

Tank Farm Dynamo

a short story by David Brin

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1.

"They finally fired Bylinsky."

I was up to my knees in agrisludge, a frothy brown mess at the bottom of my personal greenhouse tank, when I heard the remark. For a moment I thought I had imagined it.

Your hearing plays tricks when you're wading around in mucky water, barely held to the floor by under a hundredth of a gee. I was groping in the goo, trying to find whatever had gummed up the aspirator. My breath blew up little green and brown droplets that hovered in front of my face for long seconds before slowly settling down again.

"Ralph! Did you hear me? I said Bylinsky's *out!*"

I looked up this time. Don Ishido, our communications and operations chief, hung halfway through the aft hatch of the greenhouse, twenty meters away. He was watching my reaction, maybe in order to report to the others exactly how I took the news. Probably there was money riding on it.

I nodded. "Thanks, Don. Bylinsky's days were numbered. We'll miss him, but we'll survive."

Ishido smiled faintly. He must have bet on my poker face. "What do you want me to tell the others, boss?"

I shrugged. "We're still a tank farm. We buy 'em and store 'em and later we'll all get rich selling 'em back for a profit."

"Even when they cut the water ration?"

"There'll be a way. We're in the future business. Now get out of here and let me finish my recreational farming."

Don smirked at my euphemism, but withheld comment. He ducked out, leaving me alone to my "recreation"... and my worries.

After clearing a clump of gelatinized algae from the input ports, I climbed onto one of the catwalk longerons rimming the pond and turned on the bubbler. The air began to fill with tiny superoxygenated green droplets.

I took a leap and sailed across the huge chamber to alight near the exit hatch. There I stowed my waders and looked around the greenhouse to make sure it was ready.

In the ten years I've been living in tanks I doubt I've ever entered or left one without blinking at least once in awe. The hatch was at one end of a metal cylinder as long as a ten-story building is tall, with the diameter of a small house. The walls were stiffened with aluminum baffles which once kept a hundred tons of liquid hydrogen from sloshing under high stress. That ribwork now held my greenhouse ponds.

The former hydrogen tank had a volume of over fifty thousand cubic feet. It, and its brothers, were just about the largest things ever put into space. And this one was all mine -- my own huge garden to putter around in during off-duty hours, growing new types of spaceadapted algae and yeasts.

I passed through the yard-wide hatch into the intertank area between the two main sections of the External Tank. In the middle the intertank was only four feet across. The hatch closed.

Looking back into the garden tank through a tinted port, I pressed a button to let the sunshine in.

A bright point of light blossomed at the opposite end of the cylinder, mirror-focused sunlight speared through a fused quartz window to strike the cloud of rising bubbles.

I stayed long enough to watch the rainbows form.

The intertank hoop connects the big and little parts of the great External Tanks, or ETs, as we call them. The smaller cell had once contained 550 cubic meters of liquid oxygen. These days I stored gardening tools in it. Not a day had passed, in the last five years, in which I hadn't wished someone on Earth would recognize the waste, and come and take my tool shed away from me -- to be used in some grand and wonderful plan.

Now they were trying to do just that, but not in a way I cared for at all.

"Boss? You still there? There's a telex from J.S.C. coming in."

I grabbed the big steel beam that had once borne the thrust of giant, strap-on solid rocket boosters. Now it served as a convenient place to put the intercom.

"Ishido, this is Rutter. I'm on my way. Don't let them sell us for scrap till I get there. Out."

I put on my hardsuit, carefully double-checking each seal and valve. The lock cycled, and I emerged into vacuum, but not blackness.

Overhead the Earth spanned the sky, a broad velvet blanket of browns and blues and fleecy white clouds. From just five hundred kilometers up, you don't see the Earth as a spinning marble in space. She covers an entire hemisphere, filling almost half the universe.

I drifted, but after a minute my boots touched the metal of the tank again. The same faint microgravity that held my pools inside the garden worked here on the outside.

The tank was the next to last in a row of forty of the great cylinders, nestled side by side. A parallel deck of sixteen huge tanks lay about sixty kilometers "overhead" linked to this collection by six strong cables. Twenty meters away from where I stood, one of the half-inch polymer tethers rose from its anchor point, a mirror-bright streak toward the planet overhead.

Sometimes a careful observer could make out B Deck without aid -- a tiny rectangle about an eighth the apparent diameter of the moon -- against the bright bulk of the Earth. When we crossed the terminator, the tanks in Group B sparkled like gems in Terra's sunset tiara.

Today I hadn't time to look for B Deck. The Feds had finally fired Edgar Bylinsky, the Tank Farm's last big supporter in NASA. If we thought times were hard before, they were going to get worse now.

"Ralph?" It was Ishido's voice again, now coming over my suit radio. *"We've got the telex. I think this is the big one."*

I pushed off toward the control center. "Okay, what's the news?"

"Uh, they're moving fast. Pacifica's coming in with a couple of official bad news boys."

I could guess what they were coming to tell us. They'd say they were here for "consultations," but actually it would be to say that Uncle Sam wasn't going to sell us any more water.

"Don, when are the bad news boys due?"

"E.T.A. about an hour."

"I'll be right in."

Another hop took me to the entrance of the control tank. It was sheathed in layers of plating cut from dismantled ETs, to protect the crew during solar proton storms.

While waiting for the airlock to cycle, I looked up at the Indian Ocean, where they used to dump our tanks back at the beginning of the shuttle program. That awful waste had been one of the reasons for founding the Tank Farm.

For years ours had been a lonely and expensive gamble. Now we had proved our point. Proved it too well, it seemed.

They let us get a monopoly, and now they want to break us, I thought. And they might succeed, if they cut off our water.

We had safeguarded the Key to Space for them, and expected them to be grateful when they realized its worth. We should have known better.

2.

In the beginning there was the space shuttle. Never mind what came earlier. Before version two of the shuttle, space was a place for robots and daredevils.

With tight budgets and all, the Space Transportation System has stayed fundamentally the same. A big, complex manned orbiter is launched from Canaveral or Vandenberg, strapped to two solid rocket boosters and one huge fuel tank carrying 770 tons of cryogenic propellants for the shuttle main engines. The engines are part of the orbiter, so they can be brought home and reused. The solid boosters drop off minutes after liftoff and are recovered for refurbishment. Even the unmanned heavy-lift cargo launchers use the same basic system.

But until our group came along, the huge external tanks were simply dumped, after fueling the shuttle to almost orbital velocity.

Once upon a time people thought we were on the verge of colonizing space. But then tight budgets and disasters cut the size of the STS fleet, and the cost of a pound sent into orbit remained in four figures. Visions of big O'Neill colonies and grand cities on the moon

founded without the bootstrap mass needed to build the dreams.

The lock passed me through. I stowed my hardsuit in a restorer locker whose nameplate simply read "Bossman." While I racked my equipment, I recalled all the times I had explained the Tank Farm to audiences on Earth: to congressmen, housewives, investors -- to anyone who would listen.

Back in the early eighties it was shown that the thirty-five-ton external tank can be carried all the way into orbit at zero cost to the orbiter's thirty-ton cargo capacity. Thirty-five tons of aluminum and polymers, already shaped into vacuum-tight cylinders, delivered free!

And that wasn't all. On arrival the tanks would contain another five to thirty-five tons of leftover liquid hydrogen and oxygen, usable in upper stage engines, or to run fuel cells, or to be converted to precious water.

At a time when the grand hopes for space seemed about to fall apart, the ET was like manna from Earth to Heaven. When the government didn't seem eager to seize the opportunity -- when they built their cramped, delicate, little "space stations" from expensive modules in the old-fashioned way -- the Colombo-Carroll Foundation, a consortium of U.S. and Italian interests, offered to buy the tanks.

We would save them, until the world wised up, then sell them back. Meanwhile, the Tank Farm would provide orbit boosts via the tether-sling effect, saving customers fuel and time and paying our way until other investments matured.

For ten years the Farm had been on course, but it seems we'd omitted a few lines of fine print in our contract. The Feds had to let us buy the tanks at a fixed price, but nothing in the contract said they had to give us the residual hydrogen and oxygen, too.

It never occurred to us they'd not want to give us all the water we needed! Who in the world would have thought they'd ever want to take the Tank Farm away from us?

3.

Imagine six very long parallel wires, hanging in space, always aimed toward the surface of the Earth 500 kilometers below.

At both ends the wires are anchored to flat rows of giant cylinders -- forty in the upper layer, A Deck; and sixteen in the lower, B Deck. An elevator, consisting of two welded tanks, moves between the two ends, carrying people and supplies both ways.

I've lost count of the number of times I've explained the curious structure to visitors. I've compared it to a double-ended child's swing, or a bolo turning exactly once always high. It's been called a skyhook, and even a bean-stalk, though the idea's nowhere near as ambitious as the ground-to-geosynchronous space-elevators of science fiction fame.

The main purpose of the design is simply to keep the tanks from falling. The two massive ends of the Farm act like a dipole in the gradient of the Earth's gravitational field, so each deck winds up orbiting edge-forward, like a flat plate skimming. This reduces the drag caused by the upper fringes of the atmosphere, extending our orbital lifetime.

The scheme is simple, neat, and it works. Of course the arrangement doesn't prevent *all* orbital decay. It takes a little thrust from our aluminum engines, from time to time, to make up the difference.

Since our center of mass is traveling in a circular orbit, the lower deck has to move much slower than it "should" to remain at its height. The tethers keep it suspended, as it were.

The upper deck, in turn, is dragged along faster than it would normally go, at its height. It would fly away into a high ellipse if the cables ever let go.

That's why we feel a small artificial gravity at each end, directed away from the center of mass. It creates the ponds in my garden, and helps prevent the body decay of pure weightlessness.

When I entered the darkened control chamber, I moved quietly behind the chief flight controller and watched. The controller's main screen showed the interdeck elevator stopped about three clicks above B Deck. The reason for its delay came into view in a few moments: a small delta-wing whose white tiles shone against the starfield. I stood in the shadows and listened as our operators conversed with the shuttle pilot.

"*Pacifica*, this is A for Arnold Deck control. You are cleared for orbit intersection. In a minute we'll transfer you to B for Brown, for final approach. Extend your landing gear now."

"Roger, Arnold Deck. *Pacifica*, ready for landing."

The orbiter drifted toward B Deck. On the controller's screen I could see <IPACIFICA> 's landing gear deploy in the deep black of space.

The inner face of B Deck was covered with a flat surface of aluminum plates, surrounded by a low fence of soft nylon mesh.

Pacifica was at the highest point of her elliptical orbit. Her velocity would, for a few minutes at apogee, be virtually the same as B Deck's, allowing a gentle approach and contact. (A few purists still refused to call the docking a "landing.") The shuttle gave off small puffs of reaction gas to align her approach.

It was a beautiful technique, and the unargued greatest asset of the Tank Farm. When *Pacifica* was secured to B Deck, she would be carried along in the Farm's unconventional circular orbit until it was time for her to go. Then *Pacifica* would simply be pushed over the edge of B Deck, to fall toward the Earth again, finishing her original ellipse.

I looked at the screen showing the underbelly of B Deck. A great net of nylon hung below the plain of cylinders. Within, like a caterpillar trapped in a web, was *Pacifica*'s ET, the external tank that had powered her into orbit, sent ahead and snagged on a previous pass.

So the bad news boys had brought one of the magic eggs with them. I hoped it was a good omen, though it was probably just a coincidence of scheduling.

Until a year ago most of the orbiters visiting the Farm also delivered their external tanks, along with several tons of residual hydrogen and oxygen propellants in each. Then a new administration started renegeing, stockpiling ETs at the Space Stations instead, and denying us our allotment. The Foundation took them to court, of course, and forced a delivery rate of at least ten ETs a year.

The new administration didn't like losing face. Now they'd found a way to get even. Our contract said they had to sell us the tanks, but it said nothing about the water.

"Um, Dr. Rutter, could I speak with you for a minute?"

I turned to see an earnest-looking, black-haired young woman. She clutched a roll of strip charts. Emily Testa was a very promising new member of the Farm, sent up by the Italians, the junior partners in Colombo Station.

"This is really a bad time, Emily. Is it important?"

"Well, sir ..." She caught my warning look. "I mean *Ralph* ... Since I arrived I have been studying the problem of electrical currents in the tether cables, and I think I have learned something interesting."

I nodded as I recalled the project I'd given the young newcomer to get her started. It was a nagging little problem that I'd wanted to have someone look into for some time.

The super-polymer tethers that held the Tank Farm together were sheathed in an aluminum skin to protect them from solar ultraviolet radiation. Unfortunately, this meant there was an electrical conducting path from B Deck to A Deck. As the Farm swept around the Earth in its unconventional orbit, the cables cut through a changing flux from the planet's magnetic field. The resulting electrical potentials had caused some rather disconcerting side effects, especially as the Tank Farm grew larger.

"Go on, Emily," I suggested. But I couldn't help listening with only half my attention. *Pacifica* was coming in, gear extended like a fighter landing on an aircraft carrier. I could hear the controllers talking softly in their singsongy dialect.

"Well, sir," Emily said, almost without a trace of accent, "I wasn't able to find a way to prevent the potential buildup. I'm afraid the voltage is unavoidable as the conductive tethers pass through the Earth's magnetic field.

"In fact, if the charge had anywhere to go, we could see some pretty awesome currents: One deck might act as a cathode, emitting electrons into the ionosphere, and the other could be an anode, absorbing electrons from the surrounding plasma. It all depends on whether ..."

Pacifica touched down with barely a bump. Her landing gear flexed slightly as she rolled to a stop. The interdeck elevator resumed its descent as the orbiter was tied down by the B Deck crew. Her cargo was removed from the open cargo bay by giant manipulator arms.

Two spacesuited figures drifted down from *Pacifica*'s hatch and stood waiting for the elevator. It didn't take a lot of imagination to guess who they were. Our bad news boys.

Emily went on single-mindedly, apparently unaware of my split attention. "... so we could, if we ever really wanted to, use this potential difference the tethers generate! We could shunt it through some transformers here on A Deck, and apply as much as twenty thousand volts! I calculate we might pull more power out of the Earth's magnetic field, just by orbiting

through it with these long wires, than we would ever need to run lights, heat, utilities, and communications, even if we grew to ten times our present size!"

The boys in the spacesuits got into the elevator. The crew loaded *Pacifica's* cargo after them, encased in blue Department of Defense shrouding.

"Emily." I turned to face the young woman. "You know there ain't no such thing as a free lunch. Your idea certainly is interesting. I'll grant you could probably draw current from the tethers, maybe even as much as you say. But we'd pay for it in ways we can't afford."

Emily stared for a moment, then she snapped her fingers. "Angular momentum! Of course! By drawing current we would couple with the Earth's magnetic field. We would slow down, and add some of our momentum to the planet's spin, microscopically. Our orbit would decay even faster than it already does!"

I nodded. "Right. Still, it's a good idea. If we were getting all the water we used to receive, so we could run the aluminum engines as before, we might even decide to draw power your way.

"But our solar cells are really more than adequate. We could sell our excess to Earth, if they could only agree on a way to receive it."

She looked a little crestfallen. "Keep at it, though," I said for morale's sake. "Maybe there's a way to turn these electrical phenomena to our advantage. We ought to have a break coming about now." I tried to sound as if I believed it. Emily brightened a bit.

The elevator started rising, on its way up here to A Deck. I had about an hour to get ready -- to shave and shower away the aroma of my garden. It probably wouldn't do any good, but I'd want to look presentable to the bad news boys.

4.

We had our meeting in the lounge. Susan Sorbanes, our business manager, took her place to my left, Don Ishido to my right. There were no chairs, but we stood at rest in the feeble gravity, a table made of spun aluminum fibers between us and the federal officials. Our backs were to the giant quartz window.

Across the table, Colonel Robert Bahnz, the new DOD representative, floated impassively. He had said hardly a word, apparently content to leave the talking to Henry Woke, the NASA official who had come up in *Pacifica* with him. Bahnz stood at a slight angle, which had to take a certain amount of work. Was it his way of showing his contempt for the Tank Farm's famous gravity, so unlike the free-fall conditions in the government's shiny little Space Stations?

"So you people have decided to hit us on two fronts at once, Dr. Woke?" Susan spoke softly, but her voice had a cutting edge. "You're going to attack the Farm's man-rating, and you're cutting back on our share of the residual propellants and water."

Woke was a middle-aged bureaucrat who must have convinced himself long ago that space visits were a route to advancement in NASA. I could tell by his faint green pallor that he was doped up against space sickness.

"Now, Dr. Sorbanes," he said. "Safety's been an issue ever since a crewman fell from B Deck two years ago. As a quasi-federal institution, Colombo Station must adhere to man-rating policy. That's all we are interested in."

"We've had a good safety record for ten years, except for that one incident," Susan replied. "And Congress gave us exemptions back in '89, you'll remember."

"Yes, but those exemptions expire this year. And I think you'll find this Congress less willing to take chances with the safety of its citizens in orbit."

"I don't see why we have to go the gold-plated route NASA and DOD used in the Space Stations," Susan said acidly. "All that approach accomplished was to slow you down by a decade, and almost turn the country off on space for good!"

Woke shook his head. "Perhaps, Dr. Sorbanes. Indeed, it's because NASA has seen the value of the Tank Farm approach that we had last year's unfortunate misunderstanding regarding tank deliveries. Since Stations Two and Three began operating their own propellant recovery units and aluminum smelters, we've found that we need the leftover tanks as much as you do. We're all going to have to share. That's what it comes down to."

Don Ishido shook his head. "That's a load of bull! Our contract only guarantees us a third of the tanks launched, in return for which we use the slingshot effect to boost government and commercial cargoes into higher orbits, and provide shuttles like *Pacifica* with temporary angular momentum loans. That leaves you with two thirds of the tanks to do with as you

wish!

"Let's face it. It's not the tanks that are causing the problem. It's you stealing our water!"

I cleared my throat. It was time to step in, before this broke down completely.

"I think what Mr. Ishido means, Dr. Woke, is that Colombo Station depends on delivery of at least fifty tons of residual propellants a year, for life support, chemistry, and especially to provide oxydizer for our aluminum engines. Without those engines, our orbit will decay, and we'll be forced to use the extremely inefficient method of flinging away tanks to maintain altitude. The Farm will cease accumulating mass, and our value to our investors will disappear ... this just as we were about to show a real profit for the first time."

Woke shrugged. "Of course we have no intention of cutting off the water and oxygen you need to maintain life support. No one even considered such a thing."

Damn right, I thought. Nothing would alienate the public like that. But trimming our ration, forcing us to spend tanks as fast as we get them -- they could pull that off without trouble.

Yeah. We had almost closed a deal with some big Earthside chemical houses to produce large amounts of low-g biochemicals on B Deck, when NASA Station Two undercut us by \$2 million. But the killer had really been the rumors over our water situation. The investors had shied away from the uncertainty.

It hurt like hell. We were just short of making it. We had gobs of solar power, but the Earthsiders couldn't agree on how to receive it. With water and our giant tanks we could run a tremendous chemical plant, but timid companies stopped just short of buying in. We'd planned to set up a space hotel and sell vacations for scores of tourists at a time, but we were stymied by this "man-rating" straw man.

Our ecological recycling system had us ninety-five percent independent of Earth resupply. Our smelter was operational and waiting for customers: We had developed the aluminum engine.

But all anyone wanted to buy was the slingshot effect. We were a glorified switching yard in orbit. And the new government clearly wanted us to stay just that.

Woke kept up his soothing apologia. I had heard it all before. I wasn't the one to fight him, anyway. That was up to our lawyers back in Washington. My job was to come up with miracles. And right now they appeared to be in short supply.

The crewcut DOD man, Bahnz, was staring at something over my shoulder. I shifted a little to look.

Out on A Deck they were readying a Defense cargo for launch. They had peeled away the blue shrouding and set the cylinders near the edge of the deck. At the right moment the package would slip off into the starry field below us, falling away from Earth in a steep ellipse. At apogee a motor would cut in, carrying the spysat the rest of the way to geosynchronous orbit.

Bahnz had a gleam in his eyes as he observed the preparations.

You want my Farm, don't you? I thought. You peepers fought us in the beginning, but now you see we're the one thing keeping us ahead of the other nations in space. Now you want my Tank Farm for your own.

Two years ago, they had tried to get us to store "strategic assets" in the A Deck tanks. I threatened to resign, and the Foundation found the guts to refuse. That's when the troubles had started.

Bahnz noticed my look, and smiled a knowing smile.

He thinks he holds all the aces, I thought. *And he might be right.*

There were some old SF stories I read when I was a kid, about space colonies rebelling against Earth bureaucracies. I had a brief fantasy of leading my crew in a "tea party," and kicking these two jerks off our sovereign territory.

Bahnz saw the peaceful smile on my face, and must have wondered what caused it.

Of course the rebellion idea was absurd. It wasn't what any of us wanted, and it wasn't practical. We might be ninety-five percent free of Earth logistical support, but that last few percent would be with us for a hundred years. Anyway, without either water or new tanks every year, Mother Earth's atmosphere would quickly pull us down.

While Don and Susan kept our side of the charade, I looked out the window, thinking.

Next year would be solar maximum, when the coronal ion wind would come sleeting in from the active sun. The upper atmosphere would heat up and bloat outward, like a high tide

dragging at our knees. At solar max we could lose twenty kilometers of altitude in a single year. Maybe much more.

Our investors would be caving in within eighteen months. Even the Italians would soon be begging the U.S. administration to make a deal.

For an instant I saw the Earth not as a broad vague mass overhead, but as a spinning globe of rock, rushing air, and water, of molten core and invisible fields, reaching out to grapple with the tides that filled space. It was eerie. I could almost *feel* the Tank Farm, like a double-ended kite, coursing through those invisible fields, its tethers cutting the lines of force -- like the slowly turning bushings of a dynamo.

That was what young Emily Testa had compared it to. A dynamo. We could draw power from our motion if we ever had to -- buying electricity and paying for it in orbital momentum. It was a solution in search of a problem, for we already had all the power we needed.

The image wouldn't leave my mind, though. I could almost see the double-ended kite, right there in front of me ... a dynamo. We didn't need a dynamo. What we needed was the opposite. What we needed was ...

"I think we should recess," I said suddenly, interrupting Dr. Woke in the middle of a sentence. It didn't matter. My job wasn't diplomacy. It was miracle-working.

"Susan, would you show our guests to some rooms? We'll all meet again over supper in my cabin, if that's okay with you gentlemen?"

Woke nodded resignedly. I think he had hoped to go back down right away in *Pacifica*. Colonel Bahnz smiled. "Dr. Rutter, will you be serving Slingshot with dinner?"

"It's traditional," I replied, anxious to get rid of the man.

"Good. It's one of the reasons I came up today." Bahnz's grin seemed friendly enough, but there was an undertone to his voice that I understood only too well.

I waited until they had left, then turned to Ishido. "Don, go fetch Emily Testa and meet me in the power room in five minutes."

"Sure, chief. But what ...?"

"There's something I want to try. Now shake a leg!"

I kicked off down the hallway, looking for a computer terminal. I don't think I touched the floor twice in fifty yards.

5.

For all of our Spartan lifestyle, there are a few places the crew had tried to make "posh." One is the main lounge. Another is the "Captain's Cabin." My digs were given that name when the Foundation first had the idea of setting up a tourist hotel. They figured making a big deal out of dinner in my quarters would give a visit more of the flavor of a Caribbean cruise.

The aluminum walls had been anodized different pastel shades. The gold carpet had been woven from converted tank insulator material. And in wall niches there stood a dozen vacuum-spun aluminum-wire sculptures created by Dave Crisuellini, our smelter chief and resident artist.

The Captain's Table was made of oak, brought up at six hundred dollars a pound for one purpose only, to look impressive.

Henry Woke sat to my right as the volunteer stewards served us from steaming casserole dishes. Next to Woke sat Susan Sorbanes. Across from them were Emily Testa, nervously fingering her fork as her eyes darted about the room, and Ishido. Colonel Bahnz sat across from me.

Woke looked considerably less green around the gills. His eyes widened at the soufflé a waiter laid in front of him. "I'm impressed! I'd heard that a hundredth of a gee is enough to enable the inner ear to come to equilibrium, but I hadn't believed. Now, to be able to eat from plates! With forks!" He spoke around a hot mouthful. "This is delicious! What is it?"

"Well, most of our food is prepared from termite flour and caked algae ..."

Woke paused chewing. Susan and Ishido shared a look and a smile.

"... however," I went on, "recently we have begun raising our own wheat, and chickens for eggs."

Woke looked uncomfortable for another moment, then apparently decided to accept the ambiguity. "Ingenious," he said, and resumed eating.

"We have a number of ingenious people here," Susan said. "Many of our crew served aboard the Space Stations, and came here when NASA went through cutbacks and furloughed

them.

"Others were hired by the Foundation because of their varied talents. Emily here," she said, smiling at young Testa, "is a fine example of the sort of colonist we're looking for."

Emily blushed and looked down at her plate. She was very tired after the last few hours, as we had furiously experimented with the Farm's power system.

Colonel Bahnz squeezed an aluminum-foil beer bottle, his second. "You're right about one thing, Dr. Sorbanes," the DOD man said. "The U.S. government has subsidized this venture in many hidden ways. Most of your personnel got their training at taxpayer expense."

"Have we ever failed in our gratitude, Colonel?" Susan spoke with pure sincerity. And to Ishido and I, the answer was obviously no. We tank farmers think of ourselves as custodians of a trust.

But Bahnz clearly disagreed. "Do you call it *gratitude*, using lawyers' tricks to put restrictions on your country's use of valuable resources when she needs them most?"

"We believe," Susan said, "that need will be greatest in the future. And we plan to be here, with the key to a treasure chest, when the time comes."

"Dreams of glory." Bahnz sneered. "I know all about them. Tell me about lunar mines and space colonies and other fairy tales, Dr. Sorbanes. And I'll tell you about Low Earth Orbit, now filled with garbage and bombs and little cameras from half a hundred bickering, hungry little nuclear powers, all blaming each other for a world economy in a thirty-year skid!

"Have you any idea what would happen if even *one* of these arrogant little 'spacefaring nations' decided to ignite a small enhanced radiation device in that cloud of communications satellites overhead? You know as well as I how dependent we are on orbital datalinks. And you know the only way to defend those links is to put our satellites inside big Faraday cages."

Bahnz struck the nearby aluminum wall. "*This* is what your country needs, Dr. Sorbanes. This tank and others like it! And the propellants for upper-stage launches. And we need this *station*, for the momentum transfer you now almost *give* away to anyone who wants it!"

Susan was gearing up for a major rebuttal. I hurried to interrupt. "People, please! Let's try to relax, if only for a little while. Colonel Bahnz, you seem to like Slingshot. That's your third helping."

Bahnz had plucked another bottle from a passing steward. "Why not?" He shrugged. "It costs a hundred bucks a pint on Earth. It's damn fine beer."

"Dr. Ishido is our brewmaster."

Bahnz lifted the bottle and bowed his head in silent tribute to Don. An aficionado of beer need say no more; Ishido nodded at the colonel's compliment.

"Director Rutter," Bahnz said as he turned to me, "Dr. Woke and I will be leaving within two hours. I have held *Pacifica* to please you, but our business here is done. If you have anything more to say, you can speak through your Foundation's Washington office."

Bahnz was obviously the type that got straight to the point, especially when he had had a bit to drink. He showed no trace of that irreverent streak I had known in the officers and officials of the early nineties. Those fellows had been almost like co-conspirators, helping nurture the Farm along in a time of tight budgets and dubious senators.

"Two hours, Colonel? Yes. That should be enough time. Just remind *Pacifica's* crew to check their inertial tracking units before drop-off. There may be a few acceleration anomalies."

Bahnz snorted. "So? You plan to fire up your famous aluminum engines to impress us? Big deal. Go ahead and use up your reserve water, Rutter. You've got enough oxidizer to run them for maybe two months; then you'll start flinging mass away to keep orbit."

Ishido started to rise. At a sharp look from me he subsided.

"Why, Colonel," I said smoothly. "You sound down-right happy over our predicament."

The crewcut officer slapped the oak table. "Damned straight! Let's lay it out, Rutter. I think you're a bunch of unpatriotic dreamers who'd do anything rather than serve your country. July's court judgment was the last straw.

"We're going to live up to the contract, all right. You'll get your tanks, and enough water to keep from making martyrs of you. But you'll start spending more mass to stay in orbit than you take in. Your profits will disappear. Then see how fast your investors force you out as director!

"Pretty soon, Rutter, *you'll* be buying Slingshot at a hundred clams a pint!" Bahnz emptied the squeeze bottle with a flourish.

I shrugged and turned back to my meal. The second worst thing you could do to a man like Bahnz was to ignore him. I intended to do the very worst thing within an hour and a half.

6.

The face on the screen was flushed and angry. In the dimness of Arnold Deck Control Room, I could tell the man was upset.

"What the *hell* do you think you're doing, Rutter?"

I had made *Pacifica* wait for fifteen minutes while the control crew made a show of looking for me, then appeared, to look back at Bahnz with an expression of beatific innocence.

"What seems to be the problem, Colonel?"

"You know damned well what the problem is!" the man shouted. "Colombo Station is under acceleration!"

"So? I told you over dinner to have your crew check their inertial units. You knew that meant we would be maneuvering."

"But you're thrusting at two *microgees*! Your aluminum engines can't push five thousand tons that hard!"

I shrugged.

"And anyway, we can't find your thrust exhaust! We look for a rocket trail, and find nothing but a slight electron cloud spreading from A Deck!"

"Nu?" I shrugged again. "Colonel, you force me to conclude that we are *not* using our aluminum engines. It is curious, no?"

Bahnz looked as if he wanted some nails to chew -- threepenny, at least. Behind him I could see the crew of *Pacifica*, crouched over their instruments in order to stay out of his way.

"Rutter, I don't know what you're up to, but we can see from here that your entire solar cell array has been turned sunward. You have no use for that kind of power! Are you going to tell me what's going on? Or do I come back up there and make myself insufferable until you do?"

My respect for Bahnz rose two notches. He might be an SOB, but he knew how to get his way. "Oh, there won't be any need for that." I laughed.

"You see, Colonel, we need all that solar power to drive our new motor."

"Motor? What motor?"

"The motor that's enabling us to raise our orbit without spending a bit of mass -- no oxygen, not even a shred of aluminum. It's the motor that's going to make it possible for us to pull a profit next year, Colonel, even under the terms of the present contract."

Bahnz stared at me. "A *motor*?"

"The biggest motor there is, my dear fellow. It's called the Earth."

He blinked, his mind obviously struggling to figure out what I meant.

"Have a good trip, Colonel," I said. "And any time you're in the neighborhood, do stop by for a Slingshot."

"Rutter!"

I turned away and launched myself toward the window at the far end of the control room.

"RUTTER!"

The voice faded behind me as I drifted up to the crystal port. Outside, the big, ugly tanks lay like roc eggs in a row, waiting to be hatched. I could almost envision it. They'd someday transform themselves into great birds of space. And our grandchildren would ride their offspring to the stars.

Bright silvery cables seemed to stretch all the way to the huge blue globe overhead. And I know, now, that they did indeed anchor us to the Earth ... an Earth that does not end at a surface of mountain and plain and water, nor with the ocean of air, but continues outward in strong fingers of force, caressing her children still.

Right now those tethers were carrying over a hundred amps of current from B Deck to A. There, electrons were sprayed out into space by an array of small, sharp cathodes.

We could have used the forward process to extract energy from our orbital momentum. I had told Emily Testa earlier today that that would solve nothing. Our problem was to *increase* our momentum.

Current in a wire, passing through a magnetic field ... You could run a dynamo that way,

or a *motor*. With more solar power than we'll ever need, we can shove the current through the cables *against* the electromotive force, feeding energy to the Earth, and to our orbit.

A solar-powered motor, turning once per orbit, our Tank Farm rises without shedding an ounce of precious mass.

I smiled as I looked out on the fleecy clouds of home and the tanks in a row, like presents waiting to be opened. I felt Susan come up beside me. "*Pacifica's* gone," she said, grinning. "And our acceleration's climbed to three microgees, Ralph."

I nodded. "Have Don ease back a bit for now. We don't want to push the motor too hard on its first day. I'll check in later."

"Where are you going?"

I caught a rung by the hatch. "I'm going to go unwind by spending some time puttering in my garden."

Susan shook her head and muttered "Yuck" under her breath.

I pretended I didn't hear.

THE END

AUTHOR'S NOTES

I have had the great privilege of working as postdoctoral fellow with Dr. James Arnold and the California Space Institute ... ecotopia's mini-micro version of the National Aeronautics and Space Administration. At Calspace we performed NASA-contracted studies of space station automation, space industrialization, and potential uses of tethers and external tanks.

Ironically, what we thought would be obvious -- the need to find ways to use external tanks in space -- has met with substantial resistance by the aero-space community. Tethers on the other hand, an idea we thought would be seen as "California freaky" have been taken up with enthusiasm as an important future component in space transportation.

Calspace's Joseph Carroll (one of the brightest fellows I know) has carried the work of the late Italian physicist Guiseppe Colombo into the field of tether dynamics. Experiments will be flown aboard the shuttle in the near future.

The technological fix has been a mainstay of science fiction since the "golden age" of the thirties. There is still room for fiction whose purpose is to elucidate some point of science. Often this can be done while still maintaining a mix of art, characterization, and drama, but for this propaganda piece, I make no such claim.

This story has been used widely to teach some principles of physics. It illustrates ideas of micro-gravity, orbital dynamics and the problems of life support in outer space.