Chapter 1

LOG ENTRY: SOL 6

I'm pretty much screwed.

That's my considered opinion.

Screwed.

Six days in to what should be a greatest two months of my life, and it's turned in to a nightmare.

I don't even know who'll read this. I guess someone will find it eventually. Maybe a hundred years from now.

For the record… I didn't die on Sol 6. Certainly the rest of the crew thought I did, and I can't blame them. Maybe there'll be a day of national mourning for me, and my Wikipedia page will say "Mark Watney is the only human being to have died on Mars."

And it'll be right, probably. Cause I'll surely die here. Just not on Sol 6 when everyone thinks I did.

Let's see… where do I begin?

The Ares program. Mankind reaching out to Mars to send people to another planet for the very first time and expand the horizons of humanity blah, blah, blah. The Ares 1 crew did their thing and came back heroes. They got the parades and fame and love of the world.

Ares 2 did the same thing, in a different location on Mars. They got a firm handshake and a hot cup of coffee when they got home.

Ares 3. Well. That was my mission. Well, not *mine* per se. Commander Lewis was in charge. I was just one of her crew. Actually, I was the very lowest ranked member of the crew. I would only be "in command" of the mission if I were the only remaining person.

What do you know? I'm in command.

I wonder if this log will be recovered before the rest of the crew die of old age? I presume they got back to Earth all right. Well, guys, if you're reading this: It wasn't your fault. You did what you had to do. In your position I would have done the same thing. I don't blame you, and I'm

glad you survived.

I guess I should explain how Mars missions work, for any layman who may be reading this. We got to earth orbit the normal way, through an ordinary ship to Hermes. All the Ares missions use Hermes to get to and from Mars. It's really big and cost a lot so NASA only built one.

Once we got to Hermes, four additional unmanned missions brought us fuel and supplies while we prepared for our trip. Once everything was a go, we set out for Mars. But not very fast. Gone are the days of heavy chemical fuel burns and trans-Mars injection orbits.

Hermes is powered by ion engines. They throw Argon out the back of the ship really fast to get a tiny amount of acceleration. The thing is, it doesn't take much reactant mass, so a little Argon (and a nuclear reactor to power things) let us accelerate constantly the whole way there. You'd be amazed at how fast you can get going with a tiny acceleration over a long time.

I could regale you with tales of how we had great fun on the trip, but I won't. We did have fun, but I don't feel like reliving it right now. Suffice it to say we got to Mars 124 days later without strangling each other.

From there, we took the MDV (Mars Descent Vehicle) to the surface. The MDV is basically a big can with some light thrusters and parachutes attached. Its sole purpose is to get six humans from Mars orbit to the surface without killing any of them.

And now we come to the real trick of Mars exploration: Having all our shit there in advance.

A total of 14 unmanned missions deposited everything we would need for surface operations. They tried their best to land all the supply vessels in the same general area, and did a reasonably good job. Supplies aren't nearly so fragile as humans and can hit the ground really hard. But they tended to bounce around a lot.

Naturally, they didn't send us to Mars until they'd confirmed all the supplies had made it to the surface and their containers weren't breached. Start to finish, including supply missions, a Mars mission takes about 3 years. In fact, there were Ares 3 supplies en route to Mars while the Ares

2 crew were on their way home.

The most important piece of the advance supplies, of course, was the MAV. The "Mars Ascent Vehicle." That was how we would get back to Hermes after surface operations were complete. The MAV was soft-landed (as opposed to the balloon bounce-fest the other supplies had). Of course, it was in constant communication with Houston, and if there were any problems with it, we would pass by Mars and go back to Earth without ever landing.

The MAV is pretty cool. Turns out, through a neat set of chemical reactions with the Martian atmosphere, for every kilogram of hydrogen you bring to Mars, you can make 13 kilograms of fuel. It's a slow process, though. It takes 24 months to fill the tank. That's why they sent it long before we got here.

You can imagine how disappointed I was when I discovered the MAV was gone.

It was a ridiculous sequence of events that led to me almost dying. Then an even more ridiculous sequence that led to me surviving.

The mission is designed to handle sandstorm gusts up to 150 km/hr. So Houston got understandably nervous when we got whacked with 175 km/hr winds. We all got in our suits and huddled in the middle of the Hab, just in case it lost pressure. But the Hab wasn't the problem.

The MAV is a spaceship. It has a lot of delicate parts. It can put up with storms to a certain extent but it can't just get sandblasted forever. After an hour and a half of sustained wind, NASA gave the order to abort. Nobody wanted to stop a month-long mission after only six days but if the MAV took any more punishment we'd all get stranded down here.

We had to go out in the storm to get from the Hab to the MAV. That was going to be risky, but what choice did we have?

Everyone made it but me.

Our main communications dish, which relayed signals from the Hab to Hermes, acted like a parachute, getting torn from its foundation and carried with the torrent. Along the way, it crashed through the reception antenna array. Then one of those long thin antennae slammed in to me

end first. It tore through my suit like a bullet through butter and I felt the worst pain of my life as it ripped open my side. I vaguely remember suddenly having the wind knocked out of me (pulled out of me, really) and my ears popping painfully as the pressure of my suit escaped.

The last thing I remember was seeing Johanssen hopelessly reaching out toward me.

I awoke to the oxygen alarm in my suit. A steady, obnoxious beeping that eventually roused me from a deep and profound desire to just .... die.

The storm had abated; I was face down, almost totally buried in sand. As I groggily came to, I wondered why I wasn't more dead.

The antenna had enough force to punch through the suit and my side, but then it got stopped by my pelvis. So there was only one hole in the suit (and a hole in me, of course).

I had been knocked back quite a ways and rolled down a steep hill. Somehow I landed face down, which forced the antenna to a strongly oblique angle that put a lot of torque on the hole in the suit. It made a weak seal.

Then, the copious blood from my wound trickled down toward the hole. As the blood reached the site of the breach, the water in it quickly evaporated from the airflow and low pressure, leaving only a gunky residue behind. More blood came in behind it and was also reduced to gunk. Eventually, the blood sealed the gaps around the hole and reduced the leak to something the suit could counteract.

The suit did its job admirably. Seeing the drop in pressure, it constantly flooded itself with air from my nitrogen tank to equalize. Once the leak became manageable, it only had to trickle new air in slowly the relieve the air lost.

After a while, the CO2 (carbon dioxide) absorbers in the suit were expended. That's really the limiting factor to life support. Not the amount of oxygen you bring with you, but the amount of CO2 you can remove. In the Hab, we had the Oxygenator, a large piece of equipment that could break CO2 apart and give the oxygen back. But the spacesuits

had to be portable, so they used a simple chemical absorption process with expendable filters. I'd been asleep long enough that my filters were useless.

The suit saw this problem and moved in to an emergency mode the engineers call "bloodletting". Having no way to separate out the CO2, the suit deliberately vented air to the Martian atmosphere, then back-filled with nitrogen. Between the breach and the bloodletting, it quickly ran out of nitrogen. All it had left was my oxygen tank.

So it did the only thing it could to keep me alive. It started back-filling with pure oxygen. I now risked dying from oxygen toxicity, as the excessively high amount of oxygen threatened to burn up my nervous system, lungs, and eyes. An ironic death for someone with a leaky space suit: too much oxygen.

Every step of the way would have had beeping alarms, alerts, and warnings. But it was the high-oxygen warning that woke me.

The sheer volume of training for a space mission is astounding. I spent a week back on Earth practicing emergency space suit drills. I knew what to do.

Carefully reaching to the side of my helmet, I got the breach kit. It's nothing more than a funnel with a valve at the small end, and an unbelievably sticky resin on the wide end. The idea is you have the valve open and stick the wide end over a hole. The air can escape through the valve, so it doesn't interfere with the resin making a good seal. Then you close the valve and you've sealed the breach.

The tricky part was getting the antenna out of the way. I pulled it out as fast as I could, wincing as the sudden pressure drop dizzied me and made the wound in my side scream in agony.

I got the breach kit over the hole and sealed it. It held. The suit back-filled the missing air with yet more oxygen. Checking my arm readouts, I saw the suit was now at 85% oxygen. For reference, Earth's atmosphere is about 21%. I'd be ok, so long as I didn't spend too much time like that.

I stumbled up the hill back toward the Hab. As I crested the rise, I saw something that made me very happy and something that made me very

sad: The Hab was in-tact (yay!) and the MAV was gone (boo!).

Right that moment I knew I was screwed. But I didn't want to just die out on the surface. I limped back to the Hab and fumbled my way in to an airlock. As soon as it equalized, I threw off my helmet.

Entering the Hab, I doffed the suit and got my first good look at the injury. It would need stitches. Fortunately, all of us had been trained in basic medical procedures, and the Hab had excellent medical supplies. A quick shot of local anesthetic, irrigate the wound, 9 stitches and I was done. I'd be taking antibiotics for a couple of weeks, but other than that I'd be fine.

I knew it was hopeless, but I tried firing up the communication array. No signal, of course. The primary satellite dish had broken off, remember? And it took the reception antennae with it. The Hab had secondary and tertiary communication systems, but they were both just for talking to the MAV, which would use its much more powerful systems to relay to Hermes. Thing is, that only works if the MAV is still around.

I had no way to talk to Hermes. In time, I could locate the dish out on the surface, but it would take weeks for me to rig up any repairs, and that would be too late. In an abort, Hermes would leave orbit within 24 hours. The orbital dynamics made the trip safer and shorter the earlier you left, so why wait for no reason just to make the trip take longer?

Checking out my suit, I saw the antenna had plowed through my bio-monitor computer. When on an EVA, all the crew's suits are networked so we can see each others status. The rest of the crew would have seen the pressure in my suit drop to nearly 0, followed immediately by my bio-signs going flat. Add to that I was sent tumbling down a hill with a spear through me in the middle of a sandstorm… yeah. They thought I was dead. How could they not?

They may have even had a brief discussion about recovering my body, but regulations were clear. In the event a crewman died on Mars, he stayed on Mars. Leaving his body behind reduced weight for the MAV on the trip back. That meant more disposable fuel and a larger margin of error for the return thrust. No point in giving that up for sentimentality.

So that's the situation. I'm stranded on Mars. I have no way to communicate with Hermes or Earth. Everyone thinks I'm dead. I'm in a Hab designed to last 31 days.

If the Oxygenator breaks down, I'll suffocate. If the Water Reclaimer breaks down, I'll die of thirst. If the Hab breaches, I'll just kind of explode. If none of those things happen, I'll eventually run out of food and starve to death.

So yeah. I'm .....

earth, so NASA picked them as the test subjects.

So I have two problems: not enough dirt, and nothing edible to plant in it.

But I'm a botanist, damn it. I should be able to find a way to make this happen. If I don't, I'll be a really hungry botanist in about a year.

LOG ENTRY: SOL 11

I wonder how the Cubs are doing.

LOG ENTRY: SOL 14

I got my undergrad degree at the University of Chicago. Half the people who studied botany were hippies who thought they could return to some natural world system. Somehow feeding 7 billion people through pure gathering. They spent most of their time working out better ways to grow pot. I didn't like them. I've always been in it for the science, not for any New World Order bullshit.

When they made compost heaps and tried to conserve every little ounce of living matter, I laughed at them. "Look at the silly hippies!" I would scoff. "Look at their pathetic attempts to simulate a complex global ecosystem in their back yard."

Of course now I'm doing exactly that. I'm saving every scrap of biomatter I can find. Every time I finish a meal, the leftovers go to the compost bucket. As for other biological material…

The Hab has sophisticated toilets. Shit is usually vaccum-dried, then accumulated in sealed bags to be discarded on the surface.

Not any more!

In fact, I even did an EVA to recover the previous bags of shit from before the crew left. Being completely desiccated, this particular shit didn't have bacteria in it anymore, but it still had complex proteins and would serve as useful manure. Adding it to water and active bacteria

would quickly get it inundated, replacing any population killed by the Toilet Of Doom.

I found a big container and filled it with a bit of water, then added the dried shit. Since then, I've added my own shit to it as well. The worse it smells, the more successful things are going. That's the bacteria at work!

Once I get some Martian soil in here, I can mix in the shit and spread it out. Then I can sprinkle the Earth soil on top. You might not think that would be an important step, but it is. There are dozens of species of bacteria living in Earth soil, and they're critical to plant growth. They'll spread out and breed like... well, like a bacterial infection..

Within a week, the Martian soil will be ready for plants to germinate in. But I won't plant yet. I'll spread it out over a doubled area. It'll "infect" the new Martian soil. After another week, I'll double it again. And so on. Of course, all the while, I'll be adding all new manure to the effort.

My asshole is doing as much to keep me alive as my brain.

This isn't a new concept I just came up with. People have speculated on how to make crop soil out of Martian dirt for decades. I'll just be putting it to the test for the first time.

I searched through the food supplies and found all sorts of things that I can plant. Peas, for instance. Plenty of beans, too. I also found several potatoes. If *any* of them can still germinate after their ordeal, that'll be great. With a nearly infinite supply of vitamins, all I need are calories of any kind to survive.

The total floor-space of the Hab is about 92 square meters. I plan to dedicate all of it to this endeavor. I don't mind walking on dirt. It'll be a lot of work, but I'm going to need to cover the entire floor to a depth of 10 cm. That means I'll have to transport 9.2 cubic meters of Martian soil in to the Hab. I can get maybe 1/10th of a cubic meter in through the airlock at a time, and it'll be backbreaking work to collect it. But in the end, if everything goes to plan, I'll have 92 square meters of croppable soil.

Hell yeah I'm a botanist! Fear my botany powers!

Venkat watched from the observation booth. “Why ask the Timekeeper?” he mumbled. “It's on the huge mission clock in the center screen.”

“He's nervous,” Annie said. “You don't often see it, but that's what Mitch Henderson looks like when he's nervous. He double and triple checks everything.”

“Fair enough,” Venkat said.

“They're camping out on the lawn, by the way,” Annie said. “Reporters from all over the world. Our press rooms just don't have enough space.”

“The media loves a drama,” he sighed. “It'll be over tomorrow, one way or another.”

“What's our role in all this?” Annie said. “If something goes wrong, what can Mission Control do?”

“Nothing,” Venkat said. “Not a damned thing.”

“Nothing?”

“It's all happening 12 light-minutes away. That means it takes 24 minutes for them to get the answer to any question they ask. The whole launch is 12 minutes long. They're on their own.”

“Oh,” Annie said. “So we're just observers in all this?”

“Yes,” Venkat said. “Sucks, doesn't it?”

LOG ENTRY: SOL 549

I'd be lying if I said I wasn't shitting myself. In 4 hours, I'm going to ride a giant explosion into orbit. This is something I've done a few times before, but never with a jury-rigged mess like this.

Right now, I'm sitting in the MAV. I'm suited up because there's a big hole in the front of the ship where the window and part of the hull used to be. I'm “awaiting launch instructions.” Really, I'm just awaiting launch. I don't have any part in this. I'm just going to sit in the acceleration couch and hope for the best.

Last night, I ate my final meal pack. It's the first good meal I've had

in weeks. I'm leaving 41 potatoes behind. That's how close I came to starvation.

I carefully collected samples from my entire journey. But I can't bring any of them with me. So I put them in a container a few hundred meters from here. Maybe some day they'll send a probe to collect them. May as well make them easy to pick up.

This is it. There's nothing after this. There isn't even an abort procedure. Why make one? We can't delay the launch. Hermes can't stop and wait. No matter what, we're launching on schedule.

I face the very real possibility that I'll die today. Can't say I like it. It wouldn't be so bad if the MAV blew up. I wouldn't know what hit me.

If I miss the intercept I'll just float around in space until I run out of air. I have a contingency plan for that. I'll drop the oxygen mixture to zero and breathe pure nitrogen until I suffocate. It wouldn't feel bad. The lungs don't have the ability to sense lack of oxygen. I'd just get tired, fall asleep, then die.

I've had my last Martian potato. I've slept in the rover for the last time. I've had my last EVA on the surface. I'm leaving Mars today, one way or another.

About .... time.

Mars is the fourth planet from the Sun and the second-smallest planet in the Solar System after Mercury. In English, Mars carries a name of the Roman god of war, and is often referred to as the "Red Planet" because the iron oxide prevalent on its surface gives it a reddish appearancethat is distinctive among the astronomical bodies visible to the naked eye. Mars is a terrestrial planet with a thin atmosphere, having surface features reminiscent both of the impact craters of the Moon and the valleys, deserts, and polar ice caps of Earth. The days and seasons are likewise comparable to those of Earth, because the rotational period as well as the tilt of the rotational axis relative to the ecliptic plane are very similar. Mars is the site of Olympus Mons, the largest volcano and second-highest known mountain in the Solar System, and of Valles Marineris, one of the largest canyons in the Solar System. The smooth Borealis basin in the northern hemisphere covers 40% of the planet and may be a giant impact feature. Mars has two moons, Phobos and Deimos, which are small and irregularly shaped. These may be captured asteroids, similar to 5261 Eureka, a Mars trojan. There are ongoing investigations assessing the past habitability potential of Mars, as well as the possibility of extant life. Future astrobiology missions are planned, including the Mars 2020 and ExoMars rovers. Liquid water cannot exist on the surface of Mars due to low atmospheric pressure, which is less than 1% of the Earth's, except at the lowest elevations for short periods. The two polar ice caps appear to be made largely of water. The volume of water ice in the south polar ice cap, if melted, would be sufficient to cover the entire planetary surface to a depth of 11 meters (36 ft). In November 2016, NASA reported finding a large amount of underground ice in the Utopia Planitia region of Mars. The volume of water detected has been estimated to be equivalent to the volume of water in Lake Superior.

Mars can easily be seen from Earth with the naked eye, as can its reddish coloring. Its apparent magnitude reaches −2.94, which is surpassed only by Jupiter, Venus, the Moon, and the Sun. Optical ground-based telescopes are typically limited to resolving features about 300 kilometers (190 mi) across when Earth and Mars are closest because of Earth's atmosphere.

1. Cheapest: Hilled Rows
Dig straight, shallow trenches, 2 to 3 feet apart, in prepared soil. Plant seed potatoes 12 inches apart and cover with about 3 inches of soil. When the shoots reach 10 to 12 inches tall, use a hoe or shovel to scoop soil from between rows and mound it against the plants, burying the stems halfway. Repeat as needed through the growing season to keep the tubers covered.
Unlike container gardening, there's nothing to buy or build and no soil to transport. This is a simple, inexpensive, and proven method that farmers have used for millennia. It's practical for large-scale plantings, also.

2. Least Digging: Straw Mulch
Place seed potatoes on the surface of prepared soil following the spacing specified for hilled rows and cover them with 3 to 4 inches of loose, seed-free straw. Mound more straw around the stems as they grow, eventually creating a layer of one foot or more in depth.
The benefit here is that the thick mulch conserves soil moisture and smothers weeds. Harvest is effortless with no digging, and this method is suggested as a way to thwart the Colorado potato beetle. However, this produced a smaller yield than the hilled row and field mice have been known to use eat the crops under the cover of the straw.

3. Biggest Yield: Raised Beds
Loosen the soil in the bottom of a half-filled raised bed. Space seed potatoes about 12 inches apart in all directions and bury them 3 inches deep. As the potatoes grow, add more soil until the bed is filled. If possible, simplify harvest by removing the sides.
This method yielded the largest harvest in my trials, and the potatoes were uniformly large in size. Raised beds are a good choice where the garden soil is heavy and poorly drained.
The downside: The soil to fill the bed has to come from somewhere — and it takes a lot.

6. Easiest Harvest: Grow Bags
Commercial growing bags are made with heavy, dense polypropylene. Put a few inches of a soil-compost mixture in the bottom of a bag, then plant three or four seed potato pieces and cover with 3 inches of soil. Continue adding soil as the plants grow until the bag is full. To harvest, turn the bag on its side and dump out the contents.
Grow bags can go on patios or driveways or where garden soil lacks nutrients. The bags should last for several growing seasons. Their dark color captures solar heat to speed early growth. Harvest is simple and the yield can be impressive, considering the small space each bag occupies. However, this can be a pricey technique. The brand of bag I used costs $12.95.

Newton's Scholium (explanatory comment) to this law:

Whatever draws or presses another is as much drawn or pressed by that other. If you press a stone with your finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse (if I may so say) will be equally drawn back towards the stone: for the distended rope, by the same endeavour to relax or unbend itself, will draw the horse as much towards the stone, as it does the stone towards the horse, and will obstruct the progress of the one as much as it advances that of the other. If a body impinges upon another, and by its force changes the motion of the other, that body also (because of the equality of the mutual pressure) will undergo an equal change, in its own motion, toward the contrary part. The changes made by these actions are equal, not in the velocities but in the motions of the bodies; that is to say, if the bodies are not hindered by any other impediments. For, as the motions are equally changed, the changes of the velocities made toward contrary parts are reciprocally proportional to the bodies. This law takes place also in attractions, as will be proved in the next scholium.

Check Your Understanding

1. While driving down the road, a firefly strikes the windshield of a bus and makes a quite obvious mess in front of the face of the driver. This is a clear case of Newton's third law of motion. The firefly hit the bus and the bus hits the firefly. Which of the two forces is greater: the force on the firefly or the force on the bus?

Trick Question! Each force is the same size. For every action, there is an equal ... (equal!). The fact that the firefly splatters only means that with its smaller mass, it is less able to withstand the larger acceleration resulting from the interaction. Besides, fireflies have guts and bug guts have a tendency to be splatterable. Windshields don't have guts. There you have it.

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