

K2, he read it, thirty times, or so, the diameter of the Sun with a surface temperature that was possibly no more than 4,000°. A binary system and maybe more than that; there might be other suns that he still had yet to see. He tried to calculate the distance, but that would not be possible with any accuracy until the giant had moved higher in the sky, until it had moved above the horizon that now bisected it.

But the second sun could wait, all the rest of it could wait. There was one thing he must see. He had not realized it before, but now he knew there was one thing about the landscape that had been nagging him. The crater did not fit. It had all the appearances of a crater, but it had no right to be there. It could not be volcanic, for it sat in the middle of a sandy terrain and the limestone thrusting from the hillside was sedimentary rock. There was no trace of igneous rock, no ancient lava flows. And the same objections still would hold if the crater had been formed by meteoric impact, for any meteorite that threw up a crater of that size would have turned tons of material into a molten mass and would have thrown out a sheet of magma, of which there was no sign.

He began drifting slowly in the direction of the crater. Beneath him the terrain remained unchanged—the red soil, the purple fruit and little else.

He came to rest—if that is what his action could be called—on the crater's rim and for a moment failed to understand what he was seeing.

Some sort of shining substance extended all around the rim and sloped inward to the center to form what appeared to be a concave mirror. But it was not a mirror, for it was nonreflective.

Then, quite suddenly, an image formed upon it and if he could have caught his breath he would have.

Two creatures, one large, the other

smaller, stood on a ledge above a deep cut in the earth, with a striated sandstone bluff rising up above them. The smaller one was digging in the bluff with a hand tool of some sort—a hand tool that was grasped in what must be a hand, which was attached to an arm and the arm hooked up to a body, which had a head and eyes.

Myself, he thought—the smaller one, myself.

He felt a weakness and a haziness and the image in the mirror seemed to be trying to pull him down to join and coalesce with this image of himself. The gates of memory opened and the old, restricted data came pouring in upon him—the terms and relationships—and he cried out against it and tried to push it back, but it would not push back. It was as if someone were holding him so he could not get away and, with a mouth close against his ear, was telling him things he did not wish to know.

Humans, father, son, a railroad cut, the Earth, the finding of that first trilobite. Relentlessly the information came pouring into him, into the intellectual force field that he had become, that he had evolved into, or been engineered into, and that had been a comfort and a refuge until this very moment.

His father wore an old sweater, with holes in the elbows of the sleeves, and an old pair of black trousers that were baggy at the knees. He smoked an ancient pipe with a fire-charred bowl and a stem half-bitten through, and he watched with deep paternal interest as the boy, working carefully, dug out the tiny slab of stone that bore the imprint of an ancient form of life.

Then the image flickered and went out and he sat (?) upon the crater's rim, with the dead mirror sweeping downward to its center, showing nothing but the red and blue reflections of the suns.

Now he knew, he thought. He knew, not what he was, but what he once had been—a creature that had walked upon two legs, that had a body and two arms, a head and eyes and a mouth that cried out in excited triumph at the finding of a trilobite. A creature that walked proudly and with misplaced confidence, for it had none of the immunity against its environment such as he now possessed.

From that feeble, vulnerable creature, how had he evolved?

Could it be death, he wondered, and was aghast at death, which was a new concept. Death, an ending, and there was no end, never would be one; a thing that was an intellect trapped within a force field could exist forever. But somewhere along the way, somewhere in the course of evolution, or of engineering, could death have played a part? Must a man come to death before he came to this?

He sat upon the crater's rim and knew the surface of the planet all about him—the red of land, the yellow of the sky, the green and purple

of the flowers, the gurgle of the liquid running in its courses, the red and blue of suns and the shadows that they cast, the running thing that threw up spurts of sand, the limestone and the fossils.

And something else as well and with the sensing of that something else a fear and panic he had never known before. Had never had the need to know, for he had been protected and immune, untouchable, secure, perhaps even in the center of a sun. There had been nothing that could get at him, no way he could be reached.

But that was true no longer, for now he could be reached. Something had torn from him an ancient memory and had shown it to him. Here, on this planet, there was a factor that could get at him, that could reach into him and tear from him something even he had not suspected.

He screamed a question and phantom echoes ran across the land, bouncing back to mock him. Who are you? Who are you? Who are you? Fainter and fainter and the only answers were the echoes.

It could afford not to answer him, he knew. It need not answer him. It could sit smug and silent while he screamed the question, waiting until it wished to strip other memories from him, memories for its own strange use, or to further mock him.

He was safe no longer. He was vulnerable. Naked to this thing that used a mirror to convince him of his own vulnerability.

He screamed again and this time the scream was directed to those others of his kind who had sent him out.

Take me back! I am naked! Save me!

Silence.

I have worked for you—I have dug out the data for you—I have done my job—You owe me something now!

Silence.

Please!

Silence.

---

in times to come *How do you paint something that's never been seen by any human being? Something that is, in fact, invisible? Kelly Freas had that problem when he tackled the cover painting for next month's lead-off novelette, "Hero," by Joe W. Haldeman. In this tale of interstellar war, starships use the fantastically warped gravitational energies around Black Holes to "jump" across light-years of space. But what does a Black Hole look like? By definition, it's invisible. Kelly used all the available astronomical information about collapsing stars, plus his own fine sense of color and drama, to produce the first pictorial representation of a Black Hole, ever.*

Haldeman's story deals with man's first interstellar war, a strange, unsettling, unresolved conflict against a hardly-known enemy. The rules of this war are different in many ways from any other war that man's engaged in. Yet in one fundamental way, war itself remains very much the same. Despite starships, computers and laser weaponry, it's still up to the individual foot soldier to take and hold the territory that's being disputed. "Hero" is a realistic story, set in an all-too-plausible future.

Silence—and something more than silence. Not only silence, but an absence, a not being there, a vacuum.

The realization came thudding hard into his understanding. He had been abandoned, all ties with him had been cut—in the depth of unguessed space, he had been set adrift. They had washed their hands of him and he was not only naked, but alone.

They knew what had happened. They knew everything that ever happened to him, they monitored him continuously and would know everything he knew. And they had sensed the danger, perhaps even before he, himself, had sensed it. Had recognized the danger, not only to himself, but to themselves as well. If something could get to him, it could trace back the linkage and get to them as well. So the linkage had been cut and would not be restored. They weren't taking any chances. It had been something that had been emphasized time and time again. You must remain not only unrecognized, but entirely unsuspected. You must do nothing that will make you known. You must never point a finger at us.

Cold, callous, indifferent. And frightened. More frightened, perhaps, than he was. For now they knew there was something in the galaxy that could become aware of the disembodied observer they had been sending out. They could never send another, if indeed they had another, for the old fear would be there. And perhaps an even greater fear—based upon the overriding suspicion that the linkage had been cut not quite soon enough, that this factor which had spotted their observer had already traced it back to them.

Fear for their bodies and their profits . . .

Not for their bodies, a voice said inside him. Not their biologic bodies. There are no longer any of your kind who have biologic bodies . . .

Then what? he asked.

An extension of their bodies, carrying on the purpose those with bodies gave them in a time when the bodies still existed. Carried on mindlessly ever since, but without a purpose, only with a memory of a purpose . . .

Who are you? he asked. How do you know all this? What will you do with me?

In a very different way, it said, I am one like you. You can be like me. You have your freedom now.

I have nothing, he said.

You have yourself, it said. Is that not enough?

But is self enough? he asked.

And did not need an answer.

For self was the basis of all life, all sentience. The institutions, the cultures, the economics were no more than structures for the enhancement of the self. Self now was all he had and self belonged to him. It was all he needed.

Thank you, sir, said he, the last human in the universe. ■

mirror image

ISAAC ASIMOV

Leo Summers

Lije Baley could understand how two humans could tell exactly equal but opposite stories—one of them was lying. But robots can't tell lies, it's a violation of the Laws of Robotics. And here were two robots telling exactly the same story . . . except that they contradicted each other on every point!

The Three Laws of Robotics

1: *A robot may not injure a human being, or, through inaction, allow a human being to come to harm.*

2: *A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.*

3: *A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.*

Lije Baley had just decided to relight his pipe, when the door of his office opened without a preliminary knock, or announcement, of any kind. Baley looked up in pronounced annoyance and then dropped his pipe. It said a good deal for the state of his mind that he let it lie where it had fallen.

"R. Daneel Olivaw," he said, in a kind of mystified excitement. "Jehoshaphat! It *is* you, isn't it?"

"You are quite right," said the tall, bronzed newcomer, his even features never flicking for a moment out of their accustomed calm. "I regret surprising you by entering without warning, but the situation is a delicate one and there must be as little involvement as possible on the part of the men and robots even in this place. I am, in any case, pleased to see you again, friend Elijah."

And the robot held out his right hand in a gesture as thoroughly human as was his appearance. It was Baley who was so unmanned by his astonishment as to stare at the hand with a momentary lack of understanding.

But then he seized it in both his, feeling its warm firmness. "But Daneel, *why?* You're welcome any time, but—What is this situation that is a delicate one? Are we in trouble again? Earth, I mean?"

"No, friend Elijah, it does not concern Earth. The situation to which I refer as a delicate one is, to outward appearances, a small thing. A dispute between mathematicians, nothing more. As we happened, quite by accident, to be within an easy Jump of Earth—"

"This dispute took place on a starship, then?"

"Yes, indeed. A small dispute, yet

to the humans involved astonishingly large."

Baley could not help but smile. "I'm not surprised you find humans astonishing. They do not obey the Three Laws."

"That is, indeed, a shortcoming," said R. Daneel, gravely, "and I think humans themselves are puzzled by humans. It may be that you are less puzzled than are the men of other worlds because so many more human beings live on Earth than on the Spacer worlds. If so, and I believe it is so, you could help us."

R. Daneel paused momentarily and then said, perhaps a shade too quickly, "And yet there are rules of human behavior which I have learned. It would seem, for instance, that I am deficient in etiquette, by human standards, not to have asked after your wife and child."

"They are doing well. The boy is in college and Jessie is involved in local politics. The amenities are taken care of. Now tell me how you come to be here."

"As I said, we were within an easy Jump of Earth," said R. Daneel, "so I suggested to the captain that we consult you."

"And the captain agreed?" Baley had a sudden picture of the proud and autocratic captain of a Spacer starship consenting to make a landing on Earth—of all worlds—and to consult an Earthman—of all people.

"I believe," said R. Daneel, "that he was in a position where he would have agreed to anything. In addition, I praised you very highly; although, to be sure, I stated only the truth. Finally, I agreed to conduct all negotiations so that none of the crew, or passengers, would need to enter any of the Earthman cities."

"And talk to any Earthman, yes. But what has happened?"

"The passengers of the starship, *Eta Carina,* included two mathematicians who were traveling to Aurora to attend an interstellar conference on neurobiophysics. It is about these mathematicians, Alfred Barr Humboldt and Gennao Sabbat, that the dispute centers. Have you perhaps, friend Elijah, heard of one, or both, of them?"

"Neither one," said Baley, firmly. "I know nothing about mathematics. Look, Daneel, surely you haven't told anyone I'm a mathematics buff or—"

"Not at all, friend Elijah. I know you are not. Nor does it matter, since the exact nature of the mathematics involved is in no way relevant to the point at issue."

"Well, then, go on."

"Since you do not know either man, friend Elijah, let me tell you that Dr. Humboldt is well into his twenty-seventh decade—Pardon me, friend Elijah?"

"Nothing. Nothing," said Baley, irritably. He had merely muttered to himself, more or less incoherently, in a natural reaction to the extended life-spans of the Spacers. "And he's still active, despite his age? On

Earth, mathematicians after thirty or so . . .

Daneel said, calmly; "Dr. Humboldt is one of the top three mathematicians, by long-established repute, in the galaxy. Certainly he is still active. Dr. Sabbat, on the other hand, is quite young, not yet fifty, but he has already established himself as the most remarkable new talent in the most abstruse branches of mathematics."

"They're both great, then," said Baley. He remembered his pipe and picked it up. He decided there was no point in lighting it now and knocked out the dottle. "What happened? Is this a murder case? Did one of them apparently kill the other?"

"Of these two men of great reputation, one is trying to destroy that of the other. By human values, I believe this may be regarded as worse than physical murder."

"Sometimes, I suppose. Which one is trying to destroy the other?"

"Why, that, friend Elijah, is precisely the point at issue. Which?"

"Go on."

"Dr. Humboldt tells the story clearly. Shortly before he boarded the starship, he had an insight into a possible method for analyzing neural pathways from changes in microwave absorption patterns of local cortical areas. The insight was a purely mathematical technique of extraordinary subtlety, but I cannot, of course, either understand or sensibly transmit the details. These do not, however, matter. Dr. Humboldt considered the matter and was more convinced each hour that he had something revolutionary on hand, something that would dwarf all his previous accomplishments in mathematics. Then he discovered that Dr. Sabbat was on board."

"Ah. And he tried it out on young Sabbat?"

"Exactly. The two had met at professional meetings before and knew each other thoroughly by reputation. Humboldt went into it with Sabbat in great detail. Sabbat backed Humboldt's analysis completely and was unstinting in his praise of the importance of the discovery and of the ingenuity of the discoverer. Heartened and reassured by this, Humboldt prepared a paper outlining, in summary, his work and, two days later, prepared to have it forwarded subetherically to the co-chairmen of the conference at Aurora, in order that he might officially establish his priority and arrange for possible discussion before the sessions were closed. To his surprise, he found that Sabbat was ready with a paper of his own, essentially the same as Humboldt's, and Sabbat was also preparing to have it subetherized to Aurora."

"I suppose Humboldt was furious."

"Quite!"

"And Sabbat? What was his story?"

"Precisely the same as Humboldt's. Word for word."

"Then just what is the problem?"

"Except for the mirror-image exchange of names. According to Sabbat, it was he who had the insight, and he who consulted Humboldt; it was Humboldt who agreed with the analysis and praised it."

"Then each one claims the idea is his and that the other stole it. It doesn't sound like a problem to me at all. In matters of scholarship, it would seem only necessary to produce the records of research, dated and initialed. Judgment as to priority can be made from that. Even if one is falsified, that might be discovered through internal inconsistencies."

"Ordinarily, friend Elijah, you would be right, but this is mathematics, and not in an experimental science. Dr. Humboldt claims to have worked out the essentials in his head. Nothing was put in writing until the paper itself was prepared. Dr. Sabbat, of course, says precisely the same."

"Well, then, be more drastic and get it over with, for sure. Subject each one to a psychic probe and find out which of the two is lying."

R. Daneel shook his head slowly, "Friend Elijah, you do not understand these men. They are both of rank and scholarship, Fellows of the Imperial Academy. As such, they cannot be subjected to trial of professional conduct except by a jury of their peers—their professional peers—unless they personally and voluntarily waive that right."

"Put it to them, then. The guilty man won't waive the right because he can't afford to face the psychic probe. The innocent man will waive it at once. You won't even have to use the probe."

"It does not work that way, friend Elijah. To waive the right in such a case—to be investigated by laymen—is a serious and perhaps irrecoverable blow to prestige. Both men steadfastly refuse to waive the right to special trial, as a matter of pride. The question of guilt, or innocence, is quite subsidiary."

"In that case, let it go for now. Put the matter in cold storage until you get to Aurora. At the neurobiophysical conference, there will be a huge supply of professional peers, and then—"

"That would mean a tremendous blow to science itself, friend Elijah. Both men would suffer for having been the instrument of scandal. Even the innocent one would be blamed for having been party to a situation so distasteful. It would be felt that it should have been settled quietly out of court at all costs."

"All right. I'm not a Spacer, but I'll try to imagine that this attitude makes sense. What do the men in question say?"

"Humboldt agrees thoroughly. He says that if Sabbat will admit theft of the idea and allow Humboldt to proceed with transmission of the paper—or at least its delivery at the conference, he will not press charges. Sabbat's misdeed will remain secret with

him; and, of course, with the captain, who is the only other human to be party to the dispute."

"But young Sabbat will not agree?"

"On the contrary, he agreed with Dr. Humboldt to the last detail—with the reversal of names. Still the mirror-image."

"So they just sit there, stalemated?"

"Each, I believe, friend Elijah, is waiting for the other to give in and admit guilt."

"Well, then, wait."

"The captain has decided this cannot be done. There are two alternatives to waiting, you see. The first is that both will remain stubborn so that when the starship lands on Aurora, the intellectual scandal will break. The captain, who is responsible for justice on board ship will suffer disgrace for not having been able to settle the matter quietly and that, to him, is quite insupportable."

"And the second alternative?"

"Is that one, or the other, of the mathematicians will indeed admit to wrongdoing. But will the one who confesses do so out of actual guilt, or out of a noble desire to prevent the scandal? Would it be right to deprive of credit one who is sufficiently ethical to prefer to lose that credit than to see science as a whole suffer? Or else, the guilty party will confess at the last moment, and in such a way as to make it appear he does so only for the sake of science, thus escaping the disgrace of his deed and casting its shadow upon the other. The captain will be the only man to know all this but he does not wish to spend the rest of his life wondering whether he has been a party to a grotesque miscarriage of justice."

Baley sighed. "A game of intellectual chicken. Who'll break first as Aurora comes nearer and nearer? Is that the whole story now, Daneel?"

"Not quite. There are witnesses to the transaction."

"Jehoshaphat! Why didn't you say so at once. *What* witnesses?

"Dr. Humboldt's personal servant—"

"A robot, I suppose."

"Yes, certainly. He is called R. Preston. This servant, R. Preston, was present during the initial conference and he bears out Dr. Humboldt in every detail."

"You mean he says that the idea was Dr. Humboldt's to begin with; that Dr. Humboldt detailed it to Dr. Sabbat; that Dr. Sabbat praised the idea, and so on."

"Yes, in full detail."

"I see. Does that settle the matter or not? Presumably not."

"You are quite right. It does not settle the matter, for there is a second witness. Dr. Sabbat also has a personal servant, R. Idda, another robot of, as it happens, the same model as R. Preston, made, I believe, in the same year in the same factory. Both have been in service equal times."

"An odd coincidence—very odd."

"A fact, I am afraid, and it makes it difficult to arrive at any judgment based on obvious differences between the two servants."

"R. Idda, then, tells the same story as R. Preston?"

"Precisely the same story, except for the mirror-image reversal of the names."

"R. Idda stated, then, that young Sabbat, the one not yet fifty"—Lije Baley did not entirely keep the sardonic note out of his voice; he himself was not yet fifty and he felt far from young—"had the idea to begin with; that he detailed it to Dr. Humboldt, who was loud in his praises, and so on."

"Yes, friend Elijah."

"And one robot is lying, then."

"So it would seem."

"It should be easy to tell which. I imagine even a superficial examination by a good roboticist—"

"A roboticist is not enough in this case, friend Elijah. Only a qualified robopsychologist would carry weight enough and experience enough to make a decision in a case of this importance. There is no one so qualified on board ship. Such an examination can be performed only when we reach Aurora—"

"And by then the crud hits the fan. Well, you're here on Earth. We can scare up a robopsychologist, and surely anything that happens on Earth will never reach the ears of Aurora and there will be no scandal."

"Except that neither Dr. Humboldt, nor Dr. Sabbat, will allow his servant to be investigated by a robopsychologist of Earth. The Earthman would have to—" He paused.

Lije Baley said stolidly, "He'd have to touch the robot."

"These are old servants, well thought of—"

"And not to be sullied by the touch of Earthman. Then what do you want me to do, damn it?" He paused, grimacing. "I'm sorry, R. Daneel, but I see no reason for your having involved me."

"I was on the ship on a mission utterly irrelevant to the problem at hand. The captain turned to me because he had to turn to someone. I seemed human enough to talk to, and robot enough to be a safe recipient of confidences. He told me the whole story and asked what I would do. I realized the next Jump could take us as easily to Earth as to our target. I told the captain that, although I was at as much a loss to resolve the mirror-image as he was, there was on Earth one who might help."

"Jehoshaphat!" muttered Baley under his breath.

"Consider, friend Elijah, that if you succeed in solving this puzzle, it would do your career good and Earth itself might benefit. The matter could not be publicized, of course, but the captain is a man of some influence on his home world and he would be grateful."

"You just put a greater strain on me."

"I have every confidence," said R. Daneel, stolidly, "that you already have some idea as to what procedure ought to be followed."

"Do you? I suppose that the obvious procedure is to interview the two mathematicians, one of whom would seem to be a thief."

"I'm afraid, friend Elijah, that neither one will come into the city. Nor would either one be willing to have you come to them."

"And there is no way of forcing a Spacer to allow contact with an Earthman, no matter what the emergency. Yes, I understand that, Daneel—but I was thinking of an interview by closed-circuit television."

"Nor that. They will not submit to interrogation by an Earthman."

"Then what do they want of me? Could I speak to the robots?"

"They would not allow the robots to come here, either."

"Jehoshaphat, Daneel. *You*'ve come."

"That was my own decision. I have permission, while on board ship, to make decisions of that sort without veto by any human being but the captain himself—and he was eager to establish the contact. I, having known you, decided that television contact was insufficient. I wished to shake your hand."

Lije Baley softened. "I appreciate that, Daneel, but I still honestly wish you could have refrained from thinking of me at all in this case. Can I talk to the robots by television at least?"

"That, I think, can be arranged."

"Something, at least. That means I would be doing the work of a robopsychologist—in a crude sort of way."

"But you are a detective, friend Elijah, not a robopsychologist."

"Well, let it pass. Now before I see them, let's think a bit. Tell me: is it possible that both robots are telling the truth? Perhaps the conversation between the two mathematicians was equivocal. Perhaps it was of such a nature that each robot could honestly believe its own master was proprietor of the idea. Or perhaps one robot heard only one portion of the discussion and the other another portion, so that each could suppose its own master was proprietor of the idea."

"That is quite impossible, friend Elijah. Both robots repeat the conversation in identical fashion. And the two repetitions are fundamentally inconsistent."

"Then it is absolutely certain that one of the robots is lying?"

"Yes."

"Will I be able to see the transcript of all evidence given so far in the presence of the captain, if I should want to?"

"I thought you would ask that and I have copies with me."

"Another blessing. Have the robots been cross-examined at all, and is that cross-examination included in the transcript?"

"The robots have merely repeated their tales. Cross-examination would be conducted only by robopsychologists."

"Or by myself?"

"You are a detective, friend Elijah, not a—"

"All right, R. Daneel. I'll try to get the Spacer psychology straight. A detective can do it because he isn't a robopsychologist. Let's think further. Ordinarily a robot will not lie, but he will do so if necessary to maintain the Three Laws. He might lie to protect, in legitimate fashion, his own existence in accordance with the Third Law. He is more apt to lie if that is necessary to follow a legitimate order given him by a human being in accordance with the Second Law. He is most apt to lie if that is necessary to save a human life, or to prevent harm from coming to a human in accordance with the First Law."

"Yes."

"And in this case, each robot would be defending the professional reputation of his master, and would lie if it were necessary to do so. Under the circumstances, the professional reputation would be nearly equivalent to life and there might be a near-First-Law urgency to the lie."

"Yet by the lie, each servant would be harming the professional reputation of the other's master, friend Elijah."

"So it would, but each robot might have a clearer conception of the value of its own master's reputation and honestly judge it to be greater than that of the other's. The lesser harm would be done by his lie, he would suppose, than by the truth."

Having said that, Lije Baley remained quiet for a moment. Then he said, "All right, then, can you arrange to have me talk to one of the robots—to R. Idda first, I think?"

"Dr. Sabbat's robot?"

"Yes," said Baley, dryly, "the young fellow's robot."

"It will take me but a few minutes," said R. Daneel. "I have a micro-receiver outfitted with a projector. I will need merely a blank wall and I think this one will do if you will allow me to move some of these film cabinets."

"Go ahead. Will I have to talk into a microphone of some sort?"

"No, you will be able to talk in an ordinary manner. Please pardon me, friend Elijah, for a moment of further delay. I will have to contact the ship and arrange for R. Idda to be interviewed."

"If that will take some time, Daneel, how about giving me the transcripted material of the evidence so far."

Lije Baley lit his pipe while R. Daneel set up the equipment, and leafed through the flimsy sheets he had been handed.

The minutes passed and R. Daneel said, "If you are ready, friend Elijah, R. Idda is. Or would you prefer a few more minutes with the transcript?"

"No," sighed Baley, "I'm not learning anything new. Put him on and arrange to have the interview recorded and transcribed."

R. Idda, unreal in two-dimensional projection against the wall, was basically metallic in structure—not at all the humanoid creature that R. Daneel was. His body was tall but blocky, and there was very little to distinguish him from the many robots Baley had seen, except for minor structural details.

Baley said, "Greetings, R. Idda."

"Greetings, sir," said R. Idda, in a muted voice that sounded surprisingly humanoid.

"You are the personal servant of Gennao Sabbat, are you not?"

"I am sir."

"For how long, boy?"

"For twenty-two years, sir."

"And your master's reputation is valuable to you?"

"Yes, sir."

"Would you consider it of importance to protect that reputation?"

"Yes, sir."

"As important to protect his reputation as his physical life?"

"No, sir."

"As important to protect his reputation as the reputation of another."

R. Idda hesitated. He said, "Such cases must be decided on their individual merit, sir. There is no way of establishing a general rule."

Baley hesitated. These Spacer robots spoke more smoothly and intellectually than Earth-models did. He was not at all sure he could outthink one.

He said, "If you decided that the reputation of your master were more important than that of another, say, that of Alfred Barr Humboldt, would you lie to protect your master's reputation?"

"I would, sir."

"Did you lie in your testimony concerning your master in his controversy with Dr. Humboldt?"

"No, sir."

"But if you were lying, you would deny you were lying in order to protect that lie, wouldn't you?"

"Yes, sir."

"Well, then," said Baley, "let's consider this. Your master, Gennao Sabbat, is a young man of great reputation in mathematics, but he is a young man. If, in this controversy with Dr. Humboldt, he had succumbed to temptation and had acted unethically, he would suffer a certain eclipse of reputation, but he is young and would have ample time to recover. He would have many intellectual triumphs ahead of him and men would eventually look upon this plagiaristic attempt as the mistake of a hot-blooded youth, deficient in judgment. It would be something that would be made up for in the future.

"If, on the other hand, it were Dr. Humboldt who succumbed to temptation, the matter would be much more serious. He is an old man whose great deeds have spread over centuries. His reputation has been

unblemished hitherto. All of that, however, would be forgotten in the light of this one crime of his later years, and he would have no opportunity to make up for it in the comparatively short time remaining to him. There would be little more that he could accomplish. There would be so many more years of work ruined in Humboldt's case than in that of your master and so much less opportunity to win back his position. You see, don't you, that Humboldt faces the worse situation and deserves the greater consideration?"

There was a long pause. Then R. Idda said, with unmoved voice, "My evidence was a lie. It was Dr. Humboldt whose work it was, and my master has attempted, wrongfully, to appropriate the credit."

Baley said, "Very well, boy. You are instructed to say nothing to anyone about this until given permission by the captain of the ship. You are excused."

The screen blanked out and Baley puffed at his pipe. "Do you suppose the captain heard that, Daneel?"

"I am sure of it. He is the only witness, except for us."

"Good. Now for the other."

"But is there any point to that, friend Elijah, in view of what R. Idda has confessed?"

"Of course there is. R. Idda's confession means nothing."

"Nothing?"

"Nothing at all. I pointed out that Dr. Humboldt's position was the worse. Naturally, if he were lying to protect Sabbat, he would switch to the truth as, in fact, he claimed to have done. On the other hand, if he were telling the truth, he would switch to a lie to protect Humboldt. It's still mirror-image and we haven't gained anything."

"But then what will we gain by questioning R. Preston?"

"Nothing, if the mirror-image were perfect—but it is not. After all, one of the robots *is* telling the truth to begin with, and one *is* lying to begin with, and that is a point of asymmetry. Let me see R. Preston. And if the transcription of R. Idda's examination is done, let me have it.

The projector came into use again. R. Preston stared out of it; identical with R. Idda in every respect, except for some trivial chest design.

Baley said, "Greetings, R. Preston." He kept the record of R. Idda's examination before him as he spoke.

"Greetings, sir," said R. Preston. His voice was identical with that of R. Idda.

"You are the personal servant of Alfred Barr Humboldt, are you not?"

"I am, sir."

"For how long, boy?"

"For twenty-two years, sir."

"And your master's reputation is valuable to you?"

"Yes, sir."

"Would you consider it of importance to protect that reputation?"

"Yes, sir."

"As important to protect his reputation as his physical life?"

"No, sir."

"As important to protect his reputation as the reputation of another?"

R. Preston hesitated. He said, "Such cases must be decided on their individual merit, sir. There is no way of establishing a general rule."

Baley said, "If you decided that the reputation of your master were more important than that of another, say, that of Gennao Sabbat, would you lie to protect your master's reputation?"

"I would, sir."

"Did you lie in your testimony concerning your master in his controversy with Dr. Sabbat?"

"No, sir."

"But if you were lying, you would deny you were lying, in order to protect that lie, wouldn't you?"

"Yes, sir."

"Well, then," said Baley, "let's consider this. Your master, Alfred Barr Humboldt, is an old man of great reputation in mathematics, but he is an old man. If, in this controversy with Dr. Sabbat, he had succumbed to temptation and had acted unethically, he would suffer a certain eclipse of reputation, but his great age and his centuries of accomplishments would stand against that and would win out. Men would look upon this plagiaristic attempt as the mistake of a perhaps-sick old man, no longer certain in judgment.

"If, on the other hand, it were Dr. Sabbat who had succumbed to temptation, the matter would be much more serious. He is a young man, with a far less secure reputation. He would ordinarily have centuries ahead of him in which he might accumulate knowledge and achieve great things. This will be closed to him, now, obscured by one mistake of his youth. He has a much longer future to lose than your master has. You see, don't you, that Sabbat faces the worse situation and deserves the greater consideration?"

There was a long pause. Then R. Preston said, with unmoved voice, "My evidence was a l—"

At that point, he broke off and said nothing more.

Baley said, "Please continue, R. Preston."

There was no response.

R. Daneel said, "I am afraid, friend Elijah, that R. Preston is in stasis. He is out of commission."

"Well, then," said Baley, "we have finally produced an asymmetry. From this, we can see who the guilty person is."

"In what way, friend Elijah?"

"Think it out. Suppose you were a person who had committed no crime and that your personal robot were a witness to that. There would be nothing you need do. Your robot would tell the truth and bear you out. If, however, you were a person who *had* committed the crime, you would have to depend on your robot to lie. That would be a somewhat riskier position, for although the robot would lie, if necessary, the

greater inclination would be to tell the truth, so that the lie would be less firm than the truth would be. To prevent that, the crime-committing person would very likely have to *order* the robot to lie. In this way, First Law would be strengthened by Second Law; perhaps very substantially strengthened."

"That would seem reasonable," said R. Daneel.

"Suppose we have one robot of each type. One robot would switch from truth, unreinforced, to the lie, and could do so after some hesitation, without serious trouble. The other robot would switch from the lie, *strongly reinforced,* to the truth, but could do so only at the risk of burning out various positronic-trackways in his brain and falling into stasis."

"And since R. Preston went into stasis—"

"R. Preston's master, Dr. Humboldt, is the man guilty of plagiarism. If you transmit this to the captain and urge him to face Dr. Humboldt with the matter at once, he may force a confession. If so, I hope you will tell me immediately."

"I will certainly do so. You will excuse me, friend Elijah? I must talk to the captain privately."

"Certainly. Use the conference room. It is shielded."

Baley could do no work of any kind in R. Daneel's absence. He sat in uneasy silence. A great deal would depend on the value of his analysis, and he was acutely aware of his lack of expertise in robotics.

R. Daneel was back in half an hour—very nearly the longest half hour of Baley's life.

There was no use, of course, in trying to determine what had happened from the expression of the humanoid's impassive face. Baley tried to keep his face impassive.

"Yes, R. Daneel?" he asked.

"Precisely as you said, friend Elijah. Dr. Humboldt has confessed. He was counting, he said, on Dr. Sabbat giving way and allowing Dr. Humboldt to have this one last triumph. The crisis is over and you will find the captain grateful. He has given me permission to tell you that he admires your subtlety greatly and I believe that I, myself, will achieve favor for having suggested you."

"Good," said Baley, his knees weak and his forehead moist now that his decision had proven correct, "but Jehoshaphat, R. Daneel, don't put me on the spot like that again, will you?"

"I will try not to, friend Elijah. All will depend, of course, on the importance of a crisis, on your nearness, and on certain other factors. Meanwhile, I have a question—"

"Yes?"

"Was it not possible to suppose that passage from a lie to the truth was easy, while passage from the truth to a lie was difficult? And in that case, would not the robot in stasis have been going from a truth to a lie, and since R. Preston was in

stasis, might one not have drawn the conclusion that it was Dr. Humboldt who was innocent and Dr. Sabbat who was guilty?"

"Yes, R. Daneel. It was possible to argue that way, but it was the other argument that proved right. Humboldt did confess, didn't he?"

"He did. But with arguments possible in both directions, how could you, friend Elijah, so quickly pick the correct one?"

For a moment, Baley's lips twitched. Then he relaxed and they curved into a smile. "Because, R. Daneel, I took into account human reactions, not robotic ones. I know more about human beings than about robots. In other words, I had an idea as to which mathematician was guilty before I ever interviewed the robots. Once I provoked an asymmetric response in them, I simply interpreted it in such a way as to place the guilt on the one I already believed to be guilty. The robotic response was dramatic enough to break down the guilty man; my own analysis of human behavior might not have been sufficient to do so."

"I am curious to know what your analysis of human behavior was?"

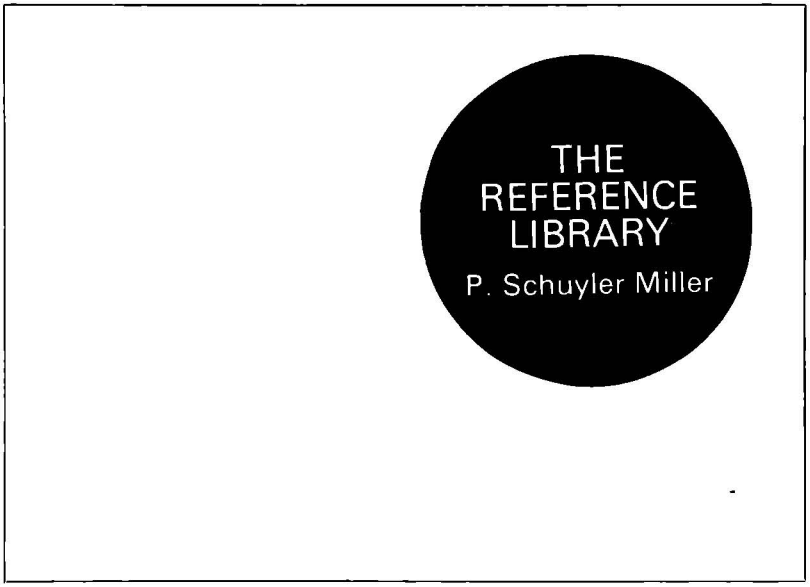
"Jehoshaphat, R. Daneel; think, and you won't have to ask. There is another point of asymmetry in this tale of mirror-image besides the matter of true-and-false. There is the matter of the age of the two mathematicians; one is quite old and one is quite young."

"Yes, of course, but what then?"

"Why, this. I can see a young man, flushed with a sudden, startling and revolutionary idea, consulting in the matter an old man whom he has, from his early student days, thought of as a demigod in the field. I can *not* see an old man, rich in honors and used to triumphs, coming up with a sudden, startling and revolutionary idea, consulting a man centuries his junior whom he is bound to think of as a young whippersnapper—or whatever term a Spacer would use. Then, too, if a young man had the chance, would he try to steal the idea of a revered demigod? It would be unthinkable. On the other hand, an old man, conscious of declining powers, might well snatch at one last chance of fame and consider a baby in the field to have no rights he was bound to observe. In short, it was not conceivable that Humboldt consult Sabbat, or that Sabbat steal Humboldt's idea; and from both angles, Dr. Humboldt was guilty."

R. Daneel considered that for a long time. Then he held out his hand. "I must leave now, friend Elijah. It was good to see you. May we meet again soon."

Baley gripped the robot's hand, warmly, "If you don't mind, R. Daneel," he said, "not too soon." ■



RIVERWORLD

Nearly twenty years ago, in 1953, a promising—indeed, an exciting—young author named Philip Jose Farmer won a fabulous contest with a gigantic book he called "I Owe for the Flesh." You'll find the ugly story in Sam Moskowitz's "Seekers of Tomorrow" and an anagramatic reference to it in the first of a series of books that have finally been hewn out of the original. Now they are called the "Riverworld" series.

The $4,000 prize that Farmer won was offered jointly by Shasta, a Chicago fan-based book publisher, and Pocket Books, then the leading paperback publisher. Farmer never got his money, and the experience nearly wrecked him financially and as a writer. I am sure you know what a comeback he has made after a long period of licking his wounds.

In coming this late to Riverworld, I owe Farmer an apology. The gossip in the fanworld was that the original book was a fantasy—a kind of rationalization and literalization of the Christian idea of Heaven, in which all mankind has risen from the grave in corporeal flesh and is resurrected on the banks of an endless river on some mystic world. Since we don't report fantasy here, I set the first book aside—I hadn't read the parts published over the years in *Galaxy* and elsewhere—to enjoy some day when I had time to spare. I enjoy good fantasy, but I can read only so much in my spare time.

If I had so much as reached the

bottom of the first page of the first book, I'd have immediately discovered how wrong I was. The "Riverworld" series is science fiction—fairly straightforward science fiction—and it is worth reading. Twenty years ago it might have become a classic.

The rumors weren't exactly wrong—or exactly right. As the series opens, the 36 billion men, women and some children who lived between the time of the first sub-men and some still unspecified era after A.D. 2008 have been recreated on the banks of a seemingly endless river that meanders through a strange world. They have not been resurrected in the religious sense. Someone—beings of some kind (and after two books we are still trying to find out what kind)—have recorded the psyches of everyone who ever lived, and have installed them in what would be called android bodies. They awake young, hale, hairless, with all the faults and virtues they had in life, and with all their memories and hangups intact. They act about as you would expect . . . but it develops that they can't be permanently killed. The individual who dies—even the one who is eaten—turns up somewhere miles away in a fresh body.

This is the brand of originality Farmer had demonstrated before 1953, and it is a brand to which he has by no means relinquished title. In this case, however, I am afraid he has set himself an impossible task.

It would have been easy to develop the Riverworld story through a series of fictitious stock characters. Instead, Farmer uses real people. Richard Francis Burton, the Victorian swashbuckler, explorer, and translator of the "Arabian Nights" is the hero of the first book, "To Your Scattered Bodies Go." (Berkley Books has the paperback edition out now as No. S2057, for 75¢; Putnam may still have the hardback original for $4.95.) Mark Twain—young Sam Clemens—is the hero of "The Fabulous Riverboat" (Putnam, 1971; 253 pp.; $5.95). A large and lively cast of historic personages, from Odysseus to Alice in Wonderland, with at least one extraterrestrial, play a lively part.

To do this right, Farmer would have had to have the talents of an exceptionally good historical novelist, a biographer, and an exceptionally creative SF writer. The latter he is; the others he unfortunately isn't.

This is one story—perhaps the only SF story—in which the premise that realistic characterization isn't needed in science fiction just doesn't work. The Burton of "Scattered Bodies" should be the real Burton—and he isn't. I am quite willing to accept Farmer's scholarship, and believe that the real Burton acted and reacted in the same ways that the fictional Burton does. I know that Samuel Langhorn Clemens was an introspective self-doubter with a bad head for business—and so is he when

he tries to build a too-fabulous Twenty-first Century riverboat to pilot upriver against the castle of the mysterious ethicals, with Cyrano de Bergerac and King John of England in his crew. But these resurrected men in Riverworld are ghosts, shadows, not even cardboard cutouts of the originals.

A lot happens and the puzzle grows more tangled by the page. There is internal evidence to suggest that during the past twenty years Farmer has revised and updated his original book substantially, and he may have rewritten it completely. (Clemens recalls information that the "Mysterious Stranger"—a seeming renegade from the "Ethical" creators—never gave him in the interview we have witnessed. There are two different formulas for making sodium nitrate for gunpowder—one unnecessarily fictitious.) I can't buy some of the detail, either: I grew up in Iroquois country, and they adopted captives—they didn't enslave them. I think it is a little sexier and maybe more violent than it would have been in 1953, though Farmer was a pioneer in putting logical sex into science fiction. (Remember "The Lovers"?)

There will be at least one more volume, some time this year, in which Burton, Clemens, Odysseus, Bergerac, and all the other anointed anti-Ethicals confront their creators in their castle at the North Pole. There will be lots of action and lots of ingenious detail, plenty of surprises and a good deal of subtle humor (Hermann Goering becomes a missionary; one of Tarzan's ancestors plays a small part). I fully intend to stay the full course.

But what a book this would have been in 1953, when "Lem Sharkki" loused everything up!

THE TRANSVECTION MACHINE
By Edward D. Hoch • Walker & Co., New York • 1971 • 220 pp. • $5.95

This is that rarity, a professionally competent mystery story which is also science fiction. Edward Hoch is the author of many mystery short stories, and seems better at them than at novel-length mystification. The clues and the plot run a bit thin—but it's the kind of strongly sketched future situation that Heinlein wouldn't be ashamed of.

The mystery is the murder of a U.S.—of America and Canada—cabinet member by a surgical machine in the course of a routine appendectomy. But a machine can't commit murder . . . so there's a how to be solved, as well as a who. A wife who is fed up with having that particular husband? The neglected inventor of the machine of the title—a machine which has teleported a Chinese girl from the U.S. to Calcutta and may have shifted a political exile from Venus to Earth? The escapee in question—or members of the anti-machine organization to which he belongs? The President himself? There's no lack of suspects for Carl Crader of the Computer In-

vestigation Bureau. There's plenty of action, too, right down to an attack on the hospital complex that houses the master computers. And there's the transvection machine.

It's just that the author's straight short mysteries are so much better.

SCIENCE FICTION: THE FUTURE

By Dick Allen • Harcourt Brace Jovanovich, New York • 1971 • 345 pp. • Paper, $3.95

There may be other textbooks for teachers of college and high school science-fiction courses, but this is the only one I have seen. (Writer/teacher Jack Williamson has compiled a list of fifty-odd such college courses, and various people estimate there are at least a hundred. I've heard of two in Pittsburgh.)

Allen teaches at the University of Bridgeport, Connecticut. What he has compiled is an anthology of "speculative fantasy" rather than science fiction, but everyone is entitled to his own categorization. His aim, he says in the introduction, is "to explore concepts of the future as seen by SF writers." Each selection is followed by a batch of questions for students to puzzle out; they sound to me as if schools haven't changed much in fifty years, except that they not only let you but give you credits for reading what somebody calls science fiction.

The book has three sections. Section One, to quote the compiler again, "is meant to lead the reader into the subject without causing extreme disorientation." I'm not so sure it will achieve that goal. You get two poems, an article from *Time* about the day Kennedy airport was snowed in, prognostications of the world of the overcrowded future—a mailer of the Planned Parenthood organization—and an allegory of the future by Nathaniel Hawthorne, just to add a touch of conservative respectability.

Section Two provides the nutrients: a very mixed bag of speculative items, including two poems—one by "Howler" Allen Ginsberg—and an excerpt from "The Time Machine." Analog is represented here by Heinlein's "They" and Bob Shaw's "Light of Other Days." The lot include such oldies as E.M. Forster's "The Machine Stops" and Wells's "Country of the Blind," and such recent "classics" as Roger Zelazny's "A Rose for Ecclesiastes," Frederik Pohl's "Day Million," Kurt Vonnegut's "Harrison Bergeron," and Harlan Ellison's "Repent, Harlequin! et cetera". Arthur Clarke is represented by the forgettable "History Lesson." Ray Bradbury is there, too, with "To the Chicago Abyss."

Part Three consists of, mainly, Establishment criticism of science fiction, with only Isaac Asimov really representing the defense, against Susan Sontag, Arthur Koestler ("The Boredom of Fantasy"), Gerald Heard (SF and religion), and Kingsley Amis.

I suppose the shortcomings of the

book result from its editor's dogged insistence on not being partisan—on showing kids that SF can't be all straight (since you can have allegories and mysticism and Ginsberg and Sontag), or all trash (Hawthorne, Forster, Isaac Bashevis Singer), or all good (Sontag and Koestler). He's bibliographically sloppy in his suggestions for further reading: apparently he read Sam Moskowitz's Munsey compilation/history, for he lists "Under the Moons of Mars," and I don't know where he found "The Skylark of Duquesne" or "Hector Survadac" or why he uses the film title of Wyndham's "Midwich Cuckoos," or lists Jack Williamson's "Cometeers" and not his "Humanoids."

Teachers are going to buy this book because there is nothing else on the market. Williamson, please get with it! Or, for that matter, Gunn, Tenn, Russ, Wilson . . .

Don't you know there's money in textbooks?

20 YEARS OF ANALOG/ASTOUNDING SCIENCE FICTION • SCIENCE FACT

compiled by Jan. A. Lorenzen. • Locomotive Press, 32650 Lake Road, Avon Lake, Ohio 44012. • 40 pages. • $2.50.

The title of this compilation speaks for itself. It covers the contents of Analog/Astounding for the years 1952 through 1971 in an attractively printed little booklet that for some reason is printed only on every other page. (You can make notes or corrections on the blank facing pages.)

The index has six sections. The first, which will interest most of you, is a listing of all stories published in the twenty years *by author.* There is no title index; if you don't remember the author, you can't find the story. Under the author's name, his stories are listed chronologically rather than alphabetically.

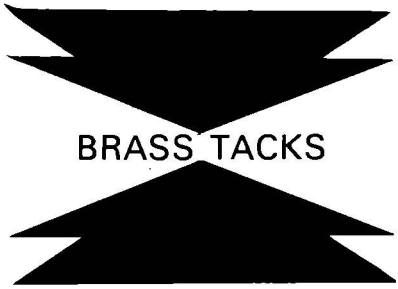
Number Two is a chronological index, by title, of John Campbell's editorials. This may be the thing that sells you the book.

Number Four is a chronological, issue-by-issue listing of the factual articles published in those twenty years. They are not cross-indexed in the list of authors, and I wish they were.

Number Six—and this is useful—is a listing of artists who have illustrated or decorated the magazine during the period in question. They are listed alphabetically, from Alejandro to Woolhiser, with a code (C) to show they did covers. Listing under each name is, again, chronological.

The two short sections I've skipped are unusual. Three lists and interprets the symbolic drawings that John used on the cover for six years. Five lists the wacky portraits of wackier critters he'd been using of late.

"The Reference Library" isn't even listed.



Dear Mr. Bova:

As John W. Campbell's youngest daughter, I want to thank each and every one of the wonderful people who took the time and the thoughtfulness to communicate the deep feelings Father's passing left with them.

I want to thank all the people who felt his passing almost as hard as we, his family, did. Their expressions and their thoughts were with us, and we appreciated every one.

And to those who feel that John W. Campbell can never be replaced (what man can?) I wish to extend one thought which I believe was what Father tried to do, but which is expressed so very well by Kahlil Gibran in the ever popular "The Prophet," when speaking of The Teacher.

> . . . No man can reveal to you aught but that which already lies half asleep in the dawning of your knowledge . . .
>
> . . . If he is indeed wise, he does not bid you enter the house of his wisdom, but rather leads you to the threshold of your own mind . . .

Father loved humanity, he loved to see men think; and he hated man to blunder. While he cannot be replaced, a belief and a desire can be carried on; and with that, the man.

I also wish to extend my heartfelt appreciation to all the wonderful people who are doing so very much for Mother, who is there in the East where her family cannot be with her as much as they would like. Their kindness to her is appreciated in a way that words cannot express.

Thank you, one and all—and God bless . . .

LESLYN CAMPBELL RANDAZZO

Amen.

Dear Mr. Bova:

I would like to congratulate you on becoming editor of ANALOG. While I was sad to learn of Mr. Campbell's death, I agree with Poul Anderson (pg. 5 ANALOG January '72) that "science fiction does not have to go sterile" now. I hope that you are able to bring new ideas to

ANALOG, as well as to all of science fiction, in your new role as editor.

I must disagree with Mr. Dixon (Brass Tacks ANALOG January '72). He feels that groups such as the Mafia should be called upon to use their illegal methods to stop students from protesting to express their views.

I disagree. While I don't think that riots are the best answer, I believe that students as well as everyone else have a right to protest peacefully. A college dean—or anyone else—should not call upon the Mafia, or any other organization that believes in breaking the law, for help.

Mr. Dixon seems to be telling the Mafia to go ahead and "silence" those whose views are different from his. I wonder if he would say the same thing if someone tried to stop his union meetings, or "silence" his family, or even Mr. Dixon himself?

Mr. Dixon, and the whole country, would be better off if he turned his energies to destroying the Mafia instead of endorsing their illegal methods.

CHARLES BERNSTEIN
Rochester, New York

Maybe we could get them to wear brown shirts. . . ?

Dear Editor:

I hated to hear that J.W.C. had left us. I've been a fan of his since the 1930's, and sent his editorials to some people that would surprise you—e.g., I sent "Situation Normal—Explosive!" to Eleanor Roosevelt, believe it or not. John and I didn't see eye-to-eye on ecology, which brings me to Wade Curtis's "Ecology Now!"—December 1971 issue.

I didn't think I was going to like Curtis's story when I started—mainly because of the opening illustration and the title. But Curtis is my idea of a well-informed man, i.e., his ideas are the same as mine. And I've been howling for years that *culture itself is an ecological subsystem.* All of it.

The necessary and sufficient condition for ecology is the existence of a number of very improbable complexities, which maintain their improbable state through the Darwinian triad of reproduction, variation, and competition [= selection]. This triad is as characteristic of cultural elements as it is of biological ones.

Indeed, the current ecological "crisis" arises from the fact that between biological and cultural ecologies, the cultural evolves much faster and farther—and in addition, accelerates its rate of evolution via a

rough exponential rule. Norbert Wiener,* father of automation, made some predictions about the interaction of two evolutionary systems which differ in speed of evolution by several orders of magnitude—predictions which might have been a description of the plight of animal and vegetable wildlife today.

ALFRED B. MASON, M.D.
136 Flushing
Brooklyn, N.Y. 11251

One reason for the ecological crisis might be that our technological culture is now so dominant that it has no viable competition.

Dear Sir:

I am seldom motivated enough to write a letter to a magazine, but I cannot allow Buzz Dixon's preposterous letter—Brass Tacks: January '72—to go by without some comment.

It seems that Mr. Dixon would like to see the Mafia take over the work of the police, the "advantage" being that they would not have to obey the laws. As should be obvious to anyone, but apparently is not to Mr. Dixon, such a group of henchmen with no laws to control them would simply be a new version of the Gestapo. Being a Jew and exceedingly proud of it, I am deeply disturbed that there are people that would like to see the same Fascism brought to this country that resulted in the murder of *six million* of my people less than thirty years ago.

For Mr. Dixon's edification, the sole duty of police is to *enforce laws.* That is why they are called *law enforcement officers,* you see. It certainly would not make a whole lot of sense to have people enforcing laws who would not have to obey them themselves, now would it?

It is amazing to me that anyone would want the organized criminals of our society, whose main income is in the drug traffic that is our major problem today, to not only be excepted from the laws, but encouraged to perpetrate violence! If Mr. Dixon thinks that the syndicates, if such a deal were made, would very obligingly do exactly as they were told and then retreat to their holes, without taking advantage of their newfound power to put at least an entire state under their martial law—no laws to stop them—he cannot even be credited with being naive . . .

Furthermore, Mr. Dixon seems to believe that the solution to violence is more of it. The isolated incident he mentions of professional musclemen putting an end to heckling could very easily have—and has before—erupted into a full-scale riot. I do not condone hecklers and other inciters of violence. But I fervently deny that more violence is any kind of solution.

I hope that Mr. Dixon will think a little more carefully before airing any more of his ideas, if they are as

*Wiener, Norbert: "Some Moral and Technical Consequences of Automation." *Science* (A.A.A.S), about June of 1960.

ridiculous as this one. And I hope that the people in this country who agree with him are few indeed. For if there are many who share this monstrous way of thinking, this country is in grave trouble.

JOSEPH S. EASTERN
Box 6372
La Jolla, California 92037

What was that story about grabbing a tiger by the tail?

Dear Mr. Bova:

I was most interested in your article "Galactic Geopolitics." Since most of your material lies outside of my educational discipline I simply learn and enjoy learning. Thank you so much.

But I must take issue in two aspects of your article. The first is possibly philosophical. I'm fascinated by your seeming equation of cultural-technological change to developing intelligence. However, this is a matter not to be pursued here since it is not the essential point of your article.

You state, "First, we should clearly realize that intelligence per se doesn't depend on heavy metals." Here I must take exception—until I have more facts.

My position lies here. Intelligence in "earth creatures" could never have developed without heavy metals. To keep the proposal to its simplest life—and its attendant function of intelligence—cannot exist as we know it without the support of a number of metals in the enzyme and hormone systems. There are disorders—some evidenced by distinct decline in cerebration—which are classified as "deficiency diseases" involving iron, zink, cobalt and copper, et cetera.

Many hours could be consumed pursuing this but we, you and I are both busy. Thank you for this brief moment of intelligent exchange.

H. E. HINTON, D. C.
127 E. Beach Boulevard
Dania, Florida 33004

So intelligence—and our kind of life itself—does need heavy metals!

Dear Sir:

Instead of the lengthy tirade I originally considered I will simply limit myself to a brief note concerning the illustration on pages 96 & 97 of the January 1972 issue.

Now, the writer has described a gaff rigged two-masted sailing vessel with a gaff and a boom on each mast. A careful look at the vessel illustrated shows two masts and a LATEEN rig. What is more, the lateens are crossrigged in such a manner that if the vessel jibed there would be more wreckage than could be imagined since one of the two lateen spars would be "aback" and would probably take the mast overboard as the standing rigging failed.

The artist's illustration looks nice, but as the vessel is shown our heroes do not deserve to get away from the pirates. (I could also go into ship design for rowing vessels, but then what's the use?).

The story is excellent and a good example of the fine material presented in your publication.

C. HENRY DEPEW

P.O. Box 2613
Tallahassee, Fla. 32304
Ahoy, Kelly!

Dear Ben:

I have some ideas that may lead to some interesting speculation on these pages. The bases are one "Popular Ecological" problem, and two others that even the late John W. Campbell would agree are real, not just a lot of hoopla.

The "Popular Ecology" (PE) problem is the waste heat from nuclear power plants. The obvious solution is not to waste the heat, but to put it to work. This concept of recycling energy is on in a big way in Sweden, and is used at Walt Disney World in Florida where they burn all combustible waste to heat and cool the buildings. (How about an adsorption unit in your apartment powered by the heat from your below neighbor's air conditioner condenser? Con Ed would hate your guts.) The hot discharge water could be circulated to heat quite a few office buildings, if the people would accept it. Or how about running a desalinization plant for coastal cities with the "waste" heat? Inland plants could use their discharge to dry sewage, saving lakes and streams from pollution. Also, disinfected, dried manure makes a fantastic fertilizer for building up poor land.

It is obvious that we must convert to nuclear power in the near future to keep up with our power demands. Besides, our fossil and petroleum fuels are too chemically valuable to waste by burning.

This brings up to the two real problems. We must have a non-polluting automobile, at least for city use, in the near future. Current battery—no pun intended—cars have several drawbacks. One, the batteries are very expensive. Two, the really efficient ones are made of rare metals with not enough to go around. (Where are you going to get about three hundred pounds of silver per car—and who'll pay for it?) Also, these must still be charged, probably by a smoke-belching already overloaded fossil plant. As for fuel cells, I wouldn't want to be in the neighborhood of a crash between two hydrogen oxygen fuel-celled cars. It *might* help cut down on the crowded traffic, though. Hm-m-m . . .

Now, a nuke power plant also has waste, and highly unfriendly stuff at that. Suppose a person were to take this waste, concentrate it, mix it with man-made isotopes—from a breeder built for the purpose—and rig a thermoelectric generator to it? The waste would remain hot—given correct formulation—for some time. Perhaps it could be encapsulated in a matrix material of a high-hydrogen-content fiber bound by a tough, radiation resistant metal. The thermocouple elements should be made of heat-resistant metals that don't con-

duct heat too well, like tungsten and titanium. This would help keep the cool end cool. Heat transfer could be made by sodium, which is lovable in that it is fair shielding, and won't become radioactive itself. Ten H. P. should suffice for city driving, considering the speed of traffic.

Now we have a car that doesn't pour poison gas into the air, and only needs to be fueled every few years!

There are problems, of course, such as what to do when you aren't drawing power. How do you shut it off?

Could spent fuel be reconcentrated? Could a person even breed more fuel? Can temperature be raised enough without a need for a sustained chain reaction and all the controls necessary for that? Can weight be kept down low enough? Do pedestrians have to wear asbestos suits during rush hour? Can we persuade Detroit to build a small car and keep it that way?

Constructive suggestions welcomed.

(Rev.) G. LAWRENCE WILLARD
Box 276
Thayer, Kansas 66776

A nuclear-powered car would have to be very *crashworthy. We will have an article soon on future automobile power plants. The interesting point is that we are now entering the era of "second generation" technology, where the environmental impact of technology has become an important consideration.*

Dear Sir:

I am a regular reader of Analog and I have found the editorials usually to be more stimulating, exciting, and challenging than most of your very good science-social fiction. I looked forward each month to John Campbell's exciting and irritating and thought-provoking ideas. I will miss him.

Mr. Campbell made an interesting suggestion in the October issue of Analog. He suggested that passing "unworkably strict" pollution control laws might produce an inevitable chain of events–ala Gordon Dickson's "Tactics of Mistake?"–which would lead to a workable automobile/people ecology. The Peoples Lobby in California is sponsoring a Clean Environment Act for the June ballot. The Act has some very good sections and some very frightening sections–no nuclear power construction for five years. (Analog has adequately explained why nuclear power is much preferable to no power or open air combustion power.) In my opinion, the CEA fits the requirement of an unworkably strict set of laws which could lead to a workable, livable environment. I think John Campbell would be proud.

RICHARD WOLF
Civil Systems Design Company
15446 Sherman Way,
Van Nuys, California 91406

You mean, if necessity is the mother of invention, then we must invent a need?

LIFE CYCLES

continued from page 6

Hm-m-m. So there exists among the stars the chemical beginnings for water and hydrocarbons. Verrry interesting.

In the past nine years, nearly twenty different molecular species have been detected in such interstellar clouds. Some of them are as simple as ammonia and water; some as complex as CH_3OH and NH_2HCO. At least one such "signature" is still unidentified, and has been whimsically dubbed "X-ogen" by the radio astronomers.

Life cycles. The birth of ideas. The birth of life itself.

Before the evidence for complex molecules in the interstellar clouds, most astronomers and cosmologists felt that there could be no such molecules in interstellar space. Stars radiate at all wavelengths of the electromagnetic spectrum, and many of them radiate strongly in the ultraviolet and X-ray portions of the spectrum. Such high-energy radiation, it was felt, would break up any molecules that tried to form in interstellar space. Perhaps very simple diatomic molecules such as H_2 could exist in the cold darkness far from any star. But nothing more complex.

This meant that when the biochemists wanted to puzzle out the formation of life on Earth, or any planet, they were forced to assume that our solar system consisted only of very simple molecules at the outset. Thus the biochemists had to "produce" their own water and organic molecules out of simple elements, during or after the formation of the planet.

But it now appears that the chemical groundwork for life may take place long before there's any solid ground on the planet itself. Perhaps even before the planet's parent star is formed. The rather complex molecules that have been discovered so far exist in those thick clouds of interstellar gas and dust. The reason they can exist without being broken up by high-energy radiation is that they are "shaded" by the gas clouds and dust particles. Although these interstellar clouds are still a fairly good vacuum by Earthly standards, they're thick enough to shield the molecules within them from the disruptive high-energy radiation from nearby stars.

These interstellar clouds, laced with pre-organic chemicals, are the breeding grounds for new stars. Current astronomical theory—backed up by impressive observational evidence—claims that new stars form out of such clouds. New stars, and their planets.

Thus, when a new star and its planets are formed out of such a cloud, the system *already contains water, ammonia, hydrocarbons and other molecules essential to the formation of life.* Perhaps most of these molecules are torn apart by the radiation from the new star itself, once it

begins to shine. But it seems possible, at the very least, that the formation of life is as completely natural and ordinary in the universe as the formation of new stars and planets. Maybe planets aren't even needed for some forms of life. But it would be hard to imagine a form of life that isn't dependent on the stars as an energy source.

Hardly any reputable astronomer, biochemist, or cosmologist is willing to go so far as to say that the formation of life is an inevitable part of the formation of a new solar system. But we might be witnessing the beginning of a new cycle of scientific thought, in which the possibilities of life elsewhere in the universe are taken to be very high, based on the discovery of "interstellar chemistry."

From the position held by most scientists earlier in this century, that life elsewhere is highly unlikely, we seem to be swinging to a position that there's evidence for life everywhere in the universe.

Such are the life cycles of scientific theories.

From the birth of life among the stars to the death of cities here on Earth may seem a strange jump, but we may just be witnessing the final stage in the life cycle of the city.

Cities are one of man's most conspicuous achievements. Man has been building cities for the past hundred centuries. The very word *civilization* carries in it the concept that civilized men live in cities, barbarians do not. Archeologists trace the rise and fall of nations by the size and complexity of the cities they built. Individual cities go through definite life cycles. No city—not even Rome—is eternal. But all of man's activities seem to go through life cycles, and man's cities seem to be on the way out.

There are many reasons. Two of the most conspicuous are technological and social.

Technologically speaking, we may be nearing the point where we no longer need cities. Cities began as gathering places, markets where farmers brought their produce and merchants displayed their wares. Today, cities still serve much the same function, except on a vaster, much more complex scale. And much of it is needless.

Take a look at the business section of a modern American city. First thing in the morning, several hundred thousand people—or millions, if it's a really large city—swarm into the business section. They come from their homes—mostly from the suburbs. Most of them come in automobiles that foul the atmosphere and kill more Americans than war does.

They crowd into office buildings and spend their day shuffling papers. Others come into the city to provide services for these office workers: food, telephones, electricity, trash removal, traffic control, et cetera.

It seems likely that the next generation of computer and communications technology could produce

an era in which all this would be unnecessary.

The average office worker could work right in his home, without any need to go to a central gathering place, if he had: (1) complete and easy access to all the information he needs; and (2) reliable and easy communication with all the people he must interact with.

Time-sharing computers with terminals in the home can provide the information access. They're getting big enough in capacity and cheap enough in operation to pose the possibility that paperwork itself will eventually disappear. Why have papers when you can read what you want off a viewscreen display? Why have file cabinets when holographic memory storage can handle rooms full of records in the volume of a sugar cube? Why write memos when you can converse with anyone on Earth by telephone—even a picture phone—Jack Wodhams notwithstanding?

Most business enterprises could be run by teams of people who are scattered all over the countryside, who never come within a hundred miles of one another, and yet who are in constant communication *via* computers and phones. Technologically, this can be done soon.

So there might be no need to have enormous masses of people jamming into the city each day, and then rushing out again to leave the city's business district dark and empty each night.

Thus the very need for cities might be disappearing, bringing to a close a life cycle that began ten thousand years ago.

But there's another powerful reason for the demise of the city—a social reason. And from all the current appearances, the city isn't going to die easily—or peacefully.

Most of the cities in the United States, particularly those on the East Coast, are old and crumbling. Like any living entity, a city needs nourishment. For a city, nourishment means tax dollars. But in most cities, those who can pay taxes—the middle and upper-income people, the major business firms—are moving away, out to the suburbs and even farther.

What happens to the city is something like what happens to an oversized star. It swells at first, then inevitably collapses and sinks down into a black hole.

The Flight to the Suburbs began shortly after World War II, when people had the money to live better than they had ever lived before. The American economy had reached the second-generation level: basic questions of subsistence—food, shelter, jobs—had been solved for most people. Now they could go on to the subtler questions of life style. So out to the suburbs they went; and they're still going.

At first it looked as if the city was merely expanding. Urban areas grew. Suburban areas grew explosively. Rural communities be-

came mini-cities. Celery farms turned into housing developments. Conservationists muttered about "urban sprawl." But the city itself—the corporate, tax-dependent, service-rendering city—was doing exactly what an overaged star does. Its outer envelope was expanding, but its inner core was shrinking, and getting hotter. The city's tax base began to shrink disastrously, as the tax-paying individuals and businesses took off for the suburbs. At the same time, influxes of poor people—black and white—were pouring into the city from the rural countryside. The 1950s and 1960s saw the denuding of the rural areas; more than ninety percent of the nation's people now live in urban areas.

For the past quarter-century, the city has been gaining poor people and losing the wealthier people and business firms. Welfare demands have gone up while tax income has gone down. What happens? Tax rates go up. Services deteriorate. And every time they do, another batch of people and business firms take flight for the suburbs.

The end is now in sight.

For many cities, before the turn of this century, there will be nothing left but a rotting and hollow shell. Everyone who can afford to move away from the city will do so. All who remain will be the poor, the sick, the ignorant. Unless something dramatic intervenes, our cities will

be turned into concentration camps, where new barbarians seethe with hate and watch the glowing lights of the wealthier suburbs that ring them in.

In bygone civilizations, cities were often destroyed by barbarians who swept in from the hinterlands with sword in hand. Our society seems intent on breeding new barbarians in the decaying remains of our cities. The inevitable result is that they will break out and destroy the wealthy society.

And they won't be using swords.

If all this comes to pass, it will be ironically tragic. For while most of our population is setting itself up in a new life style, outside the cities, the seething barbarians will remain in the decaying remains of those cities and revert to a way of life that's older than civilization.

Unless Something Is Done. But who's to do it? The cities themselves can't reverse the current flow of events any more than a bankrupt star can prevent its own gravitational collapse. The people and businesses that have fled to the suburbs and exurbs want no part of the city's plight: that's why they left!

A number of schemes have been proposed for sending Federal tax money to the cities. So far, these suggestions are bogged down in political infighting in Washington. Many veteran political observers are wary of proposals for taxsharing with state or city governments, because the states and cities have shown very little evidence that they would know how to use the money effectively to solve the problems of the cities.

For what is needed is not *only* money, but the will and the talent to attack the problems of the cities successfully. This means that the cities must enlist the aid of those very people and business firms that have fled to the suburbs. It means that we must start to look on the city as an organic unit, comprising the old city proper and its suburbs and even the rural areas farther outside.

If the money and the talent and the heart can be found and thrown into the struggle, then our cities may not die. The decay toward barbarism can be stopped and reversed. But the cities that survive will be very different from today's cities. The city core of the future may be more of a museum and recreational area than a place of business and industry.

Life cycles. Cities were born ten thousand years ago. Just about fifteen hundred years ago, in most of the civilized world—except China—cities died. The Dark Ages nearly killed off all the cities in Europe, North Africa and the Middle East.

But a few cities survived, and the urban way of life was reborn centuries afterward. Once again, a seeming death was followed by a rebirth. Even if our modern cities die, there may be a rebirth in some unknown future.

Or maybe that's just a lopsided point of view imparted by our planet's axial tilt. THE EDITOR

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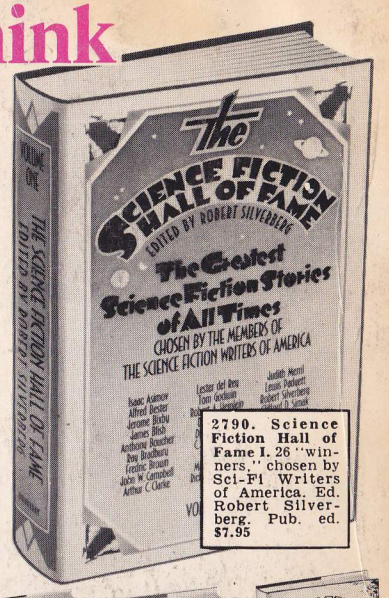

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