

And then I'll have a boring conversation with NASA. Well, the content may be interesting, but the fourteen-minute transmission time between here and Earth will be a bit dull.

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[13:07] HOUSTON: Congratulations from all of us here at Mission Control! Well done! What's your status?

[13:21] MAV: Thanks! No health or physical problems. The rover and trailer are getting pretty worn out, but still functional. Oxygenator and regulator both working fine. I didn't bring the water reclaimer. Just brought the water. Plenty of potatoes left. I'm good to last till 549.

[13:36] HOUSTON: Glad to hear it. Hermes is still on track for a Sol 549 flyby. As you know, the MAV will need to lose some weight to make the intercept. We're going to get you those procedures within the day. How much water do you have? What did you do with urine?

[13:50] MAV: I have 550 liters of remaining water. I've been dumping urine outside along the way.

[14:05] HOUSTON: Preserve all water. Don't do any more urine dumps. Store it somewhere. Turn the rover's radio on and leave it on. We can contact it through the MAV.

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#### LOG ENTRY: SOL 505

I finally made it! I'm at the MAV!

Well, right this second, I'm back in the rover. I did go into the MAV to do a systems check and boot-up. I had to keep my EVA suit on the whole time because there's no life support in there just yet.

It's going through a self-check right now, and I'm feeding it oxygen and nitrogen with hoses from the rover. This is all part of the MAV's design. It doesn't bring air along. Why would it? That's a needless weight when you'll have a Hab full of air right next door.

I'm guessing folks at NASA are popping champagne right now and sending me lots of messages. I'll read them in a bit. First things first: Get the MAV some life support. Then I'll be able to work inside comfortably.

BRUCE TRUDGED into Venkat's office and unceremoniously plopped down in a chair. He dropped his briefcase and let his arms hang limp.

"Have a good flight?" Venkat asked.

"I only have a passing memory of what sleep is," Bruce said.

"So is it ready?" Venkat asked.

"Yes, it's ready. But you're not going to like it."  
"Go on."

Bruce steeled himself and stood, picking up his briefcase. He pulled a booklet from it. "Bear in mind, this is the end result of thousands of hours of work, testing, and lateral thinking by all the best guys at JPL."

"I'm sure it was hard to trim down a ship that's already designed to be as light as possible," Venkat said.

Bruce slid the booklet across the desk to Venkat. "The problem is the intercept velocity. The MAV is designed to get to low Mars orbit, which only requires 4.1 kps. But the *Hermes* flyby will be at 5.8 kps."

Venkat flipped through the pages. "Care to summarize?"

"First, we're going to add fuel. The MAV makes its own fuel from the Martian atmosphere, but it's limited by how much hydrogen it has. It brought enough to make 19,397 kilograms of fuel, as it was designed to do. If we can give it more hydrogen, it can make more."

"How much more?"

"For every kilogram of hydrogen, it can make thirteen kilograms of fuel. Watney has five hundred and fifty liters of water. We'll have him electrolyze it to get sixty kilograms of hydrogen." Bruce reached over the desk and flipped a few

pages, pointing to a diagram. "The fuel plant can make seven hundred and eighty kilograms of fuel from that."

"If he electrolyzes his water, what'll he drink?"  
"He only needs fifty liters for the time he has left. And a human body only borrows water. We'll have him electrolyze his urine, too. We need all the hydrogen we can get our hands on."

"I see. And what does seven hundred and eighty kilograms of fuel buy us?" Venkat asked.

"It buys us 300 kilograms of payload. It's all about fuel versus payload. The MAV's launch weight is over 12,600 kilograms. Even with the bonus fuel, we'll need to get that down to 7,300 kilograms. So the rest of this booklet is how to remove over 5,000 kilograms from the ship."

Venkat leaned back. "Walk me through it."

Bruce pulled another copy of the booklet from his briefcase. "There were some gimmes right off the bat. The design presumes five hundred kilograms of Martian soil and rock samples. Obviously we won't do that. Also, there's just one passenger instead of six. That saves five hundred kilograms when you consider their weight plus their suits and gear. And we can lose the other five acceleration chairs. And of course, we'll remove all nonessential gear—the med kit, tool kit, internal harnessing, straps, and anything else that isn't nailed down. And some stuff that is.

"Next up," he continued. "We're ditching all life support. The tanks, pumps, heaters, air lines, CO<sub>2</sub> absorption system, even the insulation on the inner side of the hull. We don't need it. We'll have Watney wear his EVA suit for the whole trip."

"Won't that make it awkward for him to use the controls?" Venkat asked.

"He won't be using them," Bruce said. "Major Martinez will pilot the MAV remotely from *Hermes*. It's already designed for remote piloting. It was remotely landed, after all."

"What if something goes wrong?" Venkat asked.

"Martinez is the best trained pilot," Bruce said. "If there is an emergency, he's the guy you want controlling the ship."

"Hmm," Venkat said cautiously. "We've never had a manned ship controlled remotely before. But okay, go on."

"Since Watney won't be flying the ship," Bruce continued, "he won't need the controls. We'll ditch the control panels and all the power and data lines that lead to them."

"Wow," Venkat said. "We're really gutting this thing."

"I'm just getting started," Bruce said. "The power needs will be dramatically reduced now that life support is gone, so we'll dump three of the five batteries and the auxiliary power system. The orbital maneuvering system has three redundant thrusters. We'll get rid of those. Also, the secondary and tertiary comm systems can go."

"Wait, what?" Venkat said, shocked. "You're going to have a remote-controlled ascent with no backup comm systems?"

"No point," Bruce said. "If the comm system goes out during ascent, the time it takes to reconfigure will be too long to do any good. The backups don't help us."

"This is getting really risky, Bruce."

Bruce sighed. "I know. There's just no other way. And I'm not even to the nasty stuff yet."

Venkat rubbed his forehead. "By all means, tell me the nasty stuff."

"We'll remove the nose airlock, the windows, and Hull Panel Nineteen."

Venkat blinked. "You're taking the front of the ship off?"

"Sure," Bruce said. "The nose airlock alone is four hundred kilograms. The windows are pretty damn heavy, too. And they're connected by Hull Panel Nineteen, so may as well take that, too."

"So he's going to launch with a big hole in the front of the ship?"

"We'll have him cover it with Hab canvas."

"Hab canvas? For a launch to orbit?"

Bruce shrugged. "The hull's mostly there to keep the air in. Mars's atmosphere is so thin you don't need a lot of streamlining. By the time the ship's going fast enough for air resistance to matter, it'll be high enough that there's practically no air. We've run all the simulations. Should be good."

"You're sending him to space under a tarp."

"Pretty much, yeah."

"Like a hastily loaded pickup truck."

"Yeah. Can I go on?"

"Sure, can't wait."

"We'll also have him remove the back panel of the pressure vessel. It's the only other panel he can remove with the tools on hand. Also, we're getting rid of the auxiliary fuel pump. Sad to see it go, but it weighs too much for its usefulness. And we're nixing a Stage One engine."

"An engine?"

"Yeah. The Stage One booster works fine if one engine goes out. It'll save us a huge amount



of weight. Only during the Stage One ascent, but still. Pretty good fuel savings."

Bruce fell silent.

"That it?" Venkat asked.

"Yeah."

Venkat sighed. "You've removed most of the safety backups. What's this do to the estimated odds of failure?"

"It's about four percent."

"Jesus Christ," Venkat said. "Normally we'd never even consider something that risky."

"It's all we've got, Venk," Bruce said. "We've tested it all out and run simulations galore. We should be okay if everything works the way it's supposed to."

"Yeah. Great," Venkat said.

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108:41] MAV: You fucking kidding me?

109:55] HOUSTON: Admittedly, they are very invasive modifications, but they have to be done. The procedure doc we sent has instructions for carrying out each of these steps with tools you have on hand. Also, you'll need to start electrolyzing water to get the hydrogen for the fuel plant. We'll send you procedures for that shortly.

109:09] MAV: You're sending me into space in a convertible.

109:24] HOUSTON: There will be Hab canvas covering the holes. It will provide enough aerodynamics in Mars's atmosphere.

109:38] MAV: So it's a ragtop. Much better.

On the way here, in my copious free time, I designed a "workshop." I figured I'd need space to work on stuff without having to wear an EVA suit. I devised a brilliant plan whereby the current bedroom would become the new home of the regulator and the oxygenator, and the now-empty trailer would become my workshop.

It's a stupid idea, and I'm not doing it.

All I need is a pressurized area that I can work in. I somehow convinced myself that the bedroom wasn't an option because it's a hassle to get stuff into it. But it won't be that bad.

It attaches to the rover airlock, so the getting stuff in is going to be annoying. Bring the stuff into the rover, attach the bedroom to the airlock from the inside, inflate it, bring the stuff into the bedroom. I'll also have to empty the bedroom of all tools and equipment to fold it up any time I need to do an EVA.

So yeah, it'll be annoying, but all it costs me is time. And I'm actually doing well on that front. I have forty-three more sols before *Hermes* flies by. And looking at the procedure NASA has in mind for the modifications, I can take advantage of the MAV itself as a workspace.

The lunatics at NASA have me doing all kinds of rape to the MAV, but I don't have to open the hull till the end. So the first thing I'll do is clear out a bunch of clutter, like chairs and control panels and the like. Once they're out, I'll have a lot of room in there to work.

But I didn't do anything to the soon-to-be-mutilated MAV today. Today was all about system



checks. Now that I'm back in contact with NASA, I have to go back to being all "safety first." Strangely, NASA doesn't have total faith in my kludged-together rover or my method of piling everything into the trailer. They had me do a full systems check on every single component.

Everything's still working fine, though it's wearing down. The regulator and the oxygenator are at less-than-peak efficiency (to say the least), and the trailer leaks some air every day. Not enough to cause problems, but it's not a perfect seal. NASA's pretty uncomfortable with it, but we don't have any other options.

Then, they had me run a full diagnostic on the MAV. That's in much better shape. Everything's sleek and pristine and perfectly functional. I'd almost forgotten what new hardware even looks like.

Pity I'm going to tear it apart.

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"YOU KILLED Watney," Lewis said.

"Yeah," Martinez said, scowling at his monitor. The words "Collision with Terrain" blinked accusingly.

"I pulled a nasty trick on him," Johanssen said. "I gave him a malfunctioning altitude readout and made Engine Three cut out too early. It's a deadly combination."

"Shouldn't have been a mission failure," Martinez said. "I should have noticed the readout was wrong. It was way off."

"Don't sweat it," Lewis said. "That's why we drill."

"Aye, Commander," Martinez said. He furrowed his brow and frowned at the screen.

Lewis waited for him to snap out of it. When he didn't, she put a hand on his shoulder.

"Don't beat yourself up," she said. "They only gave you two days of remote launch training. It was only supposed to happen if we aborted before landing; a cut-our-losses scenario where we'd launch the MAV to act as a satellite. It wasn't mission-critical so they didn't drill you too hard on it. Now that Mark's life depends on it, you've got three weeks to get it right, and I have no doubt you can do it."

"Aye, Commander," Martinez said, softening his scowl.

"Resetting the sim," Johanssen said. "Anything specific you want to try?"

"Surprise me," Martinez said.

Lewis left the control room and made her way to the reactor. As she climbed "up" the ladder to the center of the ship, the centripetal force on her diminished to zero. Vogel looked up from a computer console. "Commander?"

"How are the engines?" she asked, grabbing a wall-mounted handle to stay attached to the slowly turning room.

"All working within tolerance," Vogel said. "I am now doing a diagnostic on the reactor. I am thinking that Johanssen is busy with the launching training. So perhaps I do this diagnostic for her."

"Good idea," Lewis said. "And how's our course?"

"All is well," Vogel said. "No adjustments nec-

essary. We are still on track to planned trajectory within four meters."

"Keep me posted if anything changes."

"Ja, Commander."

Floating to the other side of the core, Lewis took the other ladder out, again gaining gravity as she went "down." She made her way to the Airlock 2 ready room.

Beck held a coil of metal wire in one hand and a pair of work gloves in the other. "Heya, Commander. What's up?"

"I'd like to know your plan for recovering Mark."

"Easy enough if the intercept is good," Beck said. "I just finished attaching all the tethers we have into one long line. It's two hundred and fourteen meters long. I'll have the MMU pack on, so moving around will be easy. I can get going up to around ten meters per second safely. Any more, and I risk breaking the tether if I can't stop in time."

"Once you get to Mark, how fast a relative velocity can you handle?"

"I can grab the MAV easily at five meters per second. Ten meters per second is kind of like jumping onto a moving train. Anything more than that and I might miss."

"So, including the MMU safe speed, we need to get the ship within twenty meters per second of his velocity."

"And the intercept has to be within two hundred and fourteen meters," Beck said. "Pretty narrow margin of error."

"We've got a lot of leeway," Lewis said. "The launch will be fifty-two minutes before the intercept, and it takes twelve minutes. As soon as Mark's

S2 engine cuts out, we'll know our intercept point and velocity. If we don't like it, we'll have forty minutes to correct. Our engine's two millimeters per second may not seem like much, but in forty minutes it can move us up to 5.7 kilometers."

"Good," Beck said. "And two hundred and fourteen meters isn't a hard limit, per se."

"Yes it is," Lewis said.

"Nah," Beck said. "I know I'm not supposed to go untethered, but without my leash I could get way out there—"

"Not an option," Lewis said.

"But we could double or even triple our safe intercept range—"

"We're done talking about this," Lewis said sharply.

"Aye, Commander."

#### LOG ENTRY: SOL 526

There aren't many people who can say they've vandalized a three-billion-dollar spacecraft, but I'm one of them.

I've been pulling critical hardware out of the MAV left and right. It's nice to know that my launch to orbit won't have any pesky backup systems weighing me down.

First thing I did was remove the small stuff. Then came the things I could disassemble, like the crew seats, several of the backup systems, and the control panels.

I'm not improvising anything. I'm following a script sent by NASA, which was set up to make things as easy as possible. Sometimes I miss the days when I made all the decisions myself. Then I



shake it off and remember I'm infinitely better off with a bunch of geniuses deciding what I do than I am making shit up as I go along.

Periodically, I suit up, crawl into the airlock with as much junk as I can fit, and dump it outside. The area around the MAV looks like the set of *Sanford and Son*.

I learned about *Sanford and Son* from Lewis's collection. Seriously, that woman needs to see someone about her seventies problem.

LOG ENTRY: SOL 529

I'm turning water into rocket fuel.

It's easier than you'd think.

Separating hydrogen and oxygen only requires a couple of electrodes and some current. The problem is collecting the hydrogen. I don't have any equipment for pulling hydrogen out of the air. The atmospheric regulator doesn't even know how. The last time I had to get hydrogen out of the air (back when I turned the Hab into a bomb) I burned it to turn it into water. Obviously that would be counterproductive.

But NASA thought everything through and gave me a process. First, I disconnected the rover and trailer from each other. Then, while wearing my EVA suit, I depressurized the trailer and back-filled it with pure oxygen at one-fourth of an atmosphere. Then I opened a plastic box full of water and put a couple of electrodes in. That's why I needed the atmosphere. Without it, the water would just boil immediately and I'd be hanging around in a steamy atmosphere.

The electrolysis separated the hydrogen and

oxygen from each other. Now the trailer was full of even more oxygen and also hydrogen. Pretty dangerous, actually.

Then I fired up the atmospheric regulator. I know I just said it doesn't recognize hydrogen, but it *does* know how to yank oxygen out of the air. I broke all the safeties and set it to pull 100 percent of the oxygen out. After it was done, all that was left in the trailer was hydrogen. That's why I started out with an atmosphere of pure oxygen, so the regulator could separate it later.

Then I cycled the rover's airlock with the inner door open. The airlock thought it was evacuating itself, but it was actually evacuating the whole trailer. The air was stored in the airlock's holding tank. And there you have it, a tank of pure hydrogen.

I carried the airlock's holding tank to the MAV and transferred the contents to the MAV's hydrogen tanks. I've said this many times before, but: Hurray for standardized valve systems!

Finally, I fired up the fuel plant, and it got to work making the additional fuel I'd need.

I'll need to go through this process several more times as the launch date approaches. I'm even going to electrolyze my urine. That'll make for a pleasant smell in the trailer.

If I survive this, I'll tell people I was pissing rocket fuel.

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[19:22] JOHANSEN: Hello, Mark.

[19:23] MAV: Johanssen!? Holy crap! They finally letting you talk to me directly?



[19:24] JOHANSEN: Yes, NASA gave the OK for direct communication an hour ago. We're only 35 light-seconds apart, so we can talk in near-real time. I just set up the system and I'm testing it out.

[19:24] MAV: What took them so long to let us talk?

[19:25] JOHANSEN: The psych team was worried about personality conflicts.

[19:25] MAV: What? Just 'cause you guys abandoned me on a godforsaken planet with no chance of survival?

[19:26] JOHANSEN: Funny. Don't make that kind of joke with Lewis.

[19:27] MAV: Roger. So uh . . . thanks for coming back to get me.

[19:27] JOHANSEN: It's the least we could do. How is the MAV retrofit going?

[19:28] MAV: So far, so good. NASA put a lot of thought into the procedures. They work. That's not to say they're easy. I spent the last 3 days removing Hull Panel 19 and the front window. Even in Mars-g they're heavy motherfuckers.

[19:29] JOHANSEN: When we pick you up, I will make wild, passionate love to you. Prepare your body.

[19:29] JOHANSEN: I didn't type that! That was Martinez! I stepped away from the console for like 10 seconds!

[19:29] MAV: I've really missed you guys.

LOG ENTRY: SOL 543

I'm . . . done?  
I think I'm done.

I did everything on the list. The MAV is ready to fly. And in six sols, that's just what it'll do. I hope.

It might not launch at all. I did remove an engine, after all. I could have fucked up all sorts of things during that process. And there's no way to test the ascent stage. Once you light it, it's lit.

Everything else, however, will go through tests from now until launch. Some done by me, some done remotely by NASA. They're not telling me the failure odds, but I'm guessing they're the highest in history. Yuri Gagarin had a much more reliable and safe ship than I do.

And Soviet ships were death traps.

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"ALL RIGHT," Lewis said, "tomorrow's the big day."

The crew floated in the Rec. They had halted the rotation of the ship in preparation for the upcoming operation.

"I'm ready," Martinez said. "Johanssen threw everything she could at me. I got all scenarios to orbit."

"Everything other than catastrophic failures," Johanssen corrected.

"Well yeah," Martinez said. "Kind of pointless to simulate an ascent explosion. Nothing we can do."

"Vogel," Lewis said. "How's our course?"

"It is perfect," Vogel said. "We are within one meter of projected path and two centimeters per second of projected velocity."

"Good," she said. "Beck, how about you?"

"Everything's all set up, Commander," Beck said. "The tethers are linked and spooled in Airlock 2. My suit and MMU are prepped and ready."

"Okay, the battle plan is pretty obvious," Lewis said. She grabbed a handhold on the wall to halt a slow drift she had acquired. "Martinez will fly the MAV, Johanssen will sysop the ascent. Beck and Vogel, I want you in Airlock 2 with the outer door open before the MAV even launches. You'll have to wait fifty-two minutes, but I don't want to risk any technical glitches with the airlock or your suits. Once we reach intercept, it'll be Beck's job to get Watney."

"He might be in bad shape when I get him," Beck said. "The stripped-down MAV will get up to twelve g's during the launch. He could be unconscious and may even have internal bleeding."

"Just as well you're our doctor," Lewis said. "Vogel, if all goes according to plan, you're pulling Beck and Watney back aboard with the tether. If things go wrong, you're Beck's backup."

"Ja," Vogel said.

"I wish there was more we could do right now," Lewis said. "But all we have left is the wait. Your work schedules are cleared. All scientific experiments are suspended. Sleep if you can, run diagnostics on your equipment if you can't."

"We'll get him, Commander," Martinez said as the others floated out. "Twenty-four hours from now, Mark Watney will be right here in this room."

"Let's hope so, Major," Lewis said.

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"FINAL CHECKS for this shift are complete," Mitch said into his headset. "Timekeeper."

"Go, Flight," said the timekeeper.

"Time until MAV launch?"

"Sixteen hours, nine minutes, forty seconds . . . mark."

"Copy that. All stations: Flight director shift change." He took his headset off and rubbed his eyes.

Brendan Hutch took the headset from him and put it on. "All stations, Flight director is now Brendan Hutch."

"Call me if anything happens," Mitch said. "If not, I'll see you tomorrow."

"Get some sleep, Boss," Brendan said.

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 twelve light-minutes away. That means it takes twenty-four minutes for them to get the answer to any question they ask. The



whole launch is twelve minutes long. They're on their own."

"So we're completely helpless?"

"Yes," Venkat said. "Sucks, doesn't it?"

LOG ENTRY: SOL 549

I'd be lying if I said I wasn't shitting myself. In four 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 forty-one potatoes behind. That's how close I came to starvation.

I carefully collected samples during my 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 someday 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, but 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 still can't quite believe that this is really it. I'm really leaving. This frigid desert has been my home for a year and a half. I figured out how to survive, at least for a while, and I got used to how things worked. My terrifying struggle to stay alive became somehow routine. Get up in the morning, eat breakfast, tend my crops, fix broken stuff, eat lunch, answer e-mail, watch TV, eat dinner, go to bed. The life of a modern farmer.

Then I was a trucker, doing a long haul across the world. And finally, a construction worker, rebuilding a ship in ways no one ever considered before this. I've done a little of everything here, because I'm the only one around to do it.

That's all over now. I have no more jobs to do, and no more nature to defeat. I've had my last Martian potato. I've slept in the rover for the last time. I've left my last footprints in the dusty red sand. I'm leaving Mars today, one way or another. About fucking time.