CHAPTER 18

LOG ENTRY: SOL 197

Sigh…

Just once I'd like something to go as planned, ya know?

Mars keeps trying to kill me.

Well…Mars didn't electrocute *Pathfinder*. So I'll amend that:

Mars and my stupidity keep trying to kill me.

Okay, enough self-pity. I'm not doomed. Things will just be harder than planned. I have all I need to survive. And *Hermes* is still on the way.

I spelled out a Morse code message using rocks. "PF FRIED WITH 9 AMPS. DEAD FOREVER. PLAN UNCHANGED. WILL GET TO MAV."

If I can get to the Ares 4 MAV, I'll be set. But having lost contact with NASA, I have to design my own Great Martian Winnebago to get there.

For the time being, I've stopped all work on it. I don't want to continue without a plan. I'm sure NASA had all kinds of ideas, but now I have to come up with one on my own.

As I mentioned, the Big Three (atmospheric regulator, oxygenator, and water reclaimer) are critical components. I worked around them for my trip to *Pathfinder*. I used CO_2 filters to regulate the atmosphere, and brought enough oxygen and water for the whole trip. That won't work this time. I need the Big Three.

Problem is, they soak up a lot of power, and they have to run all day long. The rover batteries have 18 kilowatt-hours of juice. The oxygenator *alone* uses 44.1 kilowatt-hours per sol. See my problem?

You know what? “Kilowatt-hours per sol” is a pain in the ass to say. I’m gonna invent a new scientific unit name. One kilowatt-hour per sol is…it can be anything…um…I suck at this…I’ll call it a “pirate-ninja.”

All told, the Big Three need 69.2 pirate-ninjas, most of that going to the oxygenator and the atmospheric regulator. (The water reclaimer only needs 3.6 of that.)

There’ll be cutbacks.

The easiest cutback is the water reclaimer. I have 620 liters of water (I had a lot more before the Hab blew up). I need only three liters of water per sol, so my supply will last 206 sols. There’s only 100 sols after I leave and before I’m picked up (or die in the attempt).

Conclusion: I don’t need the water reclaimer at all. I’ll drink as needed and dump my waste outdoors. Yeah, that’s right, Mars, I’m gonna piss and shit on you. That’s what you get for trying to kill me all the time.

There. I saved myself 3.6 pirate-ninjas.

LOG ENTRY: SOL 198

I’ve had a breakthrough with the oxygenator!

I spent most of the day looking at the specs. It heats CO_2 to 900°C, then passes it over a zirconia electrolysis cell to yank the carbon atoms off. Heating the gas is what takes most of the energy. Why is that important? Because I’m just one guy and the oxygenator was made for six. One-sixth the quantity of CO_2 means one-sixth the energy to heat it.

The *spec* says it draws 44.1 pirate-ninjas, but all this time it’s only been using 7.35 because of the reduced load. Now we’re getting somewhere!

Then there’s the matter of the atmospheric regulator. The regulator samples the air, figures out what’s wrong with it, and corrects the problem. Too much CO_2? Take it out. Not enough

O_2? Add some. Without it, the oxygenator is worthless. The CO_2 needs to be separated in order to be processed.

The regulator analyzes the air with spectroscopy, then separates the gasses by supercooling them. Different elements turn to liquid at different temperatures. On Earth, supercooling this much air would take ridiculous amounts of energy. But (as I'm acutely aware) this isn't Earth.

Here on Mars, supercooling is done by pumping air to a component outside the Hab. The air quickly cools to the outdoor temperature, which ranges from −150°C to 0°C. When it's warm, additional refrigeration is used, but cold days can turn air to liquid for free. The real energy cost comes from heating it back up. If it came back to the Hab unheated, I'd freeze to death.

"But wait!" You're thinking, "Mars's atmosphere isn't liquid. Why does the Hab's air condense?"

The Hab's atmosphere is over 100 times as dense, so it turns to liquid at much higher temperatures. The regulator gets the best of both worlds. Literally. Side note: Mars's atmosphere *does* condense at the poles. In fact, it solidifies into dry ice.

Problem: The regulator takes 21.5 pirate-ninjas. Even adding some of the Hab's power cells would barely power the regulator for a sol, let alone give me enough juice to drive.

More thinking is required.

LOG ENTRY: SOL 199

I've got it. I know how to power the oxygenator and atmospheric regulator.

The problem with small pressure vessels is CO_2 toxicity. You can have all the oxygen in the world, but once the CO_2 gets above 1 percent, you'll start to get drowsy. At 2 percent, it's like being drunk. At 5 percent, it's hard to stay conscious. Eight percent will eventually kill you. Staying alive isn't about oxygen, it's about getting rid of CO_2.

That means I need the regulator. But I don't need the oxygenator all the time. I just need to get CO_2 out of the air and back-fill with oxygen. I have 50 liters of liquid oxygen in two 25-liter tanks here in the Hab. That's 50,000 liters in gaseous form, enough to last 85 days. Not enough to see me through to rescue, but a hell of a lot.

The regulator can separate the CO_2 and store it in a tank, and it can add oxygen to my air from my oxygen tanks as needed. When I run low on oxygen, I can camp out for a day and use *all* my power to run the oxygenator on the stored CO_2. That way, the oxygenator's power consumption doesn't eat up my driving juice.

So I'll run the regulator all the time, but only run the oxygenator on days I dedicate to using it.

Now, on to the next problem. After the regulator freezes the CO_2 out, the oxygen and nitrogen are still gasses, but they're −75°C. If the regulator fed that back to my air without reheating it, I'd be a Popsicle within hours. Most of the regulator's power goes to heating the return air so that doesn't happen.

But I have a better way to heat it up. Something NASA wouldn't consider on their most homicidal day.

The RTG!

Yes, the RTG. You may remember it from my exciting trip to *Pathfinder*. A lovely lump of plutonium so radioactive it gives off 1500 watts of heat, which it uses to harvest 100 watts of electricity. So what happens to the other 1400 watts? It gets radiated out as heat.

On the trip to *Pathfinder*, I had to actually remove insulation from the rover to vent excess heat from the damn thing. I'll be taping that back in place because I'll need that heat to warm up the return air from the regulator.

I ran the numbers. The regulator uses 790 watts to constantly reheat air. The RTG's 1400 watts is more than equal

to the task, as well as keeping the rover a reasonable temperature.

To test, I shut down the heaters in the regulator and noted its power consumption. After a few minutes, I turned them right back on again. Jesus Christ that return air was cold. But I got the data I wanted.

With heating, the regulator needs 21.5 pirate-ninjas. Without it…(drumroll) 1 pirate-ninja. That's right, almost *all* of the power was going to heat.

As with most of life's problems, this one can be solved by a box of *pure radiation*.

I spent the rest of the day double-checking my numbers and running more tests. It all checks out. I can do this.

LOG ENTRY: SOL 200

I hauled rocks today.

I needed to know what kind of power efficiency the rover/trailer will get. On the way to *Pathfinder*, I got 80 kilometers from 18 kilowatt-hours. This time, the load will be a lot heavier. I'll be towing the trailer and all the other shit.

I backed the rover up to the trailer and attached the tow clamps. Easy enough.

The trailer has been depressurized for some time now (there's a couple of hundred little holes in it, after all), so I opened both airlock doors to have a straight shot at the interior. Then I threw a bunch of rocks in.

I had to guess at the weight. The heaviest thing I'll bring with me is the water. 620 kilograms' worth. My freeze-dried potatoes will add another 200 kilograms. I'll probably have more solar cells than before, and maybe a battery from the Hab. Plus the atmospheric regulator and oxygenator, of course. Rather than weigh all that shit, I took a guess and called it 1200 kilograms.

Half a cubic meter of basalt weighs about that much (more or less). After two hours of brutal labor, during which I whined a lot, I got it all loaded in.

Then, with both batteries fully charged, I drove circles around the Hab until I drained them both.

With a blistering top speed of 25 kph, it's not an action-packed thrill ride. But I was impressed it could maintain that speed with all the extra weight. The rover has spectacular torque.

But physical law is a pushy little shit, and it exacted revenge for the additional weight. I only got 57 kilometers before I was out of juice.

That was 57 kilometers on level ground, without having to power the regulator (which won't take much with the heater off). Call it 50 kilometers per day to be safe. At that rate it would take 64 days to get to Schiaparelli.

But that's just the travel time.

Every now and then, I'll need to break for a day and let the oxygenator use all the power. How often? After a bunch of math I worked out that my 18-pirate-ninja budget can power the oxygenator enough to make about 2.5 sols of O_2. I'd have to stop every two to three sols to reclaim oxygen. My sixty-four-sol trip would become ninety-two!

That's too long. I'll tear my own head off if I have to live in the rover that long.

Anyway, I'm exhausted from lifting rocks and whining about lifting rocks. I think I pulled something in my back. Gonna take it easy the rest of today.

LOG ENTRY: SOL 201

Yeah, I definitely pulled something in my back. I woke up in agony.

So I took a break from rover planning. Instead, I spent the day taking drugs and playing with radiation.

First, I loaded up on Vicodin for my back. Hooray for Beck's medical supplies!

Then I drove out to the RTG. It was right where I left it, in a hole four kilometers away. Only an idiot would keep that thing near the Hab. So anyway, I brought it back to the Hab.

Either it'll kill me or it won't. A lot of work went into making sure it doesn't break. If I can't trust NASA, who can I trust? (For now I'll forget that NASA told us to bury it far away.)

I stored it on the roof of the rover for the trip back. That puppy really spews heat.

I have some flexible plastic tubing intended for minor water reclaimer repairs. After bringing the RTG into the Hab, I *very carefully* glued some tubing around the heat baffles. Using a funnel made from a piece of paper, I ran water through the tubing, letting it drain into a sample container.

Sure enough, the water heated up. That's not really a surprise, but it's nice to see thermodynamics being well behaved.

There's one tricky bit: The atmospheric regulator doesn't run constantly. The freeze-separation speed is driven by the weather outside. So the returning frigid air doesn't come as a steady flow. And the RTG generates a constant, predictable heat. It can't "ramp up" its output.

So I'll heat water with the RTG to create a heat reservoir, then I'll make the return air bubble through it. That way I don't have to worry about when the air comes in. And I won't have to deal with sudden temperature changes in the rover.

When the Vicodin wore off, my back hurt even more than before. I'm going to need to take it easy. I can't just pop pills forever. So I'm taking a few days off from heavy labor. To that end, I made a little invention just for me.…

I took Johanssen's cot and cut out the hammock. Then I draped spare Hab canvas over the frame, making a pit inside the cot, with extra canvas around the edges. Once I weighed

down the excess canvas with rocks, I had a water-tight bathtub!

It only took 100 liters to fill the shallow tub.

Then, I stole the pump from the water reclaimer. (I can go quite a while without the water reclaimer operating.) I hooked it up to my RTG water heater and put both the input and output lines into the tub.

Yes, I know this is ridiculous, but I hadn't had a bath since Earth, and my back hurts. Besides, I'm going to spend 100 sols with the RTG anyway. A few more won't hurt. That's my bullshit rationalization and I'm sticking with it.

It took two hours to heat the water to 37°C. Once it did, I shut off the pump and got in. Oh man! All I can say is "Ahhhhhh."

Why the *hell* didn't I think of this before?

LOG ENTRY: SOL 207

I spent the last week recovering from back problems. The pain wasn't bad, but there aren't any chiropractors on Mars, so I wasn't taking chances.

I took hot baths twice a day, lay in my bunk a lot, and watched shitty seventies TV. I've already seen Lewis's entire collection, but I didn't have much else to do. I was reduced to watching reruns.

I got a lot of thinking done.

I can make everything better by having more solar panels. The fourteen panels I took to *Pathfinder* provided the 18 kilowatt-hours that the batteries could store. When traveling, I stowed the panels on the roof. The trailer gives me room to store another seven (half of its roof will be missing because of the hole I'm cutting in it).

This trip's power needs will be driven by the oxygenator. It all comes down to how much power I can give that greedy little bastard in a single sol. I want to minimize how often I

have days with no travel. The more juice I can give the oxygenator, the more oxygen it'll liberate, and the longer I can go between those "air sols."

Let's get greedy. Let's say I can find a home for fourteen more panels instead of seven. Not sure how to do that, but let's say I can. That would give me thirty-six pirate-ninjas to work with, which would net me five sols of oxygen per air sol. I'd only have to stop once per five sols. That's much more reasonable.

Plus, if I can arrange battery storage for the extra power, I could drive 100 kilometers per sol! Easier said than done, though. That extra 18 kilowatt-hours of storage will be tough. I'll have to take two of the Hab's 9-kilowatt-hour fuel cells and load them onto the rover or trailer. They aren't like the rover's batteries; they're not small or portable. They're light enough, but they're pretty big. I may have to attach them to the outside hull, and that would eat into my solar cell storage.

One hundred kilometers per sol is pretty optimistic. But let's say I could make 90 kilometers per sol, stopping every fifth sol to reclaim oxygen. I'd get there in forty-five sols. That would be sweet!

In other news, it occurred to me that NASA is probably shitting bricks. They're watching me with satellites and haven't seen me come out of the Hab for six days. With my back better, it was time to drop them a line.

I headed out for an EVA. This time, being very careful while lugging rocks around, I spelled out a Morse code message: "INJURED BACK. BETTER NOW. CONTINUING ROVER MODS."

That was enough physical labor for today. I don't want to overdo it.

Think I'll have a bath.

LOG ENTRY: SOL 208

Today, it was time to experiment with the panels.

First, I put the Hab on low-power mode: no internal lights, all nonessential systems offline, all internal heating suspended. I'd be outside most of the day anyway.

Then I detached twenty-eight panels from the solar farm and dragged them to the rover. I spent four hours stacking them this way and that. The poor rover looked like the Beverly Hillbillies truck. Nothing I did worked.

The only way to get all twenty-eight on the roof was to make stacks so high they'd fall off the first time I turned. If I lashed them together, they'd fall off as a unit. If I found a way to attach them perfectly to the rover, the rover would tip. I didn't even bother to test. It was obvious by looking, and I didn't want to break anything.

I haven't removed the chunk of hull from the trailer yet. Half the holes are drilled, but I'm not committed to anything. If I left it in place, I could have four stacks of seven cells. That would work fine; it's just two rovers' worth of what I did for the trip to *Pathfinder*.

Problem is I need that opening. The regulator has to be in the pressurized area and it's too big to fit in the unmodified rover. Plus which, the oxygenator needs to be in a pressurized area while operating. I'll only need it every five sols, but what would I do on that sol? No, the hole has to be there.

As it is, I'll be able to stow twenty-one panels. I need homes for the other seven. There's only one place they can go: the sides of the rover and trailer.

One of my earlier modifications was "saddlebags" draped over the rover. One side held the extra battery (stolen from what is now the trailer), while the other side was full of rocks as counterweight.

I won't need the bags this time around. I can return the second battery to the trailer from whence it came. In fact, it'll save me the hassle of the mid-drive EVA I had to do every day to swap cables. When the rovers are linked up, they share resources, including electricity.

I went ahead and reinstalled the trailer's battery. It took me two hours, but it's out of the way now. I removed the saddlebags and set them aside. They may be handy down the line. If I've learned one thing from my stay at Club Mars, it's that *everything* can be useful.

I had liberated the sides of the rover and the trailer. After staring at them for a while, I had my solution.

I'll make L-brackets that stick out from the undercarriages, with the hooks facing up. Two brackets per side to make a shelf. I can set panels on the shelves and lean them against the rover. Then I'll lash them to the hull with homemade rope.

There'll be four "shelves" total; two on the rover and two on the trailer. If the brackets stick out far enough to accommodate two panels, I could store eight additional panels that way. That would give me one more panel than I'd even planned for.

I'll make those brackets and install them tomorrow. I would have done it today, but it got dark and I got lazy.

LOG ENTRY: SOL 209

Cold night last night. The solar cells were still detached from the farm, so I had to leave the Hab in low-power mode. I did turn the heat back on (I'm not insane), but I set the internal temperature to 1°C to conserve power. Waking up to frigid weather felt surprisingly nostalgic. I grew up in Chicago, after all.

But nostalgia only lasts so long. I vowed to complete the brackets today, so I can return the panels to the farm. Then I can turn the damn heat back on.

I headed out to the MAV's landing strut array to scavenge metal for the shelves. Most of the MAV is made from composite, but the struts had to absorb the shock of landing. Metal was the way to go.

I brought a strut into the Hab to save myself the hassle of working in an EVA suit. It was a triangular lattice of metal strips held together with bolts. I disassembled it.

Shaping the brackets involved a hammer and…well, that's it, actually. Making an L doesn't take a lot of precision.

I needed holes where the bolts would pass through. Fortunately, my *Pathfinder*-murdering drill made short work of that task.

I was worried it would be hard to attach the brackets to the rover's undercarriage, but it ended up being simple. The undercarriage comes right off. After some drilling and bolting, I got the brackets attached to it and then mounted it back on the rover. I repeated the process for the trailer. Important note—the undercarriage is not part of the pressure vessel. The holes I drilled won't let my air out.

I tested the brackets by hitting them with rocks. This kind of sophistication is what we interplanetary scientists are known for.

After convincing myself the brackets wouldn't break at the first sign of use, I tested the new arrangement. Two stacks of seven solar cells on the roof of the rover; another seven on the trailer, then two per shelf. They all fit.

After lashing the cells in place, I took a little drive. I did some basic acceleration and deceleration, turned in increasingly tight circles, and even did a power-stop. The cells didn't budge.

Twenty-eight solar cells, baby! And room for one extra!

After some well-earned fist-pumping, I unloaded the cells and dragged them back to the farm. No Chicago morning for me tomorrow.

LOG ENTRY: SOL 211

I am smiling a great smile. The smile of a man who fucked with his car and *didn't break it*.

I spent today removing unnecessary crap from the rover and trailer. I was pretty damn aggressive about it, too. Space inside the pressure vessels is at a premium. The more crap I clear out

of the rover, the more space there is for me. The more crap I clear out of the trailer, the more supplies I can store in it, and the less I have to store in the rover.

First off: Each vehicle had a bench for passengers. Bye!

Next: There's no reason for the trailer to have life support. The oxygen tanks, nitrogen tanks, CO_2 filter assembly…all unnecessary. It'll be sharing air with the rover (which has its own copy of each of those), and it'll be carrying the regulator and oxygenator. Between the Hab components and the rover, I'll have two redundant life support systems. That's plenty.

Then I yanked the driver's seat and control panel out of the trailer. The linkup with the rover is physical. The trailer doesn't do anything but get dragged along and fed air. It doesn't need controls or brains. However, I did salvage its computer. It's small and light, so I'll bring it with me. If something goes wrong with the rover's computer en route, I'll have a spare.

The trailer had tons more space now. It was time for experimentation.

The Hab has twelve 9-kilowatt-hour batteries. They're bulky and awkward. Over two meters tall, a half meter wide, and three-quarters of a meter thick. Making them bigger makes them take less mass per kilowatt hour of storage. Yeah, it's counterintuitive. But once NASA figured out they could increase volume to decrease mass, they were all over it. Mass is the expensive part about sending things to Mars.

I detached two of them. As long as I return them before the end of the day, things should be fine. The Hab mostly uses the batteries at night.

With both of the trailer's airlock doors open I was able to get the first battery in. After playing real-life Tetris for a while I found a way to get the first battery out of the way enough to let the second battery in. Together, they eat up the whole front half of the trailer. If I hadn't cleared the useless shit out earlier today, I'd never have gotten them both in.

The trailer's battery is in the undercarriage, but the main power line runs through the pressure vessel, so I was able to wire the Hab batteries directly in (no small feat in the damn EVA suit).

A system check from the rover showed I had done the wiring correctly.

This may all seem minor, but it's awesome. It means I can have twenty-nine solar cells and 36 kilowatt-hours of storage. I'll be able to do my 100 kilometers per day after all.

Four days out of five, anyway.

According to my calendar, the *Hermes* resupply probe is being launched from China in two days (if there were no delays). If that screws up, the whole crew will be in deep shit. I'm more nervous about that than anything else.

I've been in mortal danger for months; I'm kind of used to it now. But I'm nervous again. Dying would suck, but my crewmates dying would be way worse. And I won't find out how the launch went till I get to Schiaparelli.

Good luck, guys.