Interconnections and Porous Boundaries

A novelette by Lance Robinson

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First published in *Analog Science Fiction & Fact*, May/June 2025.

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One

If I'm going to tell you what led us to the Declaration, I suppose I need to go back to Tony's goat. Because it's all connected—the economics and the politics and our artificial ecosystem. I mean each one depends on the other. And Tony's goat—that's when our cascade of crises began. Or, to be more precise, that's when we began to notice the cascade that was already underway.

I was barely six months into my new role as Chief of Operations for Samuel Adams Colony, and I was sitting with Maria, the head of asteroid mining operations, trying to figure out what to tell Corporate about us missing our production targets, when Tony P. called me. "I need you at the farm," he said. "It's an emergency." He wouldn't tell me what the problem was, but he insisted I needed to come. Maria was gracious about our meeting being cut short, but I'll tell you, by the time I made it a third of the way round the main hab wheel to the farm, I was seriously peeved. I had my own work to do, and it seemed to me that Tony, despite all his experience, refused to stand on his own two feet. He liked to turn every task into a project, or a reason for team meeting, or some other complicated web of human interaction. And I couldn't realistically avoid him. As CoO not only was I technically his boss, but I was also still head of BLS—bioregenerative life support. BLS and the farm depended on each other, and Tony always found reasons for "cross-team collaboration".

This time was different though: when I reached the farm and saw Doc there with him, I knew that whatever Tony had called me here for, it was actually serious. Before I had a chance to say anything, he pointed to a bed of what was supposed to be intercropped beans and upland rice. It was hard to even recognize the sorry

looking yellowish stalks as rice.

"We got a problem," Doc said.

"It's almost the whole the crop!" Tony blurted. "The soil nitrogen plummeted. I checked it before sowin' and it was fine, and that was less than three weeks ago. Diana, I never saw nothin' this fast before!"

I ran through a list of possibilities with him, but whether it was denitrification, volatilization, or deadlocking, they all pointed to something gone amok with the soil bacteria. This *was* serious, but the way they both looked at me made me think I was missing something.

"We're not going to starve," I said. "If worse comes to worst, we'll eat the dehydrated crap in the emergency stores. This is a problem for sure, but we'll figure it out."

Tony didn't answer; just motioned for us to follow, and he led us to the other side of the farm, to the pen. There lying motionless on its left side was a goat, its two right legs eerily rigid in the air, and froth around its mouth. Time stopped as the possibilities raced through my mind. Any pathogen that could kill a goat was at least a potential threat to humans, and just the idea of a lethal outbreak amongst ninety-one people trapped in a sealed bottle two hundred million kilometers from help is enough to give me nightmares. I was about to ask why the hell we weren't wearing masks and gloves, but then I saw the looks on their faces, and before I even formed a coherent thought about it I knew in my gut what had actually happened.

Then Tony said it. "It suddenly started havin' seizures or convulsions or whatever you call it and within two minutes it was dead."

I wanted one of them to tell me more, but they just stood there like they expected me to have an answer. "Was it just like what happened with Luis?" I asked.

"How the hell should I know?" Tony snapped. "I wasn't there when Luis died."

"Jesus Tony, I just—"

Doc, always the peacemaker, cut us off. "This is connected to the declining molybdenum levels in the soil," she said.

Five months earlier when Luis died, the first thing Doc looked for was an infectious pathogen of one sort or another, and she couldn't find one. She had also ruled out heavy metal toxicity. Back then, molybdenum deficiency wasn't yet on anyone's radar.

"My last two crops of cauliflower failed," Tony said. "Now the upland rice. It's connected."

Doc nodded. I guess they'd been listening to me all these months talking about the soil being the heart of our life support system, because they were seeing a connection between its sudden depletion, the wilted rice stalks, the rise of nitrogen in our atmosphere, and the deaths of Luis and now this goat.

"Molybdenum deficit is the common factor," Doc said. "It's one of the building blocks of our bodies' detoxification enzymes, so if someone lacks it… a build-up of sulfites in the brain, neurological damage… seizures…" She trailed off as she stared down at the dead animal, and then shuddered. "It fits. And the problem is, the crops that that *aren't* constrained by molybdenum and that still grow well—they aren't good dietary sources of it. We're already at the point of deficiency in some of the crew."

Tony gestured toward the dead animal. "And the livestock, too, apparently. So the question is, are we gonna end up like that Luis and this goat?"

I began to realize that this was just as frightening as an outbreak. Those of us who didn't succumb to a micronutrient deficiency that let our brains drown in its

own toxic waste could look forward to food production collapsing and our air going stale. What's the expression? "Space has a thousand ways to kill you"? Apparently, we discovered number one thousand and one.

"We'll tell Corporate to send us molybdenum supplements on the next cycler," Doc said. "And something for your soils too—concentrate to add to the compost maybe."

Unfortunately, we couldn't wait that long. Here, in the innermost part of the asteroid belt, we're totally dependent on the timing of the cyclers, which is totally dependent on our alignment with Earth once every seventeen and a half months. The cyclers are permanent habitats, arranged in their respective orbits so that one swings by us at each alignment. Between alignments, we're on our own. In fact, being on our own was one of the pillars of our mission: to demonstrate that we could be self-sustaining and independent. But that isolation was a problem for the deficiency of molybdenum in our bodies and our soils. I reminded Doc that Cycler Zheng He had already swung by Earth four weeks earlier, so anything we asked Corporate to send us would get loaded on the *next cycler*, in sixteen-and-a-half months. Then it would take another 357 days after that to reach us. For a moment, the three of us pondered our vulnerability and isolation.

Eventually I broke the silence. "So how do we get some molybdenum-rich foods for the crew?"

"We trade for it," Tony declared. "With Tianlu Colony or Sarabhai. I read that Tianlu is producin' a surplus of lentils."

The asteroids where Sam Adams and Tianlu had been established—Noëmi-Toyota J-14 and J-18—were a binary system, slowly orbiting each other about 300 kilometers apart, and Sarabhai Station was situated further out at a smaller asteroid that orbited the first two. Just as the three asteroids were all remnants of a failed protoplanet still wed to each other with feeble ties of gravity, the colonies that India,

China and the United States established here are remnants of the recently defunct age of international cooperation in space exploration. We were established separately so that each country could have a rock to call its own, but together in this gravitationally connected system so that we could all be served by the same quartet of cyclers linking us to Earth. So, yeah, Tony's idea made sense on one level: Tianlu was right next door. The problem, however, was that our survival depended as much on geopolitics as it did on ecology and micronutrients, and geopolitics were very different now than when the colonies had been established.

I shook my head. "If we do anything—" I said, "—*anything* that makes it look like we're helping Tianlu or Sarabhai Station, or that *we* need *them* to help *us*, Congress would end the little bit of support for us they haven't already cut."

Tony threw up his hands. "We got some things in excess. We've saved way more seeds than we need, and we got way more diversity in our crops than either of them. And I bet Tianlu could easily spare a few sacs of lentils for us."

I took a deep breath and tried to explain. "One of the three objectives in our contract from NASA is to develop a proof-of-concept, fully self-contained, artificial ecosystem. Seriously, some people in Washington already want to cut our funding. We can't afford to look like we're not making it, like we're not self-contained and that we're not self-sufficient."

"The three colonies were established on three mutually orbiting asteroids for a reason!"

"The way things are now, if we did that, if we even *ask* to do that, the optics in Houston and D.C. could kill us. And the fact that the other colonies are Chinese and Indian would make it even—"

"Sell it to them, Diana!" Doc gestured for us to calm down, but Tony kept going. "Emphasize our surplus of seeds. Tell them it's not about *depending* on them; tell them it's 'mutually beneficial trade'. Diana, we need—"

"Enough!" I locked my eyes on his to make sure he was ready to listen. "We're not making any such suggestion to Corporate. We need to solve this on our own."

He clenched his jaw, and for a moment I thought he was about to explode, but then he closed his eyes and turned away. After a few breaths, he looked at me again. "How?"

I already had an idea where the molybdenum was going. It's in soil and it's in our skin—just a few parts per million, but it's there. That means it's also in the dust in our air. For nine years, ever since we booted up the colony's artificial ecosystem, some of that dust has been settling in nooks and crannies out of reach. And since the airlocks never get pumped down to absolute vacuum, every time someone does an EVA we lose a bit of air. That air has a bit of dust, and that dust has a bit of molybdenum. So, some portion of it just blows out into space. On Earth, anywhere that weather touches rock, molybdenum and other trace minerals make their way into the soils. But here, this rock that Corporate picked for us to mine happens to have no molybdenum. All we've got is what gets brought here from Earth. I explained to Doc and Tony that if I could find, breed or engineer the right microorganism—one that likes molybdenum and sequesters it in its proteins—then I could use that as the basis for a bioreactive air filter. We could add whatever the filter trapped and digested to our compost, and the molybdenum would make its way back into the soil, and from there into our foods.

"By all means," Tony said, "prevent the leakage from our nutrient loops. But that won't replace what we already lost."

We talked it through and decided that Doc would select some dehydrated foods from the emergency stores: things like dried beans and powdered eggs that were decent sources of molybdenum. Tony would do a survey of any non-circulating biomass that might be sequestering molybdenum: twigs, stems, dead leaves or whatever else. And I would selectively breed a planctomycete bacteria to

use in a set of bioreactive air and water filters. We'd use the filters to capture it and inject it back into our biological loops.

Yeah, that was the plan. The reality turned out to be a bit messier: the web of interconnections that make up our bioregenerative life support system is complex enough to be unpredictable but not enough to ever be resilient. Everything is connected to everything else and everything depends on everything else. That was a lesson I was still learning.

Two

Four months later I had one of those "remember where you were" moments. I remember precisely when I heard the news from Earth. I was at Pond No. 2, just downstream from the farm—had been there all morning. The ecological duct tape we had applied to the BLS systems was starting to fail. For a while, our strategy—drawing on our emergency food stores, more aggressively composting unproductive biomass, and installing the new bioreactive filters—had been enough to keep our soils and livestock and people out of immediate danger. But no good deed goes unpunished. In the rainforest mod the new filters were not only capturing molybdenum from dust in the air, but were also trapping fungal spores. That was bad enough, but what was worse was that the planctomycete bacteria I used in the filters escaped and introduced themselves to algae, and the two got along quite nicely. In fact, they formed a microbial Bonnie and Clyde that soon covered our ponds and paddies with slimy films.

That's why I was at the pond. A warning buzzer woke me up at 5:30 a.m. telling me that dissolved oxygen in the pond had dropped dangerously low. When I got there, without even needing to search I saw three fish already belly-up. The symbiont scum looked no worse here than it did on any other of the ponds, paddies, or aquaculture tanks, but clearly it had been thriving enough to use up most of the

dissolved O_2 in this one. That in itself was scary: the other ponds might also be ready to crash without warning, and they were crucial to our water treatment and our nitrogen and phosphorous cycling, not to mention the fish that provided a good twenty-two percent of our protein. I saw a tilapia still alive and swimming—lethargically, but still swimming—so if I moved fast, the situation might not be a complete loss. So I tapped my device and told Assistant to call whoever from the BLS team was next on the duty roster, and then I went to get our portable aeration pump. When I got back, Jenny was already at the pond, crouched down beside it with some testing equipment. I remember thinking that if I had just picked someone from the team myself to come help, it wouldn't have been her.

"Water flow's been down lately," she said. "The crash in dissolved oxygen might be due to that in combination with the symbiont."

"Detective work later," I replied, taking the coiled hose off my shoulder and setting the pump at the edge of the pond. "We need to get this thing up and running *now*."

As I connected one end of the hose to the pump, Jenny connected the other end to the diffuser and tossed it into the water, not getting her feet wet. *She should know better*, I thought, and I jumped into the pond and picked it up, wading out to where the water was deeper. That's when I noticed the smell. Normally it was pleasant here, just a faint odor of algae, but now there was no mistaking that we were downstream from the farm. I waited there until Jenny powered up the pump and we saw the jet of bubbles begin, then I made my way back out of the water, scooping a dead fish from the pond on the way.

"What about Ponds 1 and 3?" she asked. "We don't have a backup for this pump, do we?"

"This pump *is* the backup. The aquaculture and hydroponic tanks and the rice farm all have built-in aerators—we have replacement parts for those. But for

the ponds…" I looked over where water from the upstream mod splashed over rocks as it entered the pond. "These little rapids and the mini waterfall at Pond 3 and the fountain at Pond 1 are supposed to be enough. What we're doing here is just a stopgap." This was all stuff that Jenny should have known, and I was annoyed that I had to explain it to her.

But her questions continued. "For an actual solution, what about the ice library? Do we have any rotifer species or protists or anything we could thaw that might graze on the symbiont?"

"The AI says our best candidate is a bacterivorous a ciliate: *Colpidium colpoda*. But I don't want to make the same mistake twice—the knock-on effects of adding *another* organism to the system would be unpredictable." I remembered back to my training before I got picked for the Samuel Adams crew. The artificial ecosystem here was precisely engineered; every organism down to the microbes had been carefully selected. "Unpredictable" was an understatement. "The real problem," I told Jenny, "is that we don't have a deep enough reservoir of diversity in our ecosystem. It's complex enough to be unpredictable, but—"

"But not complex enough to be resilient. I know."

"Really, our library of options needs to be ten times bigger than it is. For the longer term, we'll work with our support team earthside to identify a suite of additional species they can send us on ice on the next cycler."

"Cycler Zheng He?"

Does she really not have a clue how the cyclers work and where they are? I asked myself. "Zheng He's already half way here."

"Right, right. So Magellan's the next one after that, right? How long until it reaches us?"

"About two years."

It was bizarre that she didn't know this. Anyone else in the Colony could tell you off the top of their head. Our lives are entirely framed by our seventeen-and-a-half month synodic cycle with Earth. It dictates everything—the Hohmann transfer orbits, the arrival and departure of crew members—a short window that opens once every seventeen and a half months. We all know where the cyclers are in relation to us and the Earth the way you just know what month it is.

"Look Jenny," I said, "I need to figure out some other things here. Why don't you go have your breakfast and then go analyze these samples you collected?"

I was already wet, so I wanted to try some new solutions I'd been thinking about. And for this, Jenny wouldn't be much help. She was good at the computer simulations and the lab work, but not the practical stuff. Besides, she got on my nerves and I simply preferred working independently. She looked like she was about to say something, but then changed her mind. Then, as she was leaving, Hossain arrived.

"There you are!" He looked quizzically at my wet clothes but didn't let that slow him down. "We got a message from Corporate: they want an asynchronous meeting today to talk about the mining shortfall and how the Senate will react."

As much as our artificial ecosystem was in crisis, we were in just as much political danger. Back at Earth, America and China sent ten thousand troops to DRC and Angola respectively, ready to fight it out over some of the same precious metals that we were mining here. And here, one of our two tunnel boring machines snapped an axle. When it happened, the machine jerked hard and that caused the tunnel it was digging to partly collapse. It took Maria and her team a good three weeks to extract it. More importantly, we didn't have what we needed to repair it. We were set up to repair almost any kind of breakdown, but not that. Our mining output was seriously crustbuggered. Ore processing on the surface was unaffected, but for the real prize—the unbihexium—we had to dig. Losing one of the boring machines had cut our unbihexium production in half.

For a long time, unbihexium was purely hypothetical and thought to be something that might, one day, be created in a particle accelerator, perhaps a few atoms at a time. It's at the center of the so-called "island of stability", atomic number 126—a spot on the eighth row of the periodic table where it was theorized that a few elements might not be hopelessly unstable and radioactive. Then we discovered it here in our asteroid and it was no longer theoretical. Noëmi-Toyota J-14 is a piece of the core of a failed protoplanet, possibly the densest asteroid in the whole Belt, and along with iron, platinum, ruthenium, and few other things, it also has unbihexium. Some physicists think that even a few grams of the stuff, with its unique conductive and magnetic properties, could help them finally solve controlled nuclear fusion. And back at Earth the geopolitics these days are all about energy, so our parent corporation and the politicians in Washington who fund it really wanted our shipments of the stuff to keep flowing. And for a lot of them, having us here—human colonists trying to establish a foothold by nurturing a self-sustaining, self-contained ecosystem—was a distraction from the important work of digging for treasure. There was a contingent in Washington and even at our own HQ in Houston who were ready to completely automate the mining and order us all back home on the next cycler.

I closed my eyes, wishing my problems would take care of themselves. But no such luck: when I opened them again, Hossain was still standing there. "Fine. I'll get ready for the meeting when I'm done here."

As much as the problems with our artificial ecosystem were never-ending, I much preferred working on them over dealing with the management issues and the politics. Unfortunately, we still depended on support from Earth, and so the politics were as important to our survival as our ecosystem. I gave myself two more hours to work on the problem at the pond. First, I scavenged a mishmash of hand nets, mesh and fabric, a piece of PVC pipe, and I even pulled a square of sponge foam from a cushion—anything that might possibly allow me to filter, scrape or scoop the scum from the surface of the water. I brought it all back to the pond, jumped

back in the water and started experimenting. The problem wasn't just what the symbiont was doing to the ponds; it was that the planctomycete half of the symbiont was optimized for finding and latching onto molybdenum. When it did that in my bioreactive filters, that was perfect: we regularly emptied the sludge and mixed it into compost, tightening the feedback loop to keep the molybdenum circulating in our soils and our crops and our bodies. But if the molybdenum stayed trapped in scum floating on the ponds, we'd face a deficit again in no time.

Of course, we ecologists get suspicious of any suggestion to "tighten feedback loops". Eutrophication in lakes, mad cow disease, and stock market crashes are all caused by feedback loops that are too tight. But in Sam Adams Colony we didn't have enough slack in our molybdenum cycling (or our nitrogen cycling or phosphorous cycling or any other cycling for that matter)—we didn't have enough slack that we could afford to let crucial elements just linger in pond scum. Besides, the prospect of another crew member dying like Luis, with toxins accumulating in the brain until seizures killed them, was not something I could let happen. So I kept tightening the feedback loops. And now our bioregenerative life support system, though still keeping us alive, was full of teetering instabilities. To save the ponds and to get at the elements that the scum was locking up, I needed to find a way to collect it and recycle it. So for the next hour, I experimented with every way of scooping, skimming and sucking the surface of the pond I could think of.

Then Lorenzo showed up, and I mean, seriously, he was pissed. Though the ponds were the responsibility of BLS, fish production belonged to Lorenzo's aquaculture team. "Why didn't you call me?" he demanded.

"Because it wasn't even six a.m. Besides, there was nothing for you to do: it only took Jenny and me a few minutes to set up the aerator. In fact, I didn't even need Jenny, really."

He made a sound that was halfway between a laugh and a harrumph, then folded his arms and glared down at me up to my thighs in the slimy water. "The

fact that you think that—that's what the real problem is. When Carmine was CoO, he never tried to do everything himself. He delegated mining tasks to his mining team and delegated management tasks to other members of the management team. He shared the problems with us. And when he had big issues to deal with, he took them to the colony council, and when he had a bad day he went and poured his heart out to Maria."

Lorenzo comparing me to the previous CoO hurt. Carmine was amazing. He inspired all of us and he cultivated a powerful collective spirit. That wasn't something I knew how to do.

"Yeah, Carmine was a better leader than me. You think I don't know that?"

"Don't twist my words, Diana. The problem is, you're acting like you're an island, and it's affecting you. And *that* affects us. We're all connected, but you seem to have lost sight of that."

Yeah, he said that—sound familiar? I told you, that day seared itself into my memory, including every word Lorenzo said. Some of those words eventually made their way into the Declaration.

He also said, "The way you're treating people, Diana—it isn't you." He didn't wait for me to respond, just whirled and strode away. That was probably for the best, because I'm sure I would have said something ugly. But he was right. I didn't fully appreciate that right at that moment, but I was starting to. I remember standing there alone in the muck and asking myself if *I* had anyone to go pour my heart out to. The answer to that had just walked away. During the year-long journey from Earth on the cycler and then for the whole of the next synodic cycle—seventeen and a half months—Lorenzo had been the one I opened up to, shared my feelings with, and vented to. We'd been an item for a while, but eventually we both realized that what brought us together wasn't sex or romance but friendship and respect. But in the eleven months since I became CoO, I hadn't made any time for

the friendship.

At that moment at the pond, I pushed all that out of my mind, and turned my attention back to the symbiont. After another hour, I concluded that physical control would never work. The only option would be biological control, but taking another species from the ice library and adding it to our ecosystem would be risky. We didn't have a comfortably diverse arsenal of options to deal with whatever curve ball our ecosystem might throw at us next. I began to think I would also need to dust off Tony's idea of trading with Tianlu and Sarabhai—if we treated the three of our colonies as a pooled set of biological resources, then maybe that could give us additional tools to deal with the inevitable surprises. I would need to think carefully about how to phrase my pitch and how to prevent the backlash that would come from some quarters in D.C., but we were at the stage where we had little choice.

But as you know, events overtook us and I never got the chance. You see, if you want to understand what led to the Declaration, you need to understand this: in any complicated system, you have a boundary separating what *is* part of the system from what *isn't*. But in a truly complex system, that boundary is always a little bit porous: species leave an ecosystem, and new species enter it; carbon dioxide and pheromones leave your body, and oxygen and pathogens enter it. Or, in our case, precious metals like rhodium and unbihexium leave our system, and politics from Earth enter it. As I packed up the nets and the rest of the junk I'd been using, Hossain came back, this time with Maria in tow. He stood there and stared at me, catching his breath, and his face had an expression I couldn't decipher. That's what I remember most about that morning: his expression. I remember it all—the pissy smell of the pond, the sound of the aerator, my regret at realizing I had shut Lorenzo out of my life—but what I remember most was Hossain's expression.

"Tell her," Maria said.

Hossain nodded. "Right. Uhh… we received a Level Three confidential

message." That explained why he brought Maria: the three of us were the only ones authorized for Level Three. "The message also referred us to this morning's news media squirt."

He stopped, as if not wanting to give me some very bad news. The first thing I thought of was Cycler Alpha—the cycler that was carrying Carmine and fourteen other former crew members on the passage back to Earth—that something had happened to it. That was my first thought, but it wasn't that.

"Two ships," Maria said, "one American and one Chinese. They collided in the South China Sea."

Hossain looked over his shoulder to be sure no one else was in the mod with us. "Corporate says that we're to cease all communication with the Chinese and Indian colonies."

"Jeez," I said, "isn't Corporate overreacting? We're two hundred million kilometers from the South China Sea—what's this gotta do with us?"

The way Hossain looked at me, that's when I finally read his expression, and it sent a chill through me. He couldn't find the words he was looking for so he turned to Maria.

"Diana," she said. "It was two *naval* vessels that collided. War ships. We're on the brink of nuclear war."

Three

The Declaration—I know—I'm getting there. After the symbiont established itself, we kept our ponds alive, moving the aerator from pond to pond, and within three weeks of releasing the bacterivore from the ice library, it brought the symbiont under control, more or less. It was still there in our ecosystem, but at least now it

had a predator to keep it in check. And then we experienced one of those periods of illusory balance you sometimes get from complex systems, and it lasted for nearly three months. I mean, things were still breaking down and falling apart, but it was all very gradual. Back at Earth, I guess the geopolitics did kind of the same thing: neither side launched any nukes yet, but with new proxy wars in South America and Africa, cyber-attacks, and arrests of each other's citizens, it was World War 2.9. And as far as I could tell from two hundred million kilometers away, our governments thought 2.9 wasn't quite high enough—they were still finding ways to get a little closer to the line.

As for us, although the ciliate from the ice library kept the symbiont mostly in check and stabilized the dissolved oxygen levels in the ponds, it and the symbiont together were gradually sequestering oxygen from our system as a whole. And they weren't the only ones: since propagation of fungi was also down, it meant that every bit of undecomposed biomass was locking up essential elements. Oxygen and carbon, instead of cycling back into the atmosphere where the humans and our livestock and the plants could breathe them, and nitrogen and phosphorous instead of cycling back into soil where roots could absorb them—they were lurking in dead twigs and leaves and rootlets and pond scum. Our ecosystem's dominos had started to topple and our life support was on life support.

One of the scariest dominos was the rice-fish system—a neat arrangement in which carp swim in the rice paddies, their waste fertilizing the mud, which in turn helped the rice. When it collapsed, it collapsed all at once: rice turning yellow and wilting, fish dying, and cloudy, smelly water draining down into Ponds 2 and 3. Photosynthesis in Pond 3 ground to a halt, and that was the straw that broke the camel's back for our oxygen recycling: for the first time in years, we needed to add bottled O_2 to our atmosphere. And we were nearly back to square one on molybdenum. Not only that, but those ponds with their plants and freshwater zooplankton and microbes were crucial to our water purification, and now they were overwhelmed. That's what I was busy with on the day of the accident at Tianlu

Colony. I was tracing the water flow, step by step, from the rice-fish paddies downstream to Pond 2, collecting samples at each stage along the way, and hoping to focus on one crisis at a time. But when Tony P. startled me as I bent over the pond, I just knew it wasn't going to be that kind of day.

"The ag team and researchers at Madison," he said, "we modeled some new options for the rice-fish systems and the vegetables." I took a deep breath, then looked back down at my sample bottles as he talked. "We'll need seeds to be sent out to us, but we've identified varieties that'll be more robust to fluctuations in CO_2."

I added the latest sample bottle to the basket of others I'd collected, then stood up and turned to face him. "Great," I said dryly. "If they don't start a nuclear war between now and then, we'll tell them to put your new seeds in our next shipment—they'll reach us one year and nine months from now."

"Jesus, Diana! I know it doesn't help us now. The point is, this is evidence that we can still be viable. If we can just keep the rice-fish systems alive, we can convince Corporate that—"

Behind him I saw Hossain, who had just come into the mod, his device in his hand. Thank God. I interrupted Tony. "Hossain, what did Corporate say about us losing the second boring machine?"

"They still haven't figured out a way for our printers to produce an axle—whatever we might try to make here ourselves wouldn't be strong enough. The replacements need to be sent from Earth."

"Maria already told us that's what they'd say." I picked up the basket and motioned for Hossain and Tony to follow me. "The wars are disrupting the supply of rare earth elements, so what we're supplying has become more valuable. What'd they say about that?"

I started walking, leading them toward the adjacent mod, which held the bioreactor room and in terms of water flow was downstream from the pond. With the ponds not able to clean the water coming down from the farm, the bioreactors downstream were now receiving stuff they weren't equipped to deal with. I would need to rig up some new solutions to at least ensure we had drinking water.

Hossain looked down at his device as we walked. "They said—let me see—here it is: 'The total loss of subsurface mining will be devastating in the next round of the Senate Committee's self-sufficiency assessment.'"

I lurched to a stop and slammed my hand against the doorway of the bioreactor room. They still had us chasing the rainbow of self-sufficiency and independence. I had enough of a crisis on my hands already, trying to save our artificial ecosystem and with it our whole BLS system. The problem was, I was still the CoO: I also needed to save our mining production targets, *and* our political alliances in Houston and Washington, *and* our crew morale. And working alone in peace on any one of those problems was clearly not going to happen today, because at that moment Maria, Doc and Lorenzo stepped into the bioreactor room with us.

"Hossain, anything else?"

"Yeah. Something's going on at Tianlu. There was an encrypted message from Security. They have information that there was an accident or some kind of 'incident' on Tianlu. But the Chinese haven't said anything publicly."

"Have you tried to contact Tianlu?" Maria asked.

"No," he answered. "The message from Security also said, 'Restrictions on communication remain in place!' In fact, it was all caps: 'Restrictions on communication remain in place!'"

I told Hossain to let me know the moment he learned anything else, then as he left, I turned to Maria. Tony, who'd been waiting patiently, was not impressed.

"I was here first!"

Lorenzo rolled his eyes. "The rice-fish systems are already dead; the ponds aren't!" Apparently he and Tony had already been exchanging words.

Tony lowered his voice and tried to calm himself down. "We need to be smart about this." Then he turned back to me. "This is what I was tryin' to tell you. If I can turn things around in the next few weeks, I can to prove to Corporate that the farm is still viable."

"What you need to do…" Doc said, looking to Tony then Lorenzo then back to Tony again, "What *both* of you need to do is also think about the effect your bickering is having on the rest of the crew."

"The built-in aerator for the rice-fish tanks needs maintenance," Tony complained. "I just want the ponds to share a bit of time from the portable."

"We can't do that," Jenny called out from behind the others. I hadn't even seen her come in. "We need the aerator for the ponds full-time again or they *will* collapse—the food webs, dissolved oxygen, fish production, all of it." Then she slipped between Doc and Lorenzo and spoke directly to me. "Two rotifer species and one copepod have died out. As far as I can tell, they've gone extinct from our systems. The current nutrient pathway is about to fail and the simulations say none of the alternatives we've thought up will work. But, we might be able to keep the fish alive if—"

"There, you see?" said Lorenzo. "We need the aerator—"

"Didn't you hear her," said Tony. "The ponds are failin' anyway."

Suddenly, Hossain was back, pushing his way forward to reach me. "We received a direct message from Tianlu Colony."

Tony protested at being interrupted again and Lorenzo began shouting at

him. As Doc pleaded with them to calm down, I focused on Hossain.

"They think they were struck by several meteorites. It caused an explosion in their ore processing facility and a spill. Carbon tetrachloride."

Maria gasped, having turned her attention from Tony and Lorenzo. "They use carbon tetrachloride for ruthenium processing," she said, "It's extremely toxic."

"Hepatoxic," Doc said. "Affects the blood and liver. Depending on how much their people breathed, they'd be looking at acute liver failure in the short term or cancer in the medium term."

"They also had a hull breach in an adjacent part of the colony," Hossain added, "and haven't been able to seal it. They evacuated that section and sealed it off. They isolated other parts of the colony from each other but not before fumes from the spill spread. They're trying to flush the air in the worst sections, but a proper clean-up to make it safe will take weeks or months."

"Will they evacuate back to Earth?" someone asked.

"The cycler and the next departure window are still three and half months away," said Hossain. "Keeping their whole crew sealed in the less contaminated sections until then isn't feasible. They're asking for our help."

For our collapsing ecosystem, for our imploding crew morale, and for the nearly total shutdown of mining production—for all of that, there was no obvious path forward, no simple solution. In fact, I suspected that in fifteen weeks' time when the cycler reached us we'd be forced to evac the colony and head back home. Not even for *one* of our problems did I know what to do. Oh, I was trying—attempting solutions, taking steps—like I was expected to do. But it's not that I *knew* what to do, or knew whether any of it was going to work.

But this was different. I thought about Carmine and how he led when he was CoO. I thought about the Tianlu crew members I spent a year with on the cycler on

our journey out to the Belt. I thought about our fragility in these outposts and how much we rely on each other for our survival. And I thought about you and the connection we still have even though we're two hundred million kilometers apart.

I called out, loud so everyone in the mod could hear. "Everyone except Lorenzo, Hossain and Maria, get out!"

There was some hesitation, but then Jenny yelled in a voice that shocked the hell out of me—equally as loud and twice as decisive as anything I could muster, and in a tone that invited no questions. "You heard her. Give the CoO some space!"

Everyone else filed out, Jenny going last and closing the hatch behind her, and then I asked, "What's the transmission time to Earth right now?"

"At the moment, we're about sixteen light minutes from Earth," Hossain answered. "So thirty-two minutes round trip communication time."

"The U.S. government considers Tianlu a military installation, and a third of their crew are technically military even if they're scientists and engineers. And we're practically at war with China. If we try to ask permission to help them, or even just to communicate directly with them, Corporate will need to contact NASA or the Pentagon or someone. It'll take way longer than thirty-two minutes for us to get an answer."

Lorenzo nodded. "If they even say 'yes'."

"We're also designated a 'strategic asset'," Hossain added. "So they won't be eager to have us bring Chinese nationals and Chinese military officers inside with us."

"Surely they'd see this is an emergency," Maria protested.

Lorenzo bobbed his head as he thought about it, and Hossain shrugged. "Maybe eventually," I said. "Maybe."

"That's why you sent everyone else out," Lorenzo realized. "If we reply to Tianlu without clearance, if we go help them, or we bring their crew here without getting permission first—if we do all that but without telling the crew that we haven't cleared it with Houston, the crew won't be faulted. The four of us would be the only ones to face repercussions."

"In fact," I said, "I'm hoping it'll only be me. But yeah, that's why I sent the others out. If we help Tianlu, the crew don't need to know that we're doing it without clearance from Houston. But for you three it's different—I need to know if you're on board with this."

"Heavens!" Maria said. "Of course. Stop wasting time."

Hossain shrugged. Not an "I don't know" shrug, but a "Why are you even asking?" shrug.

Lorenzo put his hand on my shoulder and looked me in the eye. "The three of us *might* get some kind of punishment. But you're right: if there's gonna be *serious* repercussions, they'll be for you. Hell, they might even send you to prison."

He wasn't trying to talk me out of it; he was just making sure I had both eyes open. And I could see that I didn't need to tell him the reason we needed to do this—that they're human beings, that they were in trouble, and that we're all connected. He knew all that. Instead, I gave him hug. Then we and the rest of the Sam Adams crew went into high gear rescuing the people from Tianlu.

Four

Downstream from the farm are the ponds, downstream from the ponds is the bioreactor mod, and downstream from the bioreactor mod is the living area. But go downstream from the living area and you'll get back to the farm. Samuel Adams is a circle, and everything is downstream from everything else. It's all connected. So

maybe it's fitting that I was back at the farm when I learned something important. Once again, Tony called me to come; there was something I needed to see.

If it was some minor BLS issue that affected the farm, he was supposed to contact Jenny. Six weeks earlier, right after we completed the evacuation of the Tianlu crew to Sam Adams, I transferred leadership of BLS to Jenny so I could give more time to the management issues. And there were plenty of management issues to deal with now that with the addition of the Tianlu refugees, our population had jumped by a good fifty percent. Besides, although Corporate hadn't yet fired me for ordering the Tianlu rescue without clearance from Houston, there was a good chance they still would, because if they were going to do it, they would wait until about a week before the cycler arrived and then tell me I needed to be on it. I wanted Jenny to get some experience leading the BLS team while I was still here to answer any questions.

Stepping away from most of my BLS duties left me free to focus on the joyful tasks of budget projections, work schedules, and collating data for annual reports to NASA, to HQ, and to three or four different Senate and Congressional committees. It was driving me mental. So Tony's message for me to come provided a welcome excuse to get up from my desk. On the other hand, the last time Tony called me to the farm it was because something frightening was happening, so you'll forgive me if on the way there I imagined a dozen different disasters that might be underway. Then when I reached the farm mod, there with him I saw Jenny and Lingyun, who'd been head of food production at Tianlu, and I knew that whatever Tony had called me here for, it was serious. The three of them just stared at me, waiting.

"Molybdenum levels in the soil?" I asked when none of them spoke up.

Jenny squinted as if she didn't understand the question, and Tony chuckled. "That's not why we called you," he said, "but since you asked, they're still good. The boost we got from the food Lingyun and his people brought from Tianlu is still

circulatin' in our systems."

"Why'd you call me then?"

He waved for me to follow and led me across the mod to one of the rice-fish tanks, Jenny and Lingyun close behind. The young rice stalks appeared green and healthy, and poked a couple of centimeters above the water level, young carp meandered in and out among the rice, and the water was clear. Again, the three of them just stood there looking at me, as if waiting for me to see something.

Finally, Jenny spoke up. "The planctomycete-algae symbiont numbers are up a little. But it mostly clings to the waterline around the edge of the tank, and it's not harming the rice—the colpidium bacterivore we got from the ice library still keeps it in check. But here's the thing: now another organism's keeping the colpidium in check." She turned and led me to a work bench at the end of the tank, where she had set up the stereomicroscope from our lab. With a maximum magnification of only 40x, it wasn't helpful for looking at the really small stuff, but it was perfect for examining wee beasties that were a bit too small for the naked eye to see. I bent over and took a look.

"Is that a rotifer?" I asked.

Lingyun answered. "*Asplanchna sinae*. Miss Jenny tells me you didn't used to have this in your systems, so it seems we accidentally brought it with us when you rescued us."

I straightened up. "So we have a new invasive species?"

"Diana!" Tony said, starting to laugh. "It's helping!"

"It's true," Jenny said. "The ponds and aquaculture tanks are as healthy as they've been in months. The dissolved oxygen is good and I even packed away the portable aerator. And across our whole ecosystem, the flux rates for both carbon and phosphorus have improved—they're not being sequestered anymore."

"Molybdenum flux rate?" I asked.

"It's up nine milligrams per day compared to two months ago," she said, grinning.

"Chief Diana," Lingyun said, "we are very sorry for bringing this invasive rotifer into your colony. But it is unlikely to get out of control—your juvenile tilapia and carp will see to that. In fact, the growth rate of your fish will probably go up."

I took a moment to think through what they were telling me, and to consider what other knock-on effects might result. Our artificial ecosystem was still facing other problems that this wouldn't solve, but it definitely seemed like a positive development.

"This might be one of those cases where an invasive species is beneficial," Jenny mused.

"What this is really a case of," I said, "is us finally cracking open our lid and allowing in some help from outside. We've been trying to be a hermetically sealed terrarium—completely independent—and that was never gonna work. We need our interdependencies."

And that gave me an idea. "Lingyun, where is your commander right now?"

Forty-five minutes later, I and the rest of the management team were sitting with Zhou Míngzé the Tianlu Colony commander, and three of his top people. I laid out my idea. Some of our key mining equipment was mothballed, waiting for spare parts from Earth, but not all of it; and Tianlu Colony had lost some of their equipment in the accident, but not all of it. I looked Commander Zhou in the eye. "We need each other."

"Are you saying you want to do—what do you call it in English?—horse trading? I don't think that can work. If we give you what you need to get your mining operational again, we won't have what *we* need. And vice versa."

"No," I said, "not horse trading. I'm suggesting that we pool our resources, here at the J-14 asteroid. And it's not just that we need each other; we should be *depending* on each other. And as much as we still need Earth for our survival, they need us too. Our countries are still on the verge of full scale war over precious metals that we have here."

"You're saying we would mine Noëmi-Toyota J-14 together, and the ore we get will go back to both China and America?"

"Yes."

"The rhodium?"

"Yes."

"The ruthenium?"

"Yes." He stared at me, maybe trying to gauge if I was lying or perhaps deluded. I answered his next question without waiting for him ask it. "And the unbihexium."

I knew there would be political opposition. Hawks in DC would spin this as us giving away our strategic advantage by giving the Chinese access to unbihexium. Never mind that with our mining operation crippled, we didn't have access to it either: for some hardliners, leaving it locked inside the asteroid would be better than letting the Chinese have any, especially if sharing it meant working together side by side with them. But the way I see it is like this:

We need each other. Samuel Adams and Tianlu need each other. And we need Earth. And just as we depend on Earth, we need to help you realize that you should also depend on us. We're all connected, and we all need each other.

I also knew—we all knew—that if we were going to make this arrangement fly in Houston and Washington, and in Beijing, we would need to help people see

our interdependence. That would require something big; it would require something inspirational. So we put our heads together, and by the time we were done, we had a plan far better than the vague notion I had started with. As we got the mining up and running again, back in Houston and Beijing they knew something was happening, but they didn't find out what we were really doing until we announced it, two months later. We waited until the Chinese and American freighter rockets left on the year-long journey back to Earth, loaded up not only with the stuff you were fighting over in Congo and Venezuela and Kazakhstan, but also with nearly two kilograms of unbihexium. That's where the idea for the Declaration came from: it was us trying to explain to people back home what we're trying to do here—what it really means. That's what you saw in our transmission when Zhou Míngzé and I sat side beside each other in front of the camera and read the document that people are now calling the Declaration of Interdependence.

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