The Valley of Dawns

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Table of Contents

1

GATEWAY

July 24, 2035

The star moved.

Will Elliott leaned closer to one of the lunar lifter's front portholes to see the blackness of space better. The Earth was a thin sliver of light in the corner; he moved his head back so its brightness wouldn't wash out the stars. "There it is," he said, pointing. "Gateway Station."

Commander Heather Kimball diverted her attention momentarily from the controls of the *Tranquillitatis* to glance out the window. She pointed to a different star. "It's probably that one; we're heading twenty degrees port of dead center."

The four of them scanned the space in front of them until David Alaoui nodded and pointed at Will's "star." "You're right, Moonman, that one's two tapered cylinders, a docking port, and solar panels."

Will squinted, then nodded; he saw the panels as well. "You're right too often," complained Kimball.

"But you're right, too, Kimball," added David, pointing to the star she had identified. "That one's a pinwheel of four long cones: the Columbus 1 complex."

"Boy, you guys have good eyesight!" said Dr. Armando Cruz a minute later. "I still can't see a difference! I should consider glasses."

"Lasik; the only way to go in space," replied Will.

"No thanks. I don't want to have my eyeballs sliced."

Will laughed. Dave stared out the window. “The L1 Gateway: boy, is it a sight for sore eyes!”

“You guys should have been here four months ago,” replied Kimball. “But at least you’re not too late for the departure to Mars.”

“Just for our training!” replied Dave.

“We’ve been to the Antarctic a dozen times,” replied Will. “We didn’t need it.”

“True, but there’s been no time for the team to bond, and there’s even a new member.” Dave shook his head.

“NASA’s never been strong on crew psychology,” replied Armando. “I’ve seen some disastrous personal chemistry up here. It wasn’t great at Shackleton recently.”

“Safe to say, now that we’ve left the moon,” observed Will. “I have to admit to some trepidation about this flight.”

“Y’all will be fine,” replied Kimball, lapsing into more of a southern accent than usual. “I’ve seen some pretty bad behavior in my decade and a half of lunar piloting. But everything was fine in the end. Don’t worry. We’ll all get together when you’re back from Mars in thirty months and have plenty of laughs about your experiences.”

“I suppose,” said Will. Kimball heard the hesitation and actually took her eyes off the controls to turn around.

“It’s Commander Stillwell,” replied David. “When we got separated from the rest of the crew because the lifter fleet was grounded, she tried to get us dropped.”

Kimball frowned. “Why?”

“Officially, because we would be stuck on the moon so long, the Mars trip would exceed our lifetime radiation allowance.”

“They make exceptions. Maybe Laura was concerned that everyone couldn’t train together.”

“If so, she should have said so,” replied Dave.

They grew silent while everyone considered the situation. Four months earlier the lifter *Nectaris* had an engine failure during ascent from the lunar surface to Gateway, stranding the other four members of the Mars crew in lunar orbit until they were able to override the computers and proceed on the other engine. Consequently Elliott and Alaoui had been stuck on the moon four months longer than intended—seven total—while the entire fleet of lifters was checked for the same problem. They had almost missed Columbus 1’s departure to Mars.

Kimball watched her systems; the others watched the stars grow into tiny objects. Finally Armando said “So, Columbus is on the left, right?”

“You mean ‘left, correct,’” said Kimball stoically.

“Ah-hah.”

Will nodded and pointed. “And I think the *Nectaris* is on the right of Gateway.”

Dave nodded. “Definitely; it’s the *Nectaris,* infamous source of all our troubles.”

“At least no one died,” said Kimball.

“Columbus is pretty big,” observed Armando.

“A hub with four spokes,” agreed Will. “The left and right spokes are the interplanetary transit vehicles, also know as ‘home, sweet home’ for the flight to Mars. The Mars shuttles are the spokes on the top and bottom.”

Armando nodded. “Interplanetary cruise configuration. It’s hard to tell the Mars shuttles apart from the ITVs!”

“They’re both long cones with heat shields,” agreed Will.

“But the shuttles are longer and have windows in the capsule on the top and around the cargo hold on the bottom,” Armando added, pleased he could finally tell the difference between the vehicles.

“Each ITV can accommodate all six of us in an emergency,” said Will.

“A historic trip,” commented Armando. “All the way to the Valley of Dawns, Mars.”

Kimball snorted. “ ‘Valley of Dawns’!”

“Well, it sounds better than ‘Aurorae Chaos,’” replied David. “And it’s part of the Valles Marineris system, so it is a ‘valley.’”

“I prefer plain ‘Aurorae,’” added Will.

“Whatever,” she replied. “We should have landed people on Mars thirty-five years ago.”

“Kimball, thirty-five years ago we were stuck in low Earth orbit with no hope of returning to the moon,” said Will, calmly.

“They never should have built the space shuttle. They should have cut back Apollo to two flights a year to make it affordable and continued with Saturn Vs. There could have been 100 Apollo missions, and we’d really understand the moon.”

“Assuming none of the Saturn Vs blew up. That rocket was a death trap. But politically, NASA couldn’t, they had to focus on Earth orbit.”

Kimball scowled. “Sort of. A hundred billion bucks for ISS when they could have built and launched it for a fifth as much with Saturn Vs. They could have built ISS and continued lunar exploration with the existing budget if they’d been smart! Then billions

for the Orion capsule and a small man-rated booster, then billions wasted on the shuttle-derived vehicle that Congress shortsightedly canceled to 'save money.' Then billions on a solar-powered ion tug; they could have finished the shuttle-derived vehicle with that!"

"The ion vehicle was built with European money, not American."

"Political shortsightedness; we had to accept foreign involvement to move forward. No offense, David. They could have built an efficient and reliable bimodal nuclear thermal rocket for as much."

"The public wouldn't support nuclear engines," replied Will.

"No, Democrats and their environmentalist buddies wouldn't."

"Kimball, that's not fair, the European and Japanese governments wouldn't support them either," objected David.

"And now you guys are going to Mars without a reactor for surface power, which is really foolish!"

"It'll be fine," replied David. "We arrive after the dust storm season is over."

"But you won't leave before the next one!" she replied, getting worked up. "Then how many billions more spent on two upgrades of Orion, including the Interplanetary Transit Vehicles? A few billion to design and launch the L1 Gateway. A couple billion more for the lunar-based lifters, non-reusable *and* reusable versions. Over ten billion for the Mars Shuttle. Two billion each for four missions to near-earth asteroids to test everything. And the vast administrative cost. . . it was so expensive we had to switch to an international partnership and fly under *five flags* rather than sell a few seats to other countries; no offense again. It could have been quicker and cheaper, as everyone knows!"

"Well, four hundred billion's been spent and we have a functioning system. Let's be thankful for that," said Will, trying not to sound irritated. "Maybe Mr. Swift will build a cheap shuttle and the cost situation will improve."

Kimball snorted. "Jonah Swift is just the latest alt-space businessman to throw away his money chasing the dream of cheap launch to low earth orbit."

They all grew silent. Kimball was known for her strong and nationalistic opinions. Will stared out the window; he was not one to dwell on the delays and detours of the past. They were now close enough to read *Olympus* on one Mars Shuttle and *Elysium* on the other. Mars Shuttles were named for volcanoes; the shuttle already sitting at Aurorae was the *Pavonis.* The ITVs or interplanetary transit vehicles were named for plains and other regions on Mars: the *Cimmerium* and *Ausonia.* Solar panels and antennas sprouted from the vehicles at various angles, making the complex look unplanned and unkempt.

The *Tranquillitatis* closed slowly but steadily on the hub of Columbus 1. Docking was not to be rushed; it involved a careful, delicate dance of vehicles. The last half kilometer took an hour. Kimball occasionally spoke laconically to Commander Laura Stillwell, but there was little she needed to say. The computers did much of the work, showing when the vehicle was properly aligned and when it strayed even slightly. Finally, there was a faint scrape of metal, then a clunk as soft docking was achieved. A few moments later the docking latches slipped into place and they had a hard dock.

David and Armando turned to the docking tunnel, verifying the pressurization and removing the soft docking apparatus. Soon it was ready to open. By then, Kimball, assisted by Will, had completed power-down of the navigational and propulsion systems. The four of them gathered around the tunnel as the hatches were opened.

“Welcome to Columbus,” exclaimed Laura Stillwell from the other side. Will heard ambiguity in her voice. She focused on Heather Kimball. “Heather, you old salt, how are you! Good to see you again!” Will was surprised Laura had called her “Heather”; everyone else used her last name.

“It’s good to see you, too, Laura.” Kimball pushed herself forward and floated through the docking tunnel. She and Laura caught each other by their hands and exchanged a handshake as Kimball floated into an upright position inside the docking cube. “I’m looking forward to seeing your vehicle.”

“I’ll be delighted to show you. This way, Heather. We’ll go into the *Cimmerium;* Will and David have to go into the *Ausonia.* Will, you know where you’re going?”

“Yes.”

“Good.” Stillwell led Kimball to the right and down the ladder shaft into the *Cimmerium.* Will, holding onto his garment bag, floated into the cube followed by David and Armando.

“Some greeting from our commander,” growled David.

“Really,” agreed Will, and Armando nodded empathetically. The three men turned left and floated down the *Ausonia’s* ladder shaft. The first level down was a small room barely two meters across, stuffed with supplies for the trip out and back. “Flare shelter,” observed Armando; a place packed with provisions to protect them from radiation if a flare exploded on the sun.

They paused long enough to push a button that opened the hatch, allowing them to descend to the next level. They ignored the hand holds built into the shaft on two sides and floated down. The shaft wall was interrupted by a porch on one side that was just one

meter deep; two doors opened onto it. The level, only 4 meters in diameter, had two private rooms, each five square meters in size.

They continued downward toward voices coming up from below, but stopped at the third level where four doors opened onto a porch. The doors to the left and right led into private rooms, while the two straight ahead opened into tiny toilet and shower stalls respectively. Will, who was in the lead, pushed buttons to open the doors to the rooms. “The usual?”

“Sure, just like during training,” replied David.

“Okay.” Will entered the right-hand room. Straight ahead was his closet. To its right was a desk and chair, with a porthole providing a bit of sunlight and a view. To the right of the desk and perpendicular to it was the bed, with drawers under it and shelves over the foot of the bed facing the desk. The shelves had strips of transparent plastic over the openings to keep objects inside. Around the head-end of the bed was a fifteen-centimeter thick layer of hydrogen-impregnated polyethylene plastic to provide radiation shielding for the upper body.

The room was barely 1.8 meters wide and 4 meters long and curved to fit inside the circular outline of the ITV. But it was private space, efficiently designed, and on a long trip a personal area was essential.

Armando drifted in and watched Will unpack. The clothes—nine changes, including six uniforms, a sports jacket, dress shirt, and slacks, and two casual civilian outfits—went straight into the closet. Their hangers latched quickly and securely onto the bar. There was an extra polypropylene radiation vest hanging in the closet; the one he was wearing over his shirt cut the radiation exposure of his internal organs by a quarter.

Socks and underwear went into drawers under the bed. Pictures of his white mother, his black father, and his sister and her family slipped under a sheet of transparent plastic covering the back wall of the desk. He put his attaché—a computer and communications device about the size of a thick clipboard—on the desk and anchored it to Velcro strips; it communicated with the ear piece he wore almost constantly. He placed in a drawer several notebooks and pads of electronic paper and an electronic writing pen; efforts to create paperless offices had never worked and NASA never supplied enough. Six books—mostly small paperbacks—went on one of the shelves behind the vertical plastic strips. He pulled out a collection of very small rocks, looked at it, then put it back in his bag.

Armando chuckled. “You and your rock collection.”

“Well, it’s suitably sized for the trip! I am a geologist, after all.”

“True, you’re the Moonman! They are nice specimens.”

“Some of them are meant to be gifts. But since we didn’t get back to Earth four months ago, as scheduled, they’ll have to go to Mars first.” Will looked at the pile of sheets, a blanket, washcloth, hand towel, and bath towel on the bed, anchored under an elastic strip. “Someone—probably Ethel—was kind enough to put my linens here.”

“A nice touch,” agreed Armando. “I wonder where everyone is.”

“I’m surprised we weren’t greeted by more people. Let me put this away and we’ll go look.” Will pulled the garment bag free from the floor and pushed its velcroed bottom against the closet floor, then closed the closet door. The two of them crossed the porch to David’s room.

David was almost finished as well. He had pictures of his parents, wife, and children on his desk, his Qur'an in a prominent spot on the shelf, a small framed "Allah" hung on the wall, a hand woven Moroccan blanket on his bed and a smaller, more delicate one velcroed to the floor. He also had hung on the wall a large framed citation he had received from the government of France for his contributions to the nation.

"Looking for people?" he asked. Will nodded, so the three men headed down the ladder shaft again. They stopped to glance around the next level down; a large science and medical room occupied most of the floor, with a storage area, a toilet, and the ITV's control area occupying alcoves off the main space. But no one was there. So they went down the shaft one more time and entered the great room. Except for the galley alcove, the floor, which was six meters in diameter, was an open space with a dining room table able to seat six and a lounge area with comfortable chairs that could either be pushed together to form a couch or separated into individual seats.

They quickly saw the source of the conversation; Sergei Alievitch Landsberg was talking rather emotionally in Russian to a woman with slightly oriental features whose face was projected life-sized onto the wall screen. When he saw the three of them, he was surprised.

"Sorry, my dear," he said to the woman in Russian. He turned to them. "Gentlemen, I didn't realize you had arrived; I apologize for neglecting you. Welcome on board. I am in conversation with my wife about a private matter of great importance."

"Oh, I'm sorry; we'll head over to the *Cimmerium*, then," replied Will. The other two nodded and they entered the ladder shaft. "Well, might as well give this a try, for the first time in seven months," he said, looking straight up and estimating distances. The

ladder shaft was open all the way to the top of the *Ausonia* and all the way down to the *Cimmerium's* great room thirty meters away. He carefully jumped and soared straight up. "I didn't touch until I reached the *Cimmerium!*" he called back to the others. They repeated his leap, occasionally grabbing a handhold to keep themselves going.

All three of them "landed" at almost the same time, surprising the four people gathered in the *Cimmerium's* great room. In addition to Kimball and Laura, the other two Columbus crewmembers were present: Shinji Nagatani, Japanese, their exobiologist, physician, and horticulturist; and Ethel McGregor, a Scot, whose expertise was engineering, mechanics, and computers.

"Ah, you made it," said Laura. "Sorry I didn't socialize up top; I hadn't seen Heather for months."

"We go back a long way," added Kimball.

Will nodded. He extended his hand to Nagatani. "Shinji, it's good to meet you. We were all surprised when Yamamoto suddenly had to withdraw, but I hear you can do everything he could and more."

Shinji shook his hand. "Not everything. I'm not a geologist. Never been to the moon; it's strange to look out my window and see it so big and close, and know I'm not going there!"

David extended his hand as well. "Looking forward to getting to know you."

"Thank you."

Will turned to Ethel and extended his hand. "It's good to see you again, Ethel."

She smiled and they shook hands. She was petite, attractive, a year younger than he, with short, light brown hair and blue eyes. Her eyes lingered on him for a moment.

“Thanks, Will. There have been a few times in the last three months when I didn’t think I’d see you again.”

“I worried about that, too, when the *Nectaris* lost an engine and left the four of you in low lunar orbit for twenty-four hours,” replied Will.

“It was a worrisome moment,” she said, with characteristic understatement.

“And it messed up the end of training,” growled Laura. “But I guess we’ve got six months to catch up.”

“And I hear there was a rescue on the lunar surface,” added Shinji.

“Indeed there was, of sorts,” agreed David. “Since you all had had your brush with death, Will and I decided we had to have ours.”

Will rolled his eyes. “I guess Tycho crater was never meant to be explored over land. The next explorers will have to arrive by hopper.”

“I did manage to get almost a hundred meters below the rim!” replied David.

“Yeah, and it took me so long to get you back up, we both almost ran out of air.”

“Well, you’re here safe and sound now,” said Ethel. “And David’s tumble has left a mark that will be visible a million years!”

Laura laughed. Will smiled and added, “It could have been either of us; the slope was steep and we were too close to the edge. The suits are pretty top heavy.”

“I was really surprised by the accident,” said Kimball. “You guys both have a lot of experience on the moon; what is it, fifteen months?”

Will nodded. “For me. Dave has nineteen.”

“It all goes to show that anyone can make a basic mistake,” replied Dave.

“Maybe it’s all the brain cells that were fried by radiation,” said Laura.

Kimball shook her head. “No, nothing like that, Laura. I’ve spent twenty-three months on or near the moon. You can get permission to do it. I wear radiation vests almost all the time and take the anti-radiation pills. And I’ve spent a lot of time in the hab, buried under three meters of reg. My radiation count is still okay.”

“It’s true; if you’re careful you can spend a lot of time up here,” agreed Shinji, tapping his radiation vest.

Just then there were sounds in the ladder shaft and Sergei came down. “I’m finished; I apologize again for being inhospitable.”

“Oh, no, Sergei, that’s alright,” replied Will.

“Have some punch,” added Ethel. She reached over to the counter, pulled several sippy cups from their restraints, and passed them around.

“Kimball, you were on the first flight to the moon, right?” asked Shinji. “I apologize if I’m not sure about these things; lunar missions are not my expertise.”

She nodded. “I was a junior officer, almost fifteen years ago.”

“The first woman on the moon,” added Laura, admiration in her voice.

“What was the first flight like?” asked Shinji.

Kimball shrugged. “I’m not sure what to say because it was pretty routine. We spent most of our time keeping the ice mining equipment working; it couldn’t handle the cold! The mission would have been more science-oriented if the robots had done their work. We had to redeploy the solar panels on top of Palmer Pinnacle in 95% permanent sunlight because the robots couldn’t do it. We covered the hab with regolith and were as snug as a bug in a rug inside. And we made a thirty-kilometer excursion in the portahab.”

“We would have saved a lot of money, long term, if Congress had funded the big shuttle-derived Ares V launch vehicle, or if we had let the Russians launch cargo!” complained Laura.

“Exactly,” agreed Heather, waving a finger. “After a decade and a half we have a dinky little moon base, the human presence is mostly confined to the south polar region, and the program is starved for cash because Mars has soaked up the rest; no offense meant.”

“Still, it was the first,” replied Shinji.

“You’re too modest, Heather,” added Laura. “Y’all broke ground. Even if every centimeter had already been photographed robotically, it was a big risk. A big unknown.”

“True, but all the elements of the system had been tested. The six of you will be much bigger heroes. You’re going a lot farther. We could have been rescued any time; there was an extra lifter at Shackleton and a backup vehicle waiting at Kennedy. You have no possibility of rescue. You don’t even have a fully fueled return vehicle.”

“The *Pavonis* is 90% fueled,” replied Will. “By the time we arrive it’ll be full. As for rescue: Columbus 1 is being flown with two Interplanetary Transit Vehicles and two Mars shuttles so we can rescue ourselves.”

“The *Pavonis* will be ready,” agreed David. “We’ll have three Mars shuttles. And don’t forget the three automated cargo landers with fifty tonnes of stuff already sitting at Aurorae, plus three more for Columbus 2 already on the way with sixty-six tonnes more stuff.”

“And our Russian propellant plant on Phobos has made some fuel for the lifter *Stickney*, even if the plant hasn’t functioned fully,” added Sergei. “A second plant’s on the way. We’ll have a lot more than you had, actually.”

“That’s true,” said Kimball. “And we had a lot more than Apollo 11; they just had a flimsy little lunar lander, no supplies waiting for them, and no backup.”

“It makes me wish we could go along,” added Armando. “Hey, you’ve got room for two more! We could strip Gateway of consumables, and there’s plenty of fuel. . .”

They all erupted in laughter at the idea. “It actually would be pretty easy,” added Will. “Of course, we’d all be fired!”

“I’ll be busy providing you medical support in Houston anyway,” said Armando. “But I think I’ll put in my name for Columbus 2, even if my wife will kill me.”

“No; just divorce you,” said Sergei sadly. Laura glanced at Sergei, startled, and he nodded slightly to her.

“I’ll be ‘along’ as well, as your chief capsule communicator,” said Kimball. “The first lunar mission had excellent crew dynamics. The four of us got along very well. Y’all will be together thirty months, so good crew dynamics is essential. It makes the difference between a ‘Valley of Dawns’ and ‘Aurorae Chaos.’”

“Exactly,” said Will.

“We’ll do fine,” replied Laura dismissively. She looked at the others. “All six of us are now here. The shuttles are fully fueled. The ITVs are ready. The launch window opens at noon tomorrow. What do you say? Will we be ready?”

One by one they nodded. “Good,” she concluded. “We’ll entertain our guests another hour, then they have to get to Gateway so they can rest and prepare for their flight to Earth. I’ll call Houston and tell them we’ll be ready to go tomorrow morning.”

2

Flight

July 24-Aug. 2, 2035

"It's shrinking so fast," said Will, staring at Earth out the porthole of the Mars shuttle *Elysium's* crew module. Trans-Mars injection had just occurred a few hundred kilometers over the South Atlantic Ocean.

Ethel removed her seat belts and floated over. "We can see North America and Europe now; your home and mine," she observed. "Pretty soon they'll shrink to nothing."

"Enjoy the colors," said Sergei. "We won't see anything as colorful as the home world for quite a while."

The radio crackled. "Congratulations, Columbus 1, on a successful trans-Mars injection," said Houston. "Your trajectory is spot on. Preliminary GPS data indicates that the *Olympus* is moving two centimeters per second faster than the *Elysium.* Docking maneuvers can commence on schedule."

"Thank you," replied Laura, over the radio. She was piloting the *Olympus*, which was flying about ten kilometers away with the ITV *Cimmerium* docked to it. "*Elysium,* how are you guys doing over there? David was positively turning green from the one gee of acceleration."

"Seven months in lunar gravity," said Will.

"We're fine, though Will looked a bit surprised," replied Sergei.

"We'll be docked back together in less than twenty-four hours and finally living in Martian gee. *Olympus* calling *Rigel 10,* do you copy? How was the video, Heather?"

"It was great, *Olympus*!" replied Kimball. "We caught the whole maneuver for Earth's televisions. We'll be heading down in a few hours, and we'll be sure to take a breath of fresh air and smell the flowers on behalf of all six of you."

"Thanks, Heather, and thanks for lingering and visiting with us. We enjoyed our last human contact for thirty months."

"Hey, we enjoyed soaking up a bit of the glory! Safe journey and Godspeed!"

"Thanks. *Olympus* out. *Olympus to Elysium*: no reason to wait, I want some gravity and a real shower. Let's get the docking sequence started."

"Acknowledged," replied Sergei. Will and Ethel nodded and floated across the tiny crew module to the shaft that ran past the *Elysium's* oxygen and methane tanks to its nose, where the *Cimmerium* was docked. Ethel would serve as the *Cimmerium's* pilot, Will the copilot.

Sergei steadily moved the *Elysium* closer to the *Olympus* until, after twenty-four hours, they were only a hundred meters apart. At that point Ethel separated the *Cimmerium* from the *Elysium* and moved it toward the docking cube, which was attached to the nose of the *Olympus.* At the same time David moved the ITV *Ausonia* to a different docking port so that it would counterbalance the *Cimmerium* and Sergei moved the *Elysium* toward a dock opposite the *Olympus*. One by one, over a six-hour period, the vehicles docked back together. The six of them had a joyful reunion in the docking cube. "Hey, we're actually happy to see each other!" said Laura. "That's a good sign."

"We're a family for the next two and a half years," commented Will.

"Not sure I'd go that far," she replied.

"Well, mother, let's take our seats for the spin-up maneuver," exclaimed Sergei.

Laura nodded and the six of them headed to the great room of the *Cimmerium,* where they strapped into their seats. Sergei sat in the bridge and began the spin-up command sequence. He gave an oral count down, then fired maneuvering thrusters on the two shuttles. As the four-spoked Columbus Interplanetary Transit Station began to rotate, gravity immediately could be felt. Will was relieved he now had weight and the up-down orientation that resulted. But within a few seconds he was surprised by how heavy he was getting, and the weight kept increasing. Laura, watching alarm spread across his face, laughed. “It’s not that bad, Moonman!”

“After seven months on the moon, it feels like I’m on Jupiter!”

“Spin-up maneuver complete,” announced Sergei.

They unbuckled their seat belts and stood. Will and David swayed in the artificial Martian gravity. Laura laughed; Shinji watched with the eye of a professional physician. “Take your time,” he said. “Artificial gravity produces coriolis we have to adjust to.”

“Not that bad,” replied Laura. She looked across the room, then proceeded to walk straight toward the galley. She was surprised when she almost crashed into the side of the ladder shaft. “Damn,” she said.

“We’re going round and round at what? Twenty-five kilometers per hour?” asked David.

“Twenty-four,” corrected Shinji. “If you run in the direction of movement you can easily double your weight; run in the opposite direction and you can cancel it out.”

“Until you run into a wall!” added Will. He walked carefully to the ladder shaft, where he looked up. It was now definitely “up”; they were on the bottom floor where the gravity was highest.

“When you go up the ladder shaft, climb the side toward the spin; that will push you against the wall,” reminded Shinji.

“Right. And to go down, you can literally slide down the opposite side of the shaft, because it will keep rotating toward you faster and faster as you descend. The straight shaft will function like a spiral because of rotation,” said David.

“That should be cool,” said Will. “But right now I have to get used to any gravity at all!”

“It’ll take a few days,” agreed Shinji. “But artificial gravity will make life easier.”

“I’m going to take a shower right now, in fact,” said Ethel. “Good riddance to wet towelettes!” She walked to the ladder shaft and climbed up to her bedroom.

“We’ve got chores and maintenance to do,” said Laura. “Shinji, do you need help with the plant growing cabinets?”

“No, they’re set up and functioning. The plants will grow better with some gee.”

“Will, any problems preparing for our flyby of 2015AS?”

He shook his head. “We just got new radar data with revised mass and diameter estimates. Average diameter’s just forty-six meters. Now they think it’s carbonaceous chondrite!”

“That’s smaller than they thought!” said Laura. “Too bad the flyby won’t occur in the middle of the trip; it’d break up the monotony. David, how are the inventories?”

“We’ve been accumulating waste water and sewage for ten days. Now that we have gravity, the treatment equipment will work more efficiently. We’ll see how quickly the accumulation gets processed.”

Just then Sergei slid down the ladder shaft from the bridge one level up. “How’s the trajectory?” Laura asked.

“Spot on. We may not need a midcourse correction.”

“Good.” Laura smiled and looked at the others. “Well folks, we’re on our way to Mars. Columbus 1 is in great shape. We’ve got the rest of the day off.”

The crew members dispersed. Will and Dave both slowly—almost painfully—pulled themselves up the ladder to the docking cube, then slowly slid down the shaft of the *Ausonia*. Will went to his room to finish unpacking, now that there was gravity. He lined up his mineral samples by type in rows on the shelves, removed the netting from the bed and the plastic retaining strips from the bookshelf, and finished placing useful items on his desk. Then he sat at his desk and looked out the porthole at the Earth, which was still reasonably large, though shrinking noticeably hour by hour. He felt tired; he wasn’t used to so much gravity. The shift to Martian gravity threw off his coordination, too.

The next morning he felt better. After breakfast and a quick crew meeting with mission control, he headed to his work station on the second floor of the *Ausonia* to review the latest data about 2015AS. The L2 Interferometry telescope—five ten-meter reflecting telescopes five hundred meters apart, located at the Earth-Sun Lagrange Point beyond the Earth—had pointed its mirrors at the object and had taken pictures almost as good as the ones they would take from a mere 15,000 kilometers. Earth-bound radar had bounced signals off it and determined its rotation rate with great precision. “It’s a fast rotator: once every five minutes,” Will reported to Laura, when she stopped by about 11 a.m.

“So; a collision fragment.”

“It also means the surface has no regolith; the rotational centrifugal force exceeds the pull of gravity. Our laser will have a clean target. Fast rotation is common among the smaller asteroids.”

“That was a problem with last year’s mission to 2021AR. Any further word about observatories planning to observe the laser bursts?”

“No. L2 will be watching, and that tends to dampen everyone else’s enthusiasm; no one else’s data can be as good. Besides, there’s a full moon two nights before. And now they’re saying it’s a stony, not a chondrite! The L2 data corrected earlier information. Albedo’s 0.15; chondrite is usually half that. The infrared absorption spectrum from L2’s observations detected lots of pyroxene.”

“Oh?” Laura was momentarily surprised. “Pyroxene’s a mineral I have never been able to visualize. It’s pretty rare on Earth.”

“No, it’s common in volcanic rocks, but the crystals are suboptic. They break down fast in contact with water and air. You want to see a sample? Come with me.”

“Really?” Laura was surprised by his offer and did not argue. Will stood and walked to the ladder shaft. She followed him up one level to his room. There, he reached for a sample.

“Here; this is a stony meteorite. Pretty boring and gray. It’s about half pyroxene.”

“Not much to see.” Laura took the rock, fingered it, rolled it around in her hand. “Where did you get this?”

Will pointed to his collection. “They’re all from the moon. In fact, they’re all from the last seven months. It’s not hard to pick up the entire suite of meteorite

classifications on the moon. You could do it in a few days." He grabbed a sample. "Vesta."

"Really!"

"Sure. V-type meteorites are reasonably easy to find. They were blasted from Vesta's south pole." Will picked up another tiny sample and handed it to her. She stared at it. "Limestone?"

He nodded. "From outside Tycho, though."

"Really? A piece of Earth on the moon." She held it with a new level of reverence.

"I was excited to find it. There are a lot of Earth rocks on the moon."

"Come to think of it, you were part of the team that found that 4.2 billion year old chunk of Earth in Aitken!"

"I was. That was quite special. It was the oldest known piece of Earth until an older piece was found last year. It confirmed theories that Earth once had a methane-ammonia atmosphere. I was part of the team that found the Venus rock two years ago."

"The *alleged* Venus rock."

"Sure; but it is. I've also found three chunks of Mars. Here's part of one of them." He handed her a tiny sliver of basalt.

Laura laughed. "You've brought a lithic menagerie, haven't you?"

"They're heading to my collection on Earth via Mars. They only weigh half a kilo; they fit inside my mass allocation just fine."

"I'm sure. It's a shame we haven't found a piece of Mercury."

“It’s a matter of time. The Europeans will be bringing back chunks in two years, anyway. We can thank the Moon-Mars transportation system; anything that can throw us to Mars can throw pretty good-sized cargos anywhere in the solar system.” He grabbed a rock from the back row. “Here; would you like a piece of nickel-iron meteorite?”

Laura took it, intrigued. She smiled and rolled it around on her palm. But then something changed in her eyes. She handed it back to him. “No, that’s okay. You keep it.” She turned away and looked at the pictures by his desk. “Are those your parents?”

“Yes.” He watched her closely; she seemed surprised to realize his father was light-skinned African American and his mother was of European extraction. She looked at him, noticing his wider nose and curly black hair, then looked away.

“Thanks for the geology lesson, Elliot. I’d better get back to my rounds.”

“Okay, Commander.” He watched her go, grieved by her reaction. He reminded himself that Laura Stillwell was an exceedingly difficult personality to read. You never knew what she was thinking or feeling.

He waited a minute for her to head down to the second floor, then he followed. She was talking to David about their inventories when he walked to his work station nearby. Laura wanted to recycle every atom they could. Their life-support equipment had thirty extra kilowatts thanks to extra solar panels the crew had grabbed from an ion tug a few days before departure, consequently the recycling systems could be closed even more efficiently.

As they were talking, and as if the life support system was listening, suddenly there was a loud bursting sound. They jumped. “What the hell?” exclaimed Laura.

They looked at a fountain of grayish water erupting from the top of the wall opposite them. The waterfall cascaded down onto computer equipment below.

There was the sudden flash of an electrical short, followed by momentary plunge into darkness. Then the lights came back on.

“Red alert!” shouted Laura. The ship’s computer, programmed to recognize her voice saying those words, sounded the alarm bells.

“It looks like the graywater reservoir burst!” said David. “It’s located right there, under the bathroom on the third floor.”

“Let’s salvage the computers,” said Will. He hurried over to the waterfall—smelly, it was sewage—and reach down to unlatch the work station beneath it, even though he got splashed. The water was hot. He tugged hard and the station moved across the floor, out of harm’s way.

Laura pushed a button on her earpiece. “Attention all crew! We have a bad sewage leak on the second floor of the *Ausonia.* Sergei, report to the *Cimmerium’s* bridge to monitor everything and coordinate with mission control. Shinji, get out your space suit in case you’re needed. Ethel, we need you here ASAP.”

“Copy,” said Sergei immediately.

“On my way,” added Ethel.

David hurried to a storage closet and grabbed a stack of cloth towels. The three of them spread the towels to soak up every drop they could. Ethel arrived a minute later with a special vacuum cleaner.

“How much have we lost?” asked Laura.

“Maybe fifty kilos,” replied David. “But it isn’t really lost; we can wash the towels and pour the water from the vacuum cleaner into the toilet in the other ship.”

“I’ll clean up the computer,” said Ethel. “Thank God it wasn’t on!”

“The plug shorted,” said Laura. “There was a big electrical discharge. We lost power for a second, then it came back on.”

“The power surge tripped the circuit breaker for the whole floor, then it reset itself. I’ll check the electrical wiring and circuit breakers, then the equipment.”

“We won’t be able to use the bathroom above us until the tank is repaired,” added David. “God, what a mess.”

“Why didn’t we detect this problem before it occurred?” asked Laura, angry.

“Ask Sergei,” replied David. “The tank has pressure sensors, so there should have been a warning.”

“The recycling systems work better in gravity,” noted Will. “Bacterial digestion of human waste is slowed by zero gee.”

“But in this case I suspect the temperature went up to 60 Centigrade or so, which would cause rapid breakdown of waste,” replied David.

“The water was hot,” agreed Will. This room’s going to smell for months. To clean it, we’ll need to use another hundred kilos of water.”

“Life support on the *Cimmerium’s* going to be working overtime,” growled Laura. “We’re not off to a good start any more!”

They kept up the hard and smelly work for an hour, washing from the Velcro-sensitive carpet and the walls the traces of human waste and shower water, then sucking up the entire mess with the wet vac. They did indeed use a hundred kilos of precious

wash water, though the result was reasonably good. As soon as she could, Laura got away and headed for the control room in the *Cimmerium.*

"Sergei, how did this happen?" she demanded as she entered the bridge.

He was startled. "Look before you accuse! This has nothing to do with our monitoring of systems! Look at the data!" he pushed a few buttons and called up the pressure graph of the sewage tank.

"It's pretty high!"

"No, it's at the high end of nominal! It went into the yellow zone just minutes before the rupture, but even that's not an emergency condition. Maybe the sensor is flaky, or maybe the tank had a really bad weld. Houston's asking whether we want to abort."

"Abort over a shit leak? I don't think so!"

"Well, they asked. I transmitted the clean up to them. I suspect some of it was broadcast live over cable to a million Mars fans."

"Our language was a bit salty, too," Laura commented unapologetically.

"Houston recommends that the three of us staying in the *Ausonia* move out for a few days until we fix the problem. The bathroom's already deactivated and locked. I've reprogrammed the air circulation so that the second floor has a slightly lower air pressure than the rest of the ITV; that'll keep the smells from spreading."

"Good. You can relocate to the empty bedroom on the *Cimmerium's* third floor across from me. Will and David can move to the crew modules of the *Olympus* and *Elysium.* We should set up the work area of the *Ausonia* for horticulture for the rest of the voyage and relocate the work stations for the three of you to the *Cimmerium*."

“Moving horticulture to the *Cimmerium* will take a week; the cabinets have to be dismantled to be moved through the shaft. And it frees up space for one work station.”

“I know, but the second floor here can accommodate four already, so with the one extra space that’s five. David can work in the great room of the *Ausonia* or in *Ausonia’s* spare fourth floor bedroom, or even on one of the shuttles. The plan to fly six people in the space for eight was a wise one.”

“So far. I just hope this isn’t the beginning of a string of bad luck.”

Laura scowled. “There’s no such thing as luck, Sergei, good or bad.”

“If you say so, Commander.” Sergei scowled back at her. “Please don’t accuse me of incompetence on a whim.”

“A whim? You’re too sensitive.” She turned and walked away.

3

2015AS

Sept. 2035

“Boy, it still stinks in here!” exclaimed Will.

“Be thankful we were able to put our horticultural cabinets in your old science lab, so you aren’t working here,” replied Ethel, opening one of them to pick lettuce. “The volatile imbalances are driving David crazy.”

“He worries too much. If the two ITVs have slightly different masses, it doesn’t make a big difference to the relative gravity. We can rebalance them every week, rather than every day.”

Ethel laughed. “That’s not his view.”

“Laura’s terrorizing him about it. She needs to relax.”

“She’s been hard to deal with since the accident. I suppose it’s the stress.”

“Why is she under so much stress, anyway?”

Ethel looked up. “It isn’t easy to be the female Commander of an historic mission. She feels she has to prove herself to the entire world. And the way all of us were selected was so political, you just don’t know what to make of it.”

“It wasn’t that political.”

Ethel chuckled. “That’s easy for you to say, Moonman! I’m still not sure why I was selected over Sebastian Langlais; probably because the French wanted David, and since he was a male geologist the other slot had to be filled by a mechanic and engineer who was a woman. You were the natural choice for the Americans; you’ve published more on lunar geology than anyone else in the astronaut corps, you work well with

terrestrial scientists, and you know Mars really well. The rumor is you didn't even want the assignment."

"What? Of course I wanted it!"

"But the moon's your baby, not the Red Planet."

"True, I've made my career on lunar geology. And I love roving around the moon; it's incredibly exciting. But I don't dislike Mars. It'll probably grow on me. The moon did."

"I hope it grows on me, too. Anyway, consider Laura's situation. NASA has two slots and one is filled by their crack geologist. He can't be commander because he has never commanded and isn't military, and the commander of a big mission usually has been someone with military experience. NASA wants to appoint Jerry McCord commander; he commanded a mission to Sun-Earth Lagrange 2 and the mission to Asteroid 2011AR. But he isn't a good mechanic and NASA can't send two men. One of their slots has to be filled by a woman. So, voilà! They chose a woman Air Force pilot and mechanical specialist to be Commander who has flown one mission to Sun-Earth L2 and commanded one mission to the moon. She's not Commander because she's Laura Stillwell, but because Will Elliott's the American geologist."

"They could have made a European the Commander."

"Not a chance. Not on Columbus 1. The Commander had to be American."

"I suppose. Perhaps that explains why she tried to bump me. But I can't live my life as if I am the cause of Laura's troubles. It's not my fault. Maybe you could remind her of that."

"I'll try. But she's been rough on everyone. Sergei and she have had a few fights."

“I noticed one, but with my quarters and work space elsewhere, I haven’t seen her in action as much as you have. David’s upset, too.”

“She’s always pushing him around.”

Will sighed. “Well, I don’t want to backbite about the Commander. Look at this one!” He held up a very long carrot. “So big, and it’s only six weeks old!”

“High CO_2 concentrations and constant light will do it. It’s amazing how much food these cabinets make.”

“Shinji told me they’re recycling nearly all our carbon dioxide output and producing plenty of spare plant matter for the soil organisms, not to mention the chickens and rabbits.”

“It’s a good experiment and makes me feel much better about the trip. I’d rather be going to Mars with a greenhouse and a few chickens and rabbits than with just supplies. The thought we can grow some of our food is comforting.”

Will nodded. “I agree. I even have some seeds with me.”

“Really? Does Shinji know?”

“No. Yamamoto knew; he encouraged the idea, as long as the seeds were certified germ-free. But I haven’t told Shinji yet. A lot of the seeds are for flowers; I wanted to make sure we had things that were not just strictly practical. A few are tree seeds.”

“Trees!”

Will shrugged. “Why shouldn’t we have trees on Mars? Long after we’ve left, they’ll still be growing.”

“I’m not sure where!”

“The great room of the hab; it’s got some nice, big windows.”

“That’s an idea.” Ethel closed the cabinet she had been harvesting and opened another one. “Oregano for the pasta tonight.”

“Here, let me help; I want a lot of oregano.” Will walked over, looked in, and immediately shook his head. “Maybe next week.”

“Or the week after; this oregano doesn’t like hydroponics.”

“I guess not. So, yesterday you were telling me about MIT.”

She smiled, pleased he asked about her. “That’s right, and the strange circumstances that got me in, as an undergraduate. I was just about the only Scot there. But it worked out well. My first summer I drove most of the way across the U.S. to work in Yellowstone Park for the summer as an automobile mechanic.”

“Really?”

“I wanted a chance to be a garage mechanic and tinker with cars, and I wanted to see Yellowstone, so I combined them together! A lot of women work as mechanics there.” Ethel smiled. “That was quite a trip. It really helped me understand Americans.”

“Are we that inscrutable?”

“No, but there are aspects of American culture that strike Europeans as utterly barbaric, like the fetish with guns and capital punishment. It takes some getting used to.”

“I agree, I’ve never understood them either. Laura would, though.”

“Yes, she’s a southerner, and quite conservative. I’m always surprised by that. Now your parents; one was black and one white, right?”

“My father was multiracial, actually; he was half black and half white, with a bit of Cherokee as well. My mother’s German, Polish, and Mexican; her mother’s mother was from Veracruz. So I guess I’m pretty typically American.”

“That’s typical of everyone nowadays, isn’t it? I say I’m a Scot, but my father’s mother was English and my mother was raised in Canada. Sergei may be Russian, but he has a German last name and his father was a Muslim named Ali who spoke Kazakh. And David is half French, half Moroccan.”

“I call him Daoud in private. That’s his real name.”

“Really? I didn’t know. What about Laura? I suppose she’s a mix as well.”

“Probably a WASP mix. Shinji is just Japanese; but then, most Japanese are ‘just’ Japanese. I’m glad we represent the diverse flowers of the human garden. It’s the way the first human expedition to Mars should be.”

“I agree. I just wish our little United Nations got along better.”

“It is a problem.”

They went back to picking vegetables; Will finished the green beans. “Say, you promised to give me another lesson about Martian crustal rocks, remember?” said Ethel. “Your explanation of the history of Martian volcanism was really illuminating.”

“Good. I wish we were more certain about the progression of magma types. The various landers have given us a rough picture of crustal geochemistry. There are two basic rock types, andesitic and basaltic, rather like the terrestrial crust, though the andesitic is not as high in silica as the earth’s continental crust and is much rarer. That’s to be expected; Mars had little plate tectonics. Say, I should show you. Want to see?”

“See what?”

“The two basic rock types. I have samples. The lunar surface has Mars rocks and if you tune your eyes, you can spot them.”

“And you’re famous for that. Sure, show me.”

“Then come on.” He turned and headed up the ladder shaft with his vegetable bag; she followed. One level up was his bedroom; after a week of sleeping in the *Olympus,* he had returned to his room. She was curious and started to look around. “Your parents?” She pointed to a picture.

“Yes. Mom’s retired and dad passed away a few years ago.”

“I’m sorry. Do you have kids?”

“No. Jamie and I wanted kids, but she didn’t want to be a single parent and I wouldn’t quit the Corps. She asked me for a divorce about two years ago.”

“I’m sorry. I’m divorced, too. The Corps is not an easy life for a married person or a family person.”

“No, not at all.”

“Have you considered marrying again?”

Will considered a moment. “If I retire from the astronaut corps. Right now, it seems incompatible with romance.”

“I know what you mean. Alas, I agree.” She looked at him, a pained expression on her face.

Will changed the subject by picking up a small rock. “This is andesite. It’s pretty typical, if our samples and the chemical analyses are to be trusted.”

“Hah.” Ethel turned the piece over and scrutinized it closely. “Large crystals.”

“Yes, it’s usually intrusive and slow cooling. Here’s basalt; browner on weathered surfaces, black on fresh surfaces, and microcrystalline. Mars has a lot of vesicular basalt—with bubbles—but this piece lacks them.”

“Quite a contrast.” She looked at his samples. “What else do you have?”

"The usual. Stony meteorite, like 2015AS." He handed her a grayish chunk. "Then there's the V-type, which came from Vesta, and chondrite, and nickel-iron."

She took a chunk of metal from him. "Pretty."

"Yes, I think so, too."

"What's this? Very pretty!"

"Lunar glass from an impact melt; it's usually not as multicolored as this piece."

"Wow." Ethel picked up a piece and looked it over closely.

"Take it, if you'd like. I have several spares. I collected it as a gift."

"I don't want to take it away from someone else."

"I didn't collect it for someone in particular; I picked it up to give away. You can help me discharge my obligation."

Ethel smiled. "You're very kind, Will." She put the piece in her pocket.

They headed to the *Cimmerium* with their bags full of vegetables and herbs. Will started cooking; he was the best cook on board and made the meals special. As soon as he arrived Sergei left, so Will kept one ear on the bridge as well.

The fax machine began to receive a document; unusual, since most things arrived as email attachments. They used special paper that could be passed through a cleaning solution, allowing it to be reused. When the machine stopped, Will wiped his hands and picked it up. His Russian wasn't great, but it was sufficient to understand what had arrived. He immediately called Sergei. "Hey Sergei, this is Will. You just got a private document by fax."

"Thanks, I'll be right there," Sergei replied.

It was a matter of seconds before he came down the ladder shaft and grabbed the document, which Will pretended he had not seen. Sergei looked grieved as hurried off to read the draft of his divorce settlement.

He hadn't returned ninety minutes later when dinner was served. The five of them gathered around the pasta and salad and munched down. "Will, you're incredible," said Laura. "Master cook as well as master geologist. I vote that you cook dinner every night."

"Maybe not every night," replied Will with a wan smile and concern in his voice.

"Where's Sergei?" asked David. "He loves Will's pasta."

"He received a fax about an hour and a half ago," replied Will.

"It must be his divorce agreement," said Laura. "It was expected."

"So, how many of us are divorced now?" asked Ethel. "Four?" She looked around, then fixed on Shinji.

"Not me; I've never been married," he replied.

"That's one solution," commented Laura.

"Well, a lot of people of my generation haven't gotten married."

"One of the reasons the population of Japan will have halved by the end of this century," agreed Laura. "So, David, how do you do it?"

"I have a traditional wife and she lives with my extended family, so she has a support system."

"The traditional approach," summarized Laura. "I could have used a husband like that."

"Everyone wants a 'wife,'" agreed Ethel. "And no one wants to be one."

“The solution, clearly, is partnership,” said Will. “Split the work fairly and keep the husband and wife in the same place, and it really isn’t difficult.”

Laura laughed. “But men don’t want to split the work fairly and they don’t want to stay put; at least not the ones in the Astronaut Corps!”

“You’re away a long time; it isn’t easy,” agreed David.

Will picked up Sergei’s plate and loaded it with pasta and salad. “I’ll be right back.”

“I’d leave him alone,” cautioned Laura.

Will ignored her. He looked up the ladder shaft to make sure Sergei wasn’t coming down, then pushed a button for the third floor. The platform he was standing on began to move up the shaft. It was easier to take the elevator than climb, with a plate of pasta in hand.

He got off at the third floor, where Laura’s room was also located; Sergei had never moved back to the *Ausonia*. He knocked.

“Who is it?”

“Sergei, I’ve got your dinner.”

“Oh. Thanks, come in.”

Will opened the door and walked in slowly, mindful that the roughly lunar gravity of the third level required care with plates of food. Sergei was sitting at his desk. He had puffy eyes. Will saw Earth out the window.

“You’ve got a good view from this side of Columbus.”

“Yes. I’ve been staring at it, watching it move in a circle as we rotate.”

“I thought you’d like some pasta; you’ve always said you like the way I make it.”

"I do. Thank you, Will."

"Is there anything I can do?"

Sergei sighed. "I wish someone could persuade my wife not to divorce me, but I doubt you can do that." He shook his head. "I never should have accepted this assignment. She can't handle a thirty-month separation."

"I'm sorry. We were just talking downstairs about how most of us are divorced. My wife and I split up two years ago. It was a really terrible blow. I was wounded for a long time."

"What did you do?"

"I cried, then moved on. What can you do?"

Sergei said nothing. He stared out the window. "Thanks Will. I appreciate your effort to help, I really do."

"Any time. I guess I'll go back down, now."

Sergei nodded. Will rode the elevator platform down to the great room at the bottom of the *Cimmerium.*

"How's he doing?" asked Ethel.

"Alright, I guess."

"You should leave him alone, Will," admonished Laura.

Will decided not to argue with her. They ate in silence until someone mentioned the news about the American presidential campaign—the primaries now started fourteen months before the actual election—and the conversation turned to that.

Out came the after-dinner coffee and small portions of orange sherbet. Once they were finished, David and Will headed up the shaft to their rooms and Shinji turned to

cleanup duty. Laura headed to her room. But first she knocked on Sergei's door. "How are you doing?"

A pause. "Okay, I guess."

Laura opened the door. Sergei was at his desk. He had eaten about half his food. "I'm glad you aren't starving yourself."

"Well, I guess I could be eating more."

"Is it the divorce settlement?"

He nodded. "It says exactly what we had discussed before departure. But to actually see it in print. . ." He shook his head.

"It's pretty final looking, once it's on paper." She walked over. "But what can you do? You won't be back to Earth for twenty-eight more months."

"I know, that's the problem. I'll sign it and fax it back tomorrow." He shrugged.

She put her hand on his shoulder. "My husband and I split up three years ago, and it took me at least a year to recover. Divorces are awful. Thank God we didn't have any kids to drag through the process."

"Yes, I'm relieved by that as well."

She began to rub his shoulders with both hands. He looked up at her, surprised. She looked steadily at him. "Let's make love," she whispered.

Sergei was surprised for a moment. He looked at her, considering the offer. He stood, and she was still uncertain what he would do. Then he kissed her.

The flyby of 2015AS occurred two days later. “One point three kilometers per second,” said David, as he and Will sat in front of the remote sensor controls. “That’s all we’d need to rendezvous with it.”

“Twenty-five tonnes of fuel,” added Will. “But the first mission to Mars doesn’t do extras.”

“I know. But Columbus 2 will probably visit 2018KM20.”

“I hope so.” Will checked the screen in front of him; Ethel was in the bridge trying to fix a problem with the radar and occasionally he had to give her feedback.

“Of course, Phobos would require only half a kilometer per second of delta vee to visit, and another half to head for Mars,” persisted David.

“After we get to Mars, we can ask permission for that. It’s the only way the fuel making plant is going to be fixed properly; they can’t seem to fix it by remote control.”

“What are the chances we’ll get a green light for that?”

Will shrugged. “One percent. The plant is making fuel very slowly using the one functioning drill and there’s already an adequate emergency supply for us; furthermore, plant number 2 is on the way and it should function okay. Besides, NASA never wanted it. From their point of view, it was a superfluous Russian contribution to the mission. So Columbus 2 will get the green light for the repair mission, and by then the Russians may land an inflatable hab and some emergency supplies there.”

“I’m afraid you’re right.”

Will’s earpiece beeped. “Is the radar on line now?” Ethel asked.

Will pressed an icon. “Affirmative! What did you do?”

“Gave the system a kick.”

“Thanks, Ethel.” Will turned to the radar, which quickly acquired a lock on 2015AS. “The entire remote sensing package is functioning nominally, now,” he reported to Laura and to ground control. “Resetting the radar fixed the problem. I’m powering up the laser now.” He pushed a button on the screen and the ship’s laser began to pull power from the solar panels.

A detailed radar image of 2015AS appeared on the screen. Will stared at the little a chunk of debris ejected from the asteroid belt, probably by a close encounter with Jupiter. “So Daoud, is it potato-shaped, or are potatoes asteroid-shaped?”

David laughed. “That potato could incinerate a city if it hits Earth.”

The laser’s sight appeared on the screen; it was powered up and ready. Will touched his finger to the screen and pulled the sight to a depression in the surface. Then he pushed the “fire” icon. A spot appeared on screen.

“I’ve got my first hit, right on target.” He looked to David, who nodded.

“We got a spectrum.” A moment later it popped up on the screen in front of David and Will leaned over to look.

“Yep; looks like stony meteorite to me,” said Will.

“That’s to be expected,” said David. “But even the expected is welcome.”

“Exactly. If we could plant a drill on a rock like this, we could extract tonnes of water. It could be worth a lot of money.”

“This one, and a half million others in this size range,” agreed David.

Will maneuvered the laser to another spot and fired it. They had twenty hours of steady work ahead of them; precious time to gather lots of data.

4

Christmas

Late Dec. 2035

David Alaoui pulled himself up the ladder shaft quickly as he neared the hub of Columbus. The last two floors had very low gravity and he was able to move up the shaft quite fast. He passed from the *Ausonia* into the docking cube, where he paused briefly to assess the *Cimmerium's* ladder shaft. No one in their right mind would throw themselves down a five-story shaft on Earth or even on Mars, but artificial gravity worked very differently; one was actually weightless except for centrifugal force, and one experienced no centrifugal force until one had lateral movement that was arrested by a floor or wall. David and Will had an informal contest to see who could go farther down a ladder shaft without touching a wall. Once one came in contact with a wall, its rotation pushed one sideways and created centrifugal force that pushed one down the wall to the bottom of the shaft. Even though the shaft was straight, its circular motion converted it into a kind of slide, and one could control the speed of descent by using one's hands and feet.

David had gotten fairly good at leaping down the shaft in the two months since the flyby of 2015AS. He usually could go halfway down before the wall swung around and collided with him. From there down, sliding was easy and fun.

He stared at the shaft to get a sense of its width and reminded himself that the bottom was rotating round and round at about seven meters per second or fifteen miles an hour. Ready, he launched himself down and sideways.

A perfect trajectory traced a slight arc in the rotating shaft, almost touching the leading wall, then eventually settling back against the trailing wall. But David had a bit

too much sideways motion and in a second found himself bumping against the shaft's leading wall. He slid along the leading wall a short distance, then separated from it.

Just as he was weightless again, he drifted by the third floor landing oriented so that he could see the porch plainly; and as fate would have it, Laura Stillwell chose that very moment to open Sergei Lansburg's door and step onto the porch, stark naked, as she headed for the bathroom.

David floated by her just one meter away. He was instantly embarrassed, but he disappeared down the shaft too fast to apologize. Laura saw him, shocked; then David was out of sight and could not see her face. Since he was in the middle of the shaft, he could not easily grab anything.

He bumped against the trailing side of the shaft, distracted by the incident. He clumsily grabbed the wall with his hands, but because he had traveled farther than usual, he hit the wall harder. It slid him down the shaft and pitched him suddenly onto the great room's floor, which he hit like a sack of potatoes.

Shinji jumped up from the breakfast table. "Are you alright?" he asked.

"What happened?" asked Will, following closely behind.

"Oh, I was just incredibly clumsy, I guess," replied David, standing up. His right ankle hurt; he winced slightly and shifted his weight to the left foot.

"Let me take a look," said Shinji, and he reached down to pull up David's pant leg before he could protest.

"No, I'm okay," David said. "But thanks, Shinji."

Shinji felt David's ankle briefly, noticed whether David was wincing, then was satisfied. David walked to the table, limping slightly.

“Here’s your coffee, Daoud,” said Will. “I already poured it for you.”

“Thanks.” He looked over Shinji’s shoulder at the Japanese text on his attaché. “The news?”

“Yes, *Asahi Shinbun*, a major daily newspaper. They’re discussing the presidential campaign in the United States.”

“Who wouldn’t; we’ve been debating it on board,” replied David. Laura was the only one who liked the challenger, a Protestant Fundamentalist and his gay Orthodox Jewish vice presidential candidate, who had won their party’s December primaries decisively. Eleven months of cut-throat campaigning lay ahead.

“At least he favors Mars exploration,” noted Will. He was the only crewmember who hadn’t expressed vociferous opinions.

David looked at the pancakes Will had made, with frozen strawberries. He was still too upset to eat. “I think I’m in a lot of trouble,” he said to Will, in a low voice.

“Why?”

A long pause. “The reason I fell is because as I sailed down the shaft, Laura came out to head for the bathroom, and she was, ah. . . naked.”

“That is embarrassing. But you may be more embarrassed than she. She doesn’t strike me as the modest type.”

“Nor are you the first one to see her naked,” added Shinji.

“There were unusual circumstances.” They looked at him, puzzled. “She was coming out of Sergei’s room.”

“Oh. You’re right; that may be a problem.”

“Possibly,” said Shinji cryptically.

There was a faint sliding sound in the ladder shaft and Ethel landed dramatically in the Great Room. “Good morning,” said Will, smiling. He had come to like her more and more; she was straight-talking, smart, had a pleasant sense of humor, and was pretty.

“Good morning,” she responded with a smile. “Good morning Shinji, David.”

“Morning,” they replied.

Ethel grabbed her cup and filled it with hot water; she was a tea drinker and NASA had dutifully provided her with one tea bag for every day of their mission. Yesterday’s bag was still in her cup and she added a new bag to it; the two would be adequate to make her an afternoon tea as well. She came to the table and loaded her plate with pancakes.

“I need help today changing the carbon dioxide filters,” she said. “And we have to shut down the *Cimmerium’s* Sabatier reactor to fix a compressor.”

“I can help,” said David.

“It’s not my expertise,” replied Shinji. “But I’m busy with the plant cabinets. The strawberries are about to bear, so I have to reprogram their lighting, temperature, and moisture levels. The lettuce needs the usual shuffling of volume; I’m feeding the mature plants to the rabbits today. It’s also time to cut back the beans to maintain their output.”

“It’s amazing how much time the plant cabinets take,” said Ethel. “We’re spending one person-day every day on them.”

“True; but we’re getting a quarter of our food from them, it’s fresh and not stored, and we don’t have anything else to do anyway,” said Shinji.

“Keeping us busy is half the reason,” agreed Will.

They went back to their breakfasts. A minute later there was a sliding sound. Laura appeared from the ladder shaft. She was furious.

“Don’t you ever spy on us again,” she said to David, before anyone could say anything. “Who do you think you are? I should assign you to every dirty task in the ITVs for the rest of the voyage out and the entire voyage back!”

“Laura, I was not spying! God forbid, I was just coming down the shaft and you came out! I was not trying to see anything!”

“Then why didn’t I hear you coming? You were hiding the sound!”

“No, I wasn’t! Will and I have a contest to see who can sail farther down the shaft before touching a wall. I can usually clear the entire fourth floor before touching the wall on the third! But in that case I did touch the wall; maybe you didn’t hear it, but I did!”

“We do have such a contest,” exclaimed Will.

Laura looked at Will with fury in her eyes. Then Shinji interrupted. “But as mission doctor, I am banning this content from now on. David, you almost sprained an ankle when you landed here.”

“Definitely, no more sailing in the shafts!” exclaimed Laura. “It’s dangerous to the sailor and to others who might step into the shaft at the same time!” She looked at the others, embarrassment forming on her face. Even if David hadn’t given away what he had seen, it would be hard for him not to now. Laura turned to the counter. She grabbed two plates, loaded them with pancakes and strawberries, filled two cups with coffee, grabbed forks and knives, and then retreated back up the shaft on the elevator platform.

“What was that all about?” asked Ethel, baffled.

“I sailed down the shaft while Laura came out to use the bathroom, naked.”

“Really? And she reacted like that?”

“She came out of Sergei’s room.”

“That explains a few things. Our ceilings are not as sound proof as people think.”

“Alright, now we all know that Laura and Sergei are having a relationship,” said Will. “What’s the protocol? Ignore it?”

“Better let them decide,” replied Shinji.

“I’ll raise the matter; I can talk to Laura,” said Ethel. “This is a major violation of regulations. I hope they’re being careful.”

“We have quite a supply of birth control pills on board, and everyone knows it,” said Shinji.

“This is a thirty-month trip,” noted Will. “It’s not the four to eight month mission that is typical for low earth orbit or Shackleton. I hope we can talk seriously about how we can strengthen our friendships. We have to depend on each other for our lives, yet we barely know each other, we snipe at each other, we’re uneasy together, we don’t share much common culture, and now we have favorites. This is a problem.”

“I agree,” said Ethel, and David and Shinji both nodded. “But I think we need to talk about it when all six of us are together.”

“Okay,” agreed David. “I guess that won’t happen today.”

Ethel didn’t try to talk to Laura right away; she had to let things cool off. Laura and Sergei didn’t come to lunch or dinner that day, and the next morning they came at different times. Normally, breakfast was followed by a short staff meeting to talk about

the chores; Laura talked to individuals at their work stations instead, except David, to whom she sent emails.

Everyone did show up for supper the next night because Will was cooking. Conversations were pleasant, but avoided all personal matters. When they finished eating, Ethel turned to Laura and whispered “Say, I need some advice. I’m trying on some clothes over the web; can you advise me a bit?”

“Sure; now?”

“If you’re free.”

“Of course.” Ethel nodded and headed for her room, Laura right behind. As soon as they entered, Ethel activated her attaché and connected it to the wall screen. “I might as well start with my problem: buying something for my mother’s birthday. She really likes sky blue, and she needs some new dresses for church.”

“And you have her profile?”

“Yes, she gave it to me before I left, so that I could order things for her. Let me show you the two final choices.” Ethel pushed some buttons to call up the website of a popular clothier. The screen split in half and two images of Ethel’s 65-year old mother appeared, modeling two dresses. The images walked down two parallel aisles, paused, turned to the right, then to the left, turned around, turned to each side again, then walked back.

“Again,” said Laura to the attaché, appraising the images carefully. “I think the right-hand one looked better on her. Is the hair the right shade?”

“Yes, and my mom wears it that way. I spent a lot of time getting the image customized properly. She’s concerned about hem lines.”

“Then definitely the right hand dress.”

“That’s what I thought, too. Let me show you a dress that I just found; I like it very much.” Ethel pushed a few buttons to call up her own profile and a particular dress design. The computer paused for the slightest second, then Ethel appeared walking down the aisle, modeling a very stylish Paris creation in mauve. She smiled to watch a simulated image of herself modeling the dress.

“The cut flatters you,” agreed Laura. “Yes, this is a nice one. How much?”

“A mere $15,000.”

Laura laughed. “It would be nice to buy something like that! I suppose after we get back we’ll have the money to buy such outfits, and we’ll be in so much public limelight we’ll have to have an impressive wardrobe.”

“That’s what I was thinking, too. We’ll have to shop and buy on the return flight. Say, I saw something I thought would look good on you.”

“Really? Show me.” Laura sounded eager.

Ethel nodded and pulled up the outfit number, then Laura opened a window, typed in her password, and called up her profile. A second later Commander Laura Stillwell was walking down the aisle, modeling a white and green evening gown.

“You’ve got my colors down,” said Laura approvingly. “It’s a bit low cut for my taste, though.”

“I’m always surprised by how conservative your taste is.”

“I’m from a conservative southern family.” Her drawl thickened a bit.

“That sometimes surprises me, too. Say, what do you think of this.” Ethel punched some buttons and called up another evening gown, which she projected onto her own image.

“Wow! Gorgeous; conservative and formal, but a real knockout.”

“I thought so, too. I wish I could wear this for Will; I think he’d like it.”

“Yes, he would. But I doubt he’d be into sales fantasies like this.”

“No; men usually aren’t. I’m glad you don’t mind.”

“Not at all; it’s fun.” Laura paused. “So, you like Will?”

Ethel shrugged. “Sure; he’s sweet. And he likes me; I can tell. But I don’t know whether I want it to go anywhere on a mission like this.”

“I know what you mean,” said Laura. She frowned; she could see where Ethel was going. “Where would you like it to go?”

“It’s hard to say. But on a small vessel like this, if we did start to fall in love, I suppose everyone would know, and it’d be hard for us to do anything about it. For better or for worse, I think the six of us are like a big family of brothers and sisters for the next two and a half years.”

“We aren’t much of a family.”

“Some of us were talking about that the other day and decided we probably need to work on it.”

“That’s true. Did you come to any conclusions?”

“Perhaps. First, that if two people become a couple, the rest of us need to know whether to ignore it or acknowledge it. Otherwise we’ll constantly be stepping on toes.”

“I see. I’ll . . . keep that in mind. Anything else?”

"You do realize that David wasn't spying on you?"

Laura's face tightened. "He'll get over that. What else?"

"Let's do something to bring us together more."

"Okay. Christmas is coming up in a week; we could plan a program for that. We don't have to give presents, but we could do some decorating and have a big meal."

"Hum. That might be good."

"Leave it to me, I'll take care of it," promised Laura.

They looked at a few more dresses, then Laura headed to her room. She knocked on Sergei's door. "Are you there?"

"Sure; come in."

Laura walked in. Sergei was lying in bed watching television. "Say, what do you think of a Christmas party?"

He thought a moment, then shrugged. "I guess. It's not something in my culture, you know. I'm not even sure I'm Christian; I don't go to church. My father was Muslim and my mother Jewish. Neither was a believer."

"Really? I didn't know that. I didn't know there were Muslims in Russia."

"Millions; some are only a few hundred kilometers from Moscow, and a lot live in Moscow now. But my family comes from Kazakhstan originally. Well, not originally; the Landsbergs were Germans who settled in Russia four hundred years ago, then ended up in Kazakhstan two hundred years ago and intermarried with the natives after the Communist Revolution. My father's first name was Ali."

"Like Muhammad Ali; I guess he was Muslim."

"More or less. My father was a Communist."

"Ah. Anyway, will you participate in a Christmas celebration?"

"Sure. I already said so."

"Good. I better check with Shinji." She headed up one level to Ethel's and Shinji's rooms. When Shinji didn't respond, she went down to the second floor and found him at his work station. "Shinji, I was thinking we'd plan a Christmas party, to bring all of us together a bit more. How does that sound to you?"

He shrugged. "Sure."

"I don't know whether you're Christian or not—"

"I'm not, but that doesn't matter. Christmas is popular in Japan."

"Well, we can make it popular here, too."

"Good. Okay."

She turned away and returned to her room, thinking about ways they could celebrate together. The next morning after breakfast—she didn't want to mention it there—she went to look for Will, who was at his work station in the *Ausonia*. He was taping a video interview, playing back the journalist's questions one at a time and answering each on his attaché. She waited patiently and watched; Will had a warm personality and was very articulate, so he was good on television. It made her jealous, as she was never quite what the reporters wanted, and they never asked her the questions she wanted.

"I hope you have other things to do today than just interviews," she said, after he finished a response.

"Of course; the long range sensors are trained on Mars and will take some of my time. Our telescopic camera is tracking dust storms."

“How’s the Marineris storm?”

“Still abating; by the time we get there it should be totally ended, especially since the dust storm season ended months ago.”

“Tell that to the Marineris region. Say, I was talking to Ethel last night and we decided it’d be a good idea to plan a Christmas party. It’ll help bring everyone together, break the ice a bit more, and build more community here. You can help a lot; not only by cooking, but by spreading the Christmas traditions. Shinji and Sergei don’t celebrate Christmas much.”

“I’m sorry, Commander, but neither have I. You see, my parents weren’t Christians; they were Bahá'ís.”

“Bahá'ís! I’m beginning to think I’m the only Christian on board! But Bahá'ís believe in all the religions, right? Don’t Bahá'ís celebrate Christmas?”

Will shook his head. “No, not really. We celebrated with my dad’s parents a few times, but my mom’s parents were Bahá'ís as well. My ex-wife was Catholic and I celebrated Christmas with her folks a few times, but celebrating just meant exchanging presents and eating turkey together. I can cook us a nice meal, but don’t ask me to sing any carols!”

“I see.” She shook her head. “And what are you? Are you Bahá'í, too?”

“I’m on the books as a Bahá'í, yes, but I haven’t had any time to do any Bahá'í things for about fifteen years. Who has time for religion?”

“Well, *I* did. I went to the First Baptist Church of Clear Lake every Sunday when I was home.”

“Like I said, I can cook, if you want.”

“Good. Can you ask David?”

“Ah. . . I think you should ask him. I’m not at liberty to say why.”

“Oh? I’d rather not have to ask him.”

“Well, I would prefer it that you did. He’s downstairs right now.”

“Alright.” Laura turned and headed for the ladder shaft. She jumped down one level—easy to do in Martian gravity—then walked over to his work station. David was busy with life support maintenance work. He looked up as she approached.

“I take it systems are nominal?” she asked.

David nodded. “As much as can be expected, after our little sewage leak. Until the tank and the contaminated wall and its electrical systems are replaced, we’ll be jury-rigging the *Ausonia’s* life support systems periodically.”

“Ground control promised me yesterday that they plan to launch the ITVs *Syrtis* and *Solis* early next year and dock them to International Space Station 2, so they can be broken in for a year before flying. Columbus 2 will get used equipment; but equipment with all the bugs worked out.”

“Good!”

“Say, I want to invite you to a Christmas celebration. I thought it’d be a nice way to break the ice and get to know each other better. We can have dinner, decorate the grand room and sing a bit. Could you contribute something from France?”

David looked at Laura, surprised. “Commander, what religion do you think I am?”

“I suppose Catholic; you’re French, after all.”

“Are you aware of the fact that twenty percent of the population of France is Muslim?”

“What? I had no idea French Catholics were becoming Muslims!”

“Commander, they aren’t converting. You don’t understand. I may be a French citizen, but my family is from Morocco originally. My wife and kids live in Fez. We’re Muslims.”

“Oh really? I had no idea.”

“What sort of name did you think Daoud Alaoui was?”

She shrugged. “French.”

He laughed, which angered her. “No I’m afraid not. ‘Daoud’ is Arabic for ‘David.’ And ‘Alaoui’ is a very common last name in Morocco. Of course, my family isn’t Arab; we’re Berber.” He pronounced the last word the French way.

“What’s a ‘bear-bear’?”

“The Berber were the inhabitants of the land before the Arabs arrived. Most Moroccans are at least partially Berber. But getting back to the Christmas party idea; I don’t feel comfortable with it. And my family definitely won’t like it. For that matter, since the world will know about anything we do here, I’m not sure the French will be particularly happy about it, either; it’s a secular country. Some will; some won’t.”

“Maybe we should do New Year’s instead, then. That’s neutral.”

“True. Maybe, Commander, we should ask everyone what they think, instead of deciding for them?”

“Perhaps you have a point. This is fairly personal.” Laura thought a moment, then pulled out her communicator. She punched in the number for Columbus’s intercom

system. “Attention, all crew. We’re going to have a quick meeting in ten minutes in the *Cimmerium’s* great room to settle the Christmas issue. See you there.”

She closed the communicator. David looked at her. “I apologize if I was a bit short with you. Muslims can be very sensitive about Christians and their attitudes.”

“I understand. And. . . I apologize if I unfairly accused you, the other day.”

“Thank you.”

Laura turned and headed for the ladder shaft. David saved his work, then followed her. Will heard him coming up the shaft and came over to join him.

“What did you say to her?”

“That I was Muslim and that maybe we should all decide what we to do together.”

“Good!”

“And she apologized to me.”

“Really?”

“Yes. I apologized for being short with her. I wasn’t short with her, but I thought I’d apologize anyway. She reciprocated.”

“Good. So, she *can* apologize. I’m glad to hear it.”

They climbed up the *Ausonia’s* ladder shaft to the docking cube, then looked at each other and at the ladder shaft stretching toward the bottom of the *Cimmerium.* Smiling, Will launched himself down, managing to get as far as the third floor before touching a wall. David followed and managed to go slightly farther. They both grabbed the ladder’s rungs and finished their descent on the ladder. “I beat you,” he said quietly to Will when they both reached the great room at the bottom.

The two of them had come the farthest, and thus were the last to arrive. Laura, Ethel, Sergei, and Shinji were seated at the table, waiting.

"Okay," began Laura. "I had proposed a Christmas event, but it turns out Ethel and I are the only two Christians on board. The idea is to do something to bring all of us together a bit more and to have fun together. I thought—"

"I have a suggestion," said Ethel, interrupting. "It's very simple. I'm scheduled to cook supper on Saturday night, and I'm not particularly good. Will's scheduled to clean up, and I don't mind doing that. If he and I can switch chores, we could have a nice dinner, and maybe watch a movie together afterward."

Sergei's eyes lit up; he was a movie buff. The others looked interested as well.

"Oh," said Laura. "I was going to suggest something for New Years instead of Christmas."

"How's this," suggested Will. "Something for Christmas is good for the media, but it doesn't have to include all of us, so why don't a few of us do something for the public? Apollo 8 did a Bible reading while orbiting the moon. I could help pull that together. We could do something else together for New Years; that would be fun. *And*, I wouldn't mind switching with Ethel and preparing a meal Saturday."

"All three?" asked David.

"Why not. We could do something for an Islamic holiday too, if others wanted to help. I'd be willing."

"So would I," added Sergei. "My father was a nominal Muslim, and his parents were fervent Muslims."

"Ramadan starts in October," said David. "It includes two festivals."

“Perfect,” said Will. “We’ll even be on Mars by then.”

Laura looked at her crew, a bit bewildered. “My, that was the fastest staff meeting we’ve held,” she said. “Okay, let’s plan a small Christmas event, a Saturday dinner, and a New Year’s celebration. Fine with me.”

5

Arrival

Jan. 28-Feb. 2, 2036

"Any questions about the video?" Ethel asked Will, David, and Sergei. They had just reviewed a training video about metal production for the fifth time. Will raised a finger.

"Will we be able to separate some of the rarer metal carbonyls?"

Ethel nodded. "Sure. The hot carbon monoxide gas will convert almost any metal into a carbonyl gas, and since every metal carbonyl condenses into a liquid at a different temperature, the unit can condense them at different levels in the fractionation tower. Nickel-iron meteorite is mostly iron and the unit's designed to accumulate liquid iron carbonyl so we can pour it into a mold to make parts. But we can do the same thing with platinum, iridium, osmium, or whatever, making ingots instead of metal parts of course! A tonne of nickel iron meteorite has less than half a kilogram of platinum group metals. It's a question of quantity."

"It would be worth about $40,000," noted Sergei. "I don't think Project Columbus will break even any time soon!"

"We'd make more money selling Mars rocks," quipped David.

"How strong are cold-molded parts?" asked Sergei. "Hot rolled steel is certainly stronger."

"True," agreed Ethel. "But cold-molded metals are plenty strong enough to make chairs, tables, door frames, airlocks, sheet-metal walls that can be pressurized, etc. It's good enough until Mars can import a steel rolling mill."

"I have a more philosophical question," exclaimed Will. "I sometimes feel we're going to Mars not to explore the place, but to perform experiments. We're flying almost five hundred million kilometers to get there and we're staying eighteen months, yet we won't travel more than a hundred kilometers from base. Doesn't that seem crazy?"

"But it's understandable, don't you think?" replied Sergei. "The goal of Columbus 1 and 2 is to establish a beach head. That means getting the habs set up, establishing some food production, obtaining a reliable water supply, proving that Mars shuttles work there, and testing the surface exploration system. Once that's done, we won't have to carry liquid hydrogen to make return fuel and we'll be able to double the cargo load. We won't need to import as much food. At that point, it'll be feasible to send more people and machines and launching extensive exploration."

"Will just wishes he were coming here later," said David. "And I can understand that. He and I are explorers."

"The 'Moonman,'" added Sergei.

"Maybe I can come back," said Will. "I'd like to stand on the rim of Argyre Basin and sample rocks from the beginning of Mars. Or explore the young volcanics in Amazonis, or the ancient layered sedimentary deposits in Gangis. Those are my ambitions, not setting up an outpost."

"We might make it to Gangis if the equipment proves reliable and we finish the nominal mission," said David.

"It's scheduled for Columbus 2," replied Will. "I understand the logic of our mission objectives, but they are very conservative. I bet we can do much more."

“Don’t forget that you’ll get to some of those places telerobotically,” exclaimed Ethel. “We have six Prospector-200s to deploy and operate.”

“I know; but exploring a place by telerobotically operated vehicle is not the same. A five year old with a video camera can do a better job.”

“You’ll have to teach me more geology,” replied Ethel. “Meanwhile, I appreciate the interest three of you have shown in metal production. It’s an important experiment; just as important as chemical and plastics synthesis.”

“All three are vital,” agreed Will. “And we do have valuable exploration objectives; I’m not complaining about that.” He rose and walked over to a window that punctured the wall of the *Cimmerium’s* great room. It faced toward their destination and he was startled to see how big it was. “Wow; we’re noticeably closer than yesterday. It looks almost as big as the full moon.”

“Really?” said Sergei, skeptically. The others walked over and huddled around the window.

“Let’s see, we’re still two million kilometers away, six times the Earth-moon distance, and Mars has twice the diameter of the moon,” said David. “Will, you’re close; it should be about a third the dimensions of a full moon.”

“Alright. That big, dark patch on the right is Syrtis Major; I’m amazed it’s so easy to see with the naked eye. To the left you can see the edge of the Marineris dust storm.”

“So, that’s what’s delaying our landing,” exclaimed Sergei.

“Yes,” said Will. He sighed. “I wonder when we’ll clear trails to the north and south poles, or the length of Marineris, or to the top of the Tharsis volcanoes.”

“Whoa! You’re talking about decades from now,” replied Sergei. “We’ll need a lot of vehicles and people to pull off those tasks. We’ll need reliable air transportation and a solidly established hub, like McMurdo in Antarctica.”

“But with one difference; McMurdo is less than twenty-four hours from any major city on Earth. Even Shackleton is only four days from Earth. Mars takes months to reach Earth,” noted Ethel. “That means some people will sacrifice and stay, and maybe eventually establish families. That doesn’t happen on Antarctica or the moon.”

“I wonder what sort of society will be built on Mars,” mused David.

“One dependent on Earth,” said Will. “I hope they have a closer knit social life than we’ve achieved.”

“We’re getting better,” replied Sergei. “After six months of floating across the solar system together, we’re finally getting to know each other.”

“It’ll be a society dependent on machines, and with little contact with nature,” observed David.

“I don’t know,” replied Will. “Everyone on Earth is dependent on machines as well, and on Mars everyone will know where their food comes from. They won’t buy it in a supermarket.”

“True, but a greenhouse and nature are not the same thing,” replied David. “Their contact with nature will be potted trees, not a forest; or it’ll be a Martian dust storm.”

“True, but that will be interesting in its own way.”

“I wonder what sort of society can or will be built here some day,” said Ethel. “The six of us have found out how hard it is to create a multinational team. We don’t have a common culture. Mars will need a common culture of some sort.”

“One will probably evolve gradually,” said Will.

“And we get to start the process,” added Sergei. “We have quite a responsibility.”

Just then they heard someone slide down the ladder shaft. Laura popped out.

“How was the video?” she asked.

“We see something new in the plot every time,” quipped Will.

Laura was not amused. “We just got a solar storm warning. If the storm comes this way, it’ll hit about the time of aerocapture.”

“We can’t be in our acceleration couches and in the shelter at the same time,” commented Sergei, shaking his head.

“Mission Control is, as one might expect, asking us whether we want to abort.”

There was silence for a moment as everyone considered the matter. “Don’t be ridiculous. We can’t fly 500 million kilometers and abort,” said Will. “We’d be stuck in this can for eighteen more months before we returned to Earth, with nothing to show for.”

“Well, we can’t fry, either,” responded Laura.

“Aerocapture only takes fifteen or twenty minutes, and the plasma will shield us substantially from the radiation,” said David.

“We could probably rearrange our supplies to shield the couches, too,” noted Ethel.

“I’m not advocating an abort; just that we need to know what we’re getting ourselves into,” said Laura.

“But what about that aeroshield sensor,” said Sergei, looking at Laura. He turned to the others. “I was checking the systems on the *Elysium* today and got a warning about one of the aeroshield’s latches. I was planning to go out and take a look.”

“We can’t have a shield fall off during aerocapture,” agreed David. “What are the chances it’s real?”

Sergei shrugged. “One in a thousand. The guys who latched the aeroshield on at ISS2 were pretty careful. And the latches are overdesigned; if one failed, the others would hold the shield in place.”

“Is there time to check before the storm arrives?” asked Will.

Laura nodded. “I think so, but we can ask Houston.”

“What else can go wrong,” sighed Ethel.

“What’s the situation on Phobos?” asked Will, looking at Sergei.

“As soon as we’re in orbit, Moscow has authorized us to take over the controls. Maybe with nearly instantaneous response time, we can jiggle the driller free. So far, nothing they’ve tried has worked.”

“A person in a spacesuit with a flashlight and a long pole could probably bang the rock loose and free the drill head in half an hour,” said Will.

“True, but we aren’t authorized to do it, and we have enough delta vee for either Mars or Phobos; not both,” reminded Laura. “You guys figure out what the EVA will involve; I’ll email Houston about it.”

The next afternoon they slowed the rotation rate of Columbus Station. Sergei and Will, who had low-gravity experience exploring near-earth asteroids, went out to inspect the latching mechanism. It looked fine, so they removed and replaced the sensor, which immediately caused the false warning to go away. Relieved, they went back inside.

That problem resolved, the crew members turned to moving supplies and furniture so that the bridges of both ITVs—and their adjacent bathrooms—could serve as radiation shelters. The solar storm hit and for two days the six of them rarely left the bridges. It abated about twelve hours before the aerocapture maneuver; just enough time to take showers and clean up before ending artificial gravity.

They hurried to secure the vehicles, undock them, and point each vehicle's wide aeroshield towards Mars's edge, so it would just nick the atmosphere. Atmospheric entry involved teeth jarring vibration, an ear-disturbing wail, and chest-compressing deceleration. Will viewed it stoically; it was necessary and if something went wrong there was nothing he could do to avoid death, so he stayed composed and patient, occasionally silently repeating Bahá'í prayers he had learned in childhood. Laura tended to swear her way through irritating anomalies; David and Ethel focused on their tasks; Sergei was somewhere in between; Shinji dealt with the situation with Buddhist detachment.

Each vehicle dipped to within five kilometers of the surface, then headed back out of the atmosphere almost as quickly as it entered. Gravity, vibration, and noise steadily rose to a crescendo, then gradually faded. In three minutes they slowed to a little less than escape velocity from the Red Planet. The pilots of the four vehicles called each other on the radio, verified their status, and began to rendezvous. Within thirty hours the Columbus mission's two shuttles and two ITVs were docked together and rotating; artificial gravity was restored, and they were in their intended 24.6 hour elliptical orbit. Over breakfast the next day they held a staff meeting.

"I gather the landing site is still too dusty?" asked Laura.

Sergei nodded. "It'll be another week at least."

“This is amazing; the dust storm season ended in October,” said Will. “But the Marineris system is prone to storms.”

“We can wait,” said Laura. “We’ve got plenty of time. Will, are you turning to the Phobos driller problem?”

“David and I will focus on it today.”

“Good. What’s our fuel reserve?”

“Both shuttles have a delta-vee of a thousand meters per second,” replied David. “Forty percent above the seven hundred required for landing.”

“But we’re way short of the amount needed to visit Phobos,” added Sergei.

“I wasn’t even thinking about Phobos,” responded Laura.

“Phobos has twenty tonnes of fuel,” noted Will. “And we can transfer it. It’s more than enough for a trip to Phobos and landing on Mars.”

“Like I said, I wasn’t even thinking about Phobos,” repeated Laura more forcefully. “It’s out of the question. Columbus 1 is focused on Mars, not Phobos.”

Will nodded. “And I’ll focus on the drill rig today.”

“Good. Then staff meeting’s over. Thanks, everyone,” said Laura.

Will rose. David tapped him on the shoulder. “I have to take care of an interview with Agence France Press, so I’ll join you in fifteen or twenty minutes.”

“Okay,” agreed Will. He headed up the ladder shaft to the docking cube, then down the *Ausonia’s* shaft to the lab on the second level. They had finally moved everything back to where it was before aerocapture; the smell of the leaking sewage tank had finally dissipated.

Will noted the red glow of Mars coming from a porthole window, so he walked over and stood for several minutes to look at Dusty Red. At the moment Columbus was only about a thousand kilometers up. From that distance, the detail visible to the unaided eye was astounding. They were flying over the Tharsis volcanic province and the three big volcanoes—Arsia, Pavonis, and Ascreus—were all plainly visible. Olympus Mons, the solar system's highest volcano, was just visible on the horizon. He looked down and it suddenly hit him forcefully: *I am about to be one of the first human beings to land on Mars.* A chill ran up his spine and he wasn't sure whether it was excitement, fear, or both.

Landing gave him shivers. Aerocapture was simple in contrast. Missing the landing zone was almost as serious as a crash because neither shuttle carried the supplies or equipment for an entire mission. They had to have access to the three cargo landers already there or the three bringing the equipment designated for Columbus 2, which would arrive in six weeks. If both Mars shuttles missed the primary landing zone, the death of half the crew was a near certainty. He considered how difficult it would be to function as a three-person crew on Mars, mourning the loss of the other three.

He turned away from the porthole. There was no reason to dwell on the negative. He returned to his work station and activated the computer for telerobotic control of equipment. But rather than turning to Phobos—David still had not arrived—he connected to the Prospector telerover at Aurorae. Mars's network of communications and global positioning satellites made the connection almost instantly.

A picture from the main camera snapped into focus. He knew the site well; for the last month he had wheeled the Prospector across the gravely plain at a fairly quick clip.

At the moment it was perched on the edge of a rise facing west. Will scanned right—toward the north—and the escarpment edge of Aurorae Chaos came into view, a wall of layered rocks almost two kilometers high about twenty kilometers away, as magnificently impressive and grand as the Tetons near Jackson Hole or the Front Range of the Rockies near Denver. He contemplated the layers for a moment, wondering for the twentieth time what they were; that was a question he wanted to answer in person.

Then he panned to the east. A mere fifty meters from the rover was a mesa about 300 meters long, 200 meters wide, and 100 meters high dubbed “Boat Rock” because its shape roughly resembled an overturned row boat. Beyond it, not visible from the rover, was “Face Rock,” a house-sized mass, so called because at a certain angle one could see a face-like profile in its crags, rather similar to the “Old Man of the Mountain” once visible on New Hampshire’s Cannon Mountain. Behind the rover’s cameras was “Layercake Mesa,” the largest erosional remnant in the area, also 100 meters high, but four kilometers long and up to a kilometer wide. Will was itching to find a way to the top of all three mesas; the rover couldn’t do it, but climbing to the top should be possible for a person in a pressure suit. The three mesas provided excellent exposures of the deposits that once filled the area—mostly lake-formed sediments, with some volcanic and meteoritic debris—and all three mesas could hold clues to whether Mars ever had life. The tops were also excellent locations for wind turbines, which eventually could supplement the base’s solar power supply.

Finally, he panned the camera southward, across the expanse of Aurorae Chaos to the horizon. The plain that stretched as far as one could see was fairly flat and covered with small rocks and gravel, the top of over a kilometer of water-washed fill that had

been deposited from the Mariner Valleys farther west. The sedimentary strata, according to ground-penetrating radar, were filled with permafrost; drill down, add heat, and water vapor would escape the shaft. Scattered across the plain were three automated cargo landers and the Mars Shuttle *Pavonis*, all sent to the Red Planet two years earlier. Each vehicle had unrolled solar arrays on landing able to generate forty kilowatts of power at midday. Each of the four vehicles was equipped with a two hundred-kilogram rover; the rovers had hauled electrical cable across the desert between the vehicles and connected them together, giving the Mars base an electrical grid. An additional three hundred square meters of panels had also been deployed, able to produce another fifty kilowatts of peak power. The electricity had been used, over the last two years, to combine the ten tonnes of liquid hydrogen inside the *Pavonis* with carbon dioxide from the Martian atmosphere to make liquid oxygen and methane; additional oxygen had been extracted from the carbon dioxide, so that the *Pavonis* was fully fueled for the return trip to Earth.

Will looked up as he heard the sound of someone sliding down the ladder shaft. It was David. “How was the interview?”

“It went fine. The reporter did ask the standard tricky question I always get: ‘do you consider yourself a representative of France or of the Arab world?’”

“What did you say?”

“I said I was a Frenchman, my parents were French, and we were proud of it, but I was also proud to be an Arab and Muslim. That usually works.” He looked at the screen. “How’s everything down on the surface?”

“Pretty good; still dusty.”

David squinted at the screen. “Yes, the horizon especially is obscured. Those mesas ten klicks away are barely visible.”

“They’re worse than yesterday. But let’s switch to Phobos and see what we can do.”

David nodded. He sat next to Will and pulled up the videomails from Moscow mission control summarizing the latest efforts to get the two drills to work. Two years earlier a Russian vehicle had landed on a ridge close to Phobos’s equator; the altitude gave it days slightly longer than its nights, and its position on the anti-Martian hemisphere meant the sun was eclipsed by Mars when it was nighttime. After landing, the vehicle fired harpoons into the moon’s loose, fluffy regolith, unfolded enormous solar wings—650 square meters—and deployed its two drills. But the first drill had malfunctioned almost immediately after drilling only ten meters into the chondritic bedrock of the moon; a simple malfunction that an astronaut could fix in a few hours. The second drill had done better, managing to get thirty-six meters into the moon before the drill bit had gotten stuck near the bottom of the shaft. The engineers had lowered a microwave heater into the shaft anyway and had heated the chondrite with microwaves to several hundred degrees Centigrade, driving off water vapor and carbon dioxide gas. Both had drifted up the shaft and been captured by the lander’s volatile processing unit, which electrolyzed the water into hydrogen and oxygen and brought the carbon dioxide and hydrogen together to make methane gas and more water. In spite of all the troubles, the Lifter *Stickney,* docked to the lander, had managed to amass twenty tonnes of liquid methane and oxygen.

Will and David reviewed the latest report about the efforts to free drill number 2. It was designed to penetrate one hundred meters into Phobos. Every additional meter meant six more tonnes of chondritic bedrock that could be broken down to release up to ten percent of its mass in water and carbon dioxide. Once a second lander arrived on the moon and all four drills were hard at work, Phobos had the potential to produce several hundred tonnes of rocket propellant every two years; more than enough to power the entire transportation system between Earth orbit and Mars orbit if it could be shipped back to Earth. The methane alone was worth a lot of money because the moon produced surplus oxygen.

They initiated the procedure mission control recommended: repeatedly yanking on the cable with the motors, something that was tricky to do when round trip communications from Earth took at least five minutes. They watched closely and started to jerk on the cable repeatedly, pausing briefly each time to see whether anything happened, then repeating the effort with a bit more torque. This had been tried from Earth twice, each time over several weeks, with no results.

Even taking their time, they built up to maximum torque in about fifteen minutes. “It’s simply not budging,” said David, shaking his head. “The drill bit must be wedged.”

Will pointed to a gage. “According to this, we did manage to pull the bit upward by about a centimeter. So it can move.”

“Yes, but not much. It’d take a month to pull it up, at this rate.”

“Maybe we should try higher torque levels,” said Will. He hesitated, then turned to the microphone near him. Moscow and Houston were watching and listening in and had offered a few words of encouragement, though the eight-minute communications

delay precluded their playing a central role. “Moscow, we want permission to try higher torque levels. I think I should try twice as much torque as we’ve used so far. Please advise.”

Will repeated the request in English, even though his Russian wasn’t bad, then he turned back to the controls and made several more efforts with the torque levels they were approved to use. He tried a very slow rotation of the bit; it didn’t work. In fact, nothing did.

It seemed like forever, but finally a reply arrived from Moscow in Russian: “Thanks, Will. We copy. You are go for trying up to twice as much torque.”

Will smiled at David. “They agree. Well, here goes,” and he set the amount of torque into the red level of the motor, then fired it up.

On the screen he could see the cable rotate and twist, then slow. It almost stopped moving entirely; then it seemed to speed up in its turn. “Ah-hah,” he said, pleased by the progress. He backed off on the rotation and set the drill to pull upward on the drill string, in order to break it free of the wedging it was in. The cable on the screen suddenly grew taut as the drill pulled at the maximum on the drill string trapped underground.

Then suddenly the cable accelerated, then shot free entirely from the drill. Will stared in disbelief.

“*Merde,*” exclaimed David forcefully.

“Shi---” Will caught himself swearing in public before a few million people. “We seem to have a major cable failure here,” he said. “It appears that the cable connecting the drill head to the drilling mechanism has severed entirely.”

“That’s not something we can fix, is it?” asked David.

“In person, yes. We’ve got spare cables.”

Well, so much for this lander,” concluded David, shaking his head. “Let’s hope the next one has more luck.”

“I don’t know. Microgravity is just about the worst environment for deploying anything.” Will shook his head. Damn it!”

“At least we had permission to use the torque levels we did.”

“Terrible way to start the day!”

They stared at the screen. Then Will panned the camera upward. They could plainly see the break in the cable; a complete, clean break. There was no doubt.

“At least we’ve got twenty tonnes of methane and oxygen fuel,” noted David. “It’s enough for emergency backup.”

“True. But that vehicle can hold thirty-six tonnes. We could have been returning to Earth with enough fuel to fly a shuttle back here.”

“I know. Phobos isn’t essential as a refueling station, but it’d be pretty valuable. Maybe Columbus 2 can visit and fix the break.”

Will stared glumly in silence.

Will and David did little the rest of the day. They stared at the screen and watched nothing, first on Phobos, then at Aurorae. It wasn’t until suppertime when they felt better.

“Don’t blame yourselves,” said Ethel, who had cooked supper that night. “You had permission for every step.”

“And the folks in Moscow mission control had tried to shake the drill loose for two years, even at the higher torque level,” added Sergei. “They were unsuccessful. Something drastic had to be tried.”

“We’ve already got enough fuel there to serve as a backup for the trans-Earth injection,” pointed out Laura. “The mission is fine and the second lander will have two more drills.”

“I know, but I hate to see us miss an opportunity,” replied Will. “My recommendation, for what it’s worth, is for the *Elysium* to fly to Phobos on its way to the surface. The Lifter *Stickney* would have to fly from Phobos to meet us; we’d refuel, fly to Phobos, then fly to the Aurorae. The Lifter would also be out of the way when we repaired the fuel-making plant.”

There was silence. Laura stared at him. “That’s a simple modification of an option in our emergency plans, but that doesn’t mean we can do it,” she finally said.

“The objection from Houston will be that Mars is our primary mission and we shouldn’t get distracted from it,” noted Shinji.

“More specifically, we’re repairing a Russian piece of the mission that they say isn’t needed,” grumbled Sergei.

“We’ll be stuck in orbit two to three weeks anyway,” replied Will.

“The Marineris dust storm is abating very slowly,” agreed David. “In fact, today it reintensified somewhat.”

“Dust storm season was supposed to end months ago,” growled Laura.

“This idea has merit,” said Sergei, deciding to stress the positive. “Moscow’s put a lot of resources into the Phobos plant. It has already made enough fuel to make a Phobos landing possible.”

“You don’t have a specialized suit for Phobos,” said Laura.

“But we have EVA suits,” replied Sergei. “They have maneuvering jets. That’s the main thing one needs. We’ll have to watch out about Phobosian dust. We know that from the flight to 2011AR last year.”

“You don’t have training.”

“On the contrary; I do,” replied Sergei. “I was on the mission to 2023RB6.”

“And I flew to 2014KO three years ago,” replied Will. “Phobos is essentially a zero-gee environment; we all know that environment. Phobos’s morphology roughly resembles the moon, and its geochemistry resembles chondritic meteorites. David has that kind of training, too.”

They nodded, but Laura persisted. “Look, Columbus 1 has to keep it simple. If we make the mission complicated, we increase the risk of accidents. What do you do if someone breaks an arm on Phobos?”

“Set it,” replied Will.

“I don’t know why the Americans have always been dead set against Phobos exploration and our fuel making plant,” added Sergei. “It’s politics.”

“You’re the one bringing up politics,” replied Laura. “Don’t blame the U.S. This is *not* central to the mission. If it weren’t for Project Columbus, you wouldn’t be here.”

“And Project Columbus wouldn’t be here without Russian rocket engines!”

“Let’s stick to the facts,” intervened Will. “We can’t get stranded there. The *Olympus* could always come rescue us, and it could be refueled from newly made fuel. Phobos has two drills; both can make plenty of water once they’re fixed.”

“The Lifter could even go dock to one of the ITVs and haul it to Phobos, if necessary,” added David.

Laura threw her hands up. “Well, why not. Let’s tear up the standard mission and make up our own!”

“It’s not like we’ll be bored up here for three weeks,” added Shinji. “We can drive the prospectors on Mars much faster than the guys on Earth, and there’s outpost set up work to do.”

“That’s right,” reinforced Laura.

“I don’t know why you Americans have a problem with Phobos,” said Sergei, shaking his head. “NASA has been consistently against exploring the moons for three decades at least.”

“Drop it,” replied Laura.

“Hey, I’m not,” replied Will. “I think it’s a great idea. I’d love to visit a chondritic asteroid, which is what Phobos is.”

Ethel looked at Will; he looked at her, and it appeared they were exchanging a telepathic message. “You know, this is our mission,” she said. “This isn’t Apollo. We’re here for a year and a half. Our equipment is designed for ten years and has been extensively field tested. Mission control really can’t help us much; they’re at least eight light-minutes away, usually much more. We need their permission, yes, but it’s our call.”

Laura looked at Shinji. “What do you think?”

He looked around, then shrugged. “I have no objection. I suppose I won’t be going, anyway if the *Elysium* carries out the mission. The *Olympus* is scheduled to be the first on Mars.”

“Exactly.” Laura looked around; she could see the majority favored the trip. “Okay, we have a reasonable plan. Landing on Phobos involves two half kilometer-per-second delta-vees; extremely simple maneuvers. We’ve got a good system of global positioning satellites here and a beacon on Phobos already, so navigation is simple. We have the equipment and relevant training. Sergei, do we know how to fix the drillers?”

He nodded. “We’ve got the schematics, Ethel and I know the equipment, and the folks in Moscow are very good at explaining things to us.”

“They are,” agreed Ethel. “And the Phobos drillers share many design elements with the drillers on the Martian surface, so I am familiar with them.”

“Okay,” said Laura. “Let’s put the plan forward. I’ll contact mission control. All of you have contacts as well; feel free to email or videomail them. Let’s propose it.”

6

Phobos

Mid Feb. 2036

There it was, a whitish-gray rock six centimeters long surrounded by a flashing white circle. The Japanese telerover had notified Will of it and his computer had analyzed its infrared signature automatically. It had calcium carbonate; a rare mineral on Mars. Will moved the joystick and the rover rolled over to it.

He zoomed in on it with the standard cameras, examined it, then positioned the sensory suite against the sample. He turned to another screen where the short-focus, high-magnification microscopic camera's image was projected; the equivalent of the geologist's hand lens. The crystals did look a bit like calcite. The alpha-backscattering instrument began its work; in five minutes his computer would have the analysis. Will popped up the infrared and ultraviolet reflection and absorption spectra, to which the computer added its interpretation. It definitely had calcium carbonate, though it had a little silicate as well. Unfortunately, the rock had been blasted to its current location by a meteor impact, so its origin was unknown. Will definitely would transfer it to the telerover's storage bin. If their upcoming landing was successful, in a year they'd send a solar-powered robotic aircraft to the northern edge of Alba Patera to retrieve the bin.

Will's attaché beeped; a videomail had arrived from Jerome McCord in Houston. He activated the message and Jerry's face appeared. He was older than Will—46, rather than 34—and balding. He looked tired. "Will, sorry I didn't reply last night. We've been trying to arrive at an effective response. This Russian scheme for going to Phobos has made us furious. They've been pushing a Phobos mission for years. I wish we had never

included them; we didn't need their engineers, we don't need their Phobos fueling plant, and the good Lord knows we didn't need their money. We only have so many number one accomplishments; we gotta spread them out. You certainly shouldn't feel guilty for breaking the driller, it wasn't your fault. It can be fixed by Columbus 2. We really don't want a crew that wants to depart from the mission plan all the time. You've got plenty to do in orbit already. Please help us squash this proposal. Bye."

Will watched the screen fade and felt his anger mount. He moved in front of the screen so that the camera would capture his face better and hit reply. "Thanks for the reply, Jerry. This isn't a Russian scheme; it was my idea. And it wasn't my idea out of guilt; as you said, I did everything properly. The guys in Moscow still don't know why the cable broke. Why should we go fix it? Because it's more important than driving the three functioning rovers on the surface. Laura, David, and Shinji can keep them going, anyway. The plant will make the Mars transportation system fully functional. Even if the second Phobos lander and its drillers don't work, Phobos will be able to make 90 tonnes of methane and oxygen fuel by the time we fly back to Earth, which is plenty to get us home with all the Mars rocks we want—up to forty tonnes!—or plenty of fuel for the next flight to Mars.

"As for the number of firsts, so what? Columbus 2 can always visit Deimos. You guys' problem is rivalry with the Russians. I think you should get over it. Our purpose should be to explore Mars and its moons, not to further national rivalries. The Russians have set up an excellent fuel-making plant and landed some great scientific instruments. We can easily get there, repair the two drills, explore for a week, collect rock samples to return to Earth, then head to the surface. The flight analysts say the risk of failure is 0.002

or one in five hundred. That's safer than the old Space Shuttle! So Jeremy, give it to me straight: *What's the problem?*

"Remember when you and I hiked to the top of the Mount of Perpetual Sunlight? There were risks in that trip; we pushed our oxygen supply just about to the limit, we scaled slopes outside our allowable range, etc. But we did it; we succeeded. This is simpler and less risky that that. What's NASA scared of? Bye."

Will surprised himself by his remarks. He briefly debated whether to send them at all. Then he hit the "send" icon and turned back to the rover.

Laura popped in a few minutes later. "Sergei just unstuck the one solar panel on Phobos that hadn't deployed properly, so don't use that as an argument any more."

"He did?"

She nodded. "Live control of a rover can do wonders. Of course, the driller had 90% of its power beforehand, so it wasn't badly needed. How's Alba?"

"I just found a chunk of carbonate, so I grabbed it. The alpha scan should be done by now." He pushed a few buttons. "Yup, it is, and damn, it's komatiite instead!"

"Volcanic instead of sedimentary. Well, we don't have samples of komatiite."

"Yes, many theories of the magmatic evolution of the Martian interior predict komatiite, especially earlier in the Noachian. But I wanted to find limestone!"

"Maybe we will eventually. See you." Laura popped back out as fast as she popped in. Ten minutes later Jerry McCord's response arrived.

"Will, you made some interesting points, but I don't know why you make them. You're right about rivalry; but we're *Americans* and they're *Russians*! That won't go away. So why are you helping them?

"But you're also right about the Mount of Perpetual Sunlight. You have to stretch the rules sometimes to accomplish things. Of course, I'm not sure the time to stretch the rules is at the very beginning of the first mission. Usually you prove that your training and equipment will let you stretch the rules. We're meeting about this in six hours. I'll convey your points."

Much to the Columbus crew's surprise, the result of the meeting—reported to have been noisy and chaotic in Houston, Paris, Moscow, and Tokyo simultaneously—was a green light. The *Olympus* was scheduled to fly to the Martian surface with Laura, David, and Shinji, which implied that the *Elysium* would fly to Phobos with Sergei, Will, and Ethel. David wanted to switch with Ethel and go to Phobos instead. After discussion, that was vetoed; the geologists would have to fly down on separate shuttles, to make sure at least one of them arrived safely.

They had a week before the next launch window to Phobos opened. Ironically, as they completed preparations, the dust storm at Aurorae abruptly and unexpectedly began to clear; but they weren't going to change their plans now. On February 19, 2036, the *Elysium* separated from Columbus Station and fired its engines briefly, dipping its periapsis into Mars's thin atmosphere. A brief, fiery ride slowed them by 600 meters per second and lowered the apoapsis to a point just 100 kilometers above the orbit of Phobos. A second small burn raised the periapsis to 400 kilometers; well above the Martian atmosphere. They were now in the same orbit as the *Stickney,* which had left Phobos a few days earlier. In 26 hours they caught up with the Lifter.

The two vehicles docked nose to nose, aligning fuel transfer pipes, which docked together as well. A short firing of the attitude control system set the docked vehicles to rotating slowly, making a sixth of a gravity in the crew module; sufficient to settle the fuel so that it could be pumped from vehicle to vehicle. In six hours they transferred fourteen tonnes of methane and oxygen, enough to land on Phobos and head for the Martian surface.

Four hours later, as Phobos approached them in its orbit one hundred kilometers closer to Mars, they fired their engines to raise the periapsis of the *Elysium's* orbit almost to the orbit of Phobos. Phobos, in a lower, faster orbit, slowly caught up to them.

"I can see the volatile processing plant," said Will, looking out one of the forward navigational windows once they were only twenty kilometers up

Ethel looked out; Sergei was piloting. "I see it. Pretty easy to spot, isn't it."

"Six hundred fifty square meters of solar panels makes it stand out like a sore thumb!"

"Why didn't it land at one of the poles?" she asked.

"Phobos's poles get half a year of darkness. There's no perpetual sunlight there, like on the moon."

"The Russians' proposed excursions look fascinating." She smiled at him, a smile that conveyed more than scientific interest. He smiled back.

"I'd love to explore one of the fissures the Stickney impact made; we might find a cave. Phobos is full of them."

They watched the moon grow closer. The cameras sent a steady stream of high-resolution video images to Earth via the Mars communications and navigation satellites.

When they were about fifteen kilometers from Phobos, Mars began to disappear behind it; quite a pretty picture. When they were just a kilometer above their landing spot, Mars disappeared completely.

In one respect, landing was tricky: Phobos had only seven ten-thousandths the gravity of Earth, so the Mars shuttle, with its mass of sixty tons, had a weight of only 42 kilograms, about half that of an adult man on Earth. Sergei brought them in slowly; Ethel, then Will napped as they approached. The last hundred meters took half an hour. Finally, the five landing legs sank half a meter into the fluffy regolith covering Phobos. There was no sound or feeling of coming to rest, and no change of gravity.

"I think we've landed on Phobos," announced Sergei. "It was so imperceptible, only the instruments detected the event. Nothing seems to have changed in the cabin."

"Congratulations, *Elysium!*" exclaimed Laura. "We've been watching and waiting, and we're delighted."

"Thanks, Columbus 1," replied Sergei.

"It's time to suit up," said Ethel, unbuckling her seatbelt.

"Hey, let me finish shutting down the systems! I'm the first one out."

"Sergei, I can shut things down; I'm scheduled to be last," said Will. Sergei nodded, so they switched seats.

Sergei and Ethel stripped down to their under garments and wiggled into their suits. Will followed fifteen minutes later. The crew module occupied a cramped corner of the cargo bay, which was six meters in diameter; not very large for suiting up.

Will helped Sergei and Ethel suit up, then they helped him. Sergei and Ethel squeezed into the tiny airlock; it could hold only two at a time. As Will waited to enter

the lock, he could hear Sergei exclaim “The human presence begins on Phobos”; the first words spoken on the moonlet. Then he watched them on the screen struggling on the surface; walking and micro-gravity were not compatible.

Will floated into the airlock, sealed and depressurized it, then pulled the outer door open when the door light turned green. Phobos stretched out before him: reddish-gray and rolling, with fluffy hillocks and shallow pits dotted with boulders and rocks. The curved landscape was terminated by the horizon less than a hundred meters away, except for a hill poking above it to the right. To the left he could see the automated lander with its volatile processing unit and drills on top; the solar arrays were mostly out of sight below the curve of the moonlet’s surface. Two pairs of long streaks showed where Sergei and Ethel had landed and bounced off the surface; a diaphanous cloud of dust floated in the vacuum, settling at an imperceptible rate.

“You’re better off flying,” said Sergei.

“He fell,” added Ethel.

“I see the tracks his hands made. I told you to fly instead.” Will floated in the door, holding onto a railing with one hand and onto two pointed aluminum “ski poles” with the other. He reminded himself of the flight rules before starting. With his suit, he had a mass of 140 kilograms but a weight of only 84 grams or three ounces; the same as two candy bars, so little that trying to push a foot into the regolith would propel him off the surface instead. The maneuvering jets on his backpack were programmed to give him an acceleration of ten centimeters—four inches—per second per burst. One vertical burst would lift his feet about a meter off the ground and return them to the surface 34 seconds later. He could sink his ski poles into the regolith almost any time to anchor himself. Ten

horizontal bursts would give him one meter per second of forward motion, enough to carry him forward 34 meters in 34 seconds; when he settled to the surface he could use his feet to “bounce” himself back upward and repeat the maneuver. That was the basic plan for moving around Phobos slowly and methodically.

He gave himself 10 centimeters per second of upward velocity and 1.5 meters per second of forward motion, which was walking speed. As he coasted he looked down at the fluffy, sandy regolith of the moon with the occasional mix of rocks. The surface had been pounded over the ages by micrometeorites, fragmenting the regolith into a powder devoid of most of its water and carbon. He could see colored bits as well; grains of nickel-iron meteorite and occasional chunks of ejecta from Mars.

Ahead a waist-high rock stuck up. Rather than coasting over it, Will reached down with both ski poles and sank them into the regolith using his forward motion, then allowed his feet to bounce off the rock. He managed to stop without falling!

“Hey Will, pretty neat maneuver!” said Ethel. She and Sergei were half way to the lander.

“Thank you; I’ve got to look at this rock.” Will slowly pivoted his feet down to the ground and wiggled them into the powder to anchor himself. The maneuver worked fairly well. He was disappointed to realize he had wasted his historic first words on Phobos. Geology had proved more important.

He slowly wiggled his feet into the powder more deeply, then leaned over and straightened up a few times to make sure the movement didn’t propel him off the surface. The powder gave him a pretty good anchor. He wrapped a stretchable cord around the rock and around his knees to anchor himself to it, then leaned over to look closely. He

pulled out his rock hammer and tapped it a few times. Well anchored, he whacked the rock harder. Pieces broke off, but they flew everywhere.

"Rocks in orbit," he mumbled. He reached down and picked off his suit a small fragment. Then he looked at the exposed surface. It was a boulder of carbonaceous chondrite, as he expected; Phobos was made of the stuff. He named the rock "Gibraltar" because of its shape and began to dictate a detailed description while his helmet camera transmitted images of everything he looked at. He was famous for his complete and precise soliloquies about field geology; they had earned him the sobriquet "Moonman" as much as his publications. Hundreds of terrestrial geologists were watching and hanging on every word.

Finished with Gibraltar, he grabbed a scoop from his belt and picked up powdery regolith. He spent five minutes scooping, spreading the fluff with his gloved fingers, separating out certain particles for later examination, and dictating a continuous description of what he saw. Sometimes he went back and repeated parts of the description to add a detail he had forgotten. With a round trip communications time of nearly nine minutes, there was no opportunity for live questions, but he remained at Gibraltar long enough for questions to arrive. The geology desk at mission control vetted and emailed particularly good ones to him; they were displayed on the right side of his visor in such a way that he could look through them to the terrain outside. A few journalists' questions were admitted as well. He went through the questions one by one; the geologists had noted a few things he had missed.

“Hey Will, when you look at something, you have to hold still a few seconds longer, so we can look at it, too,” said David. He was following the expedition closely from Columbus Station and commenting often.

“Thanks. I figure a lot of people are freezing the frames.”

“Maybe. The helmet camera is doing great, but sometimes an individual frame is blurred, so freezing the frame doesn’t always work.”

“Got it.”

Twenty minutes passed at the same spot before Will finished. Sergei and Ethel had been working hard on the driller that had drilled only ten meters into the moon because of a misplaced bolt. They said they didn’t need a third set of hands yet, so he flew to another boulder. After twenty minutes there he flew even farther to a crater that had punched through the dust. There were exposed rock layers in the crater wall to examine. The camera close-ups were the most interesting, though he did push a mesh bag against the cliff and hit it with his hammer; it propelled him out into space, but the mesh kept some of the pieces for close examination. For forty-five minutes he described crude layering, examined contacts, debated with himself about what he saw, and answered questions.

“Will, we need your ski poles!” exclaimed Sergei.

“Oh? Okay, I’ll be right over. For what?”

“We’re trying to fish the rock fragments from shaft number two.”

“Okay.” Will glanced at his watch; he was surprised to see he had been outside for two hours. “What happened to drill number one?”

“Haven’t you been listening? It’s fixed. A robot couldn’t do it after months of trying, but two workers can do it in two hours. We’ll test it later.”

“I’m on my way.” Will looked around and couldn’t remember which way was which, so he fired his jets vertically and shot upward at half a meter per second. In a bit less than minute he was twenty-five meters up and spotted the lander. He turned to face it and fired jets to head toward it. In five minutes he was there, managing a reasonably skillful landing on the metal surface.

“You’ve been doing some impressive geology!” exclaimed Ethel.

“The geologists can run me ragged.”

“It’s one reason you’re popular; you don’t mind having the world looking over your shoulder,” said Sergei. He pointed. “You guys wedged the rock in here really good. But all the poles will fit together to make a boom long enough to push it downward. Maybe we can free it that way.”

“I went back to the ship and got the rest of them,” added Ethel. She had twelve more two-meter lengths with her.

They assembled eighteen segments together, making a single aluminum pole thirty-six meters long. The bottom pole had a sharp point; Sergei lowered it into the hole and slowly pushed it downward until it hit resistance.

“We need to be up there, pushing downward,” he said, pointing to the open metal frame of the driller two meters above their heads. He pulled himself up the pole, then very slowly flipped himself upside down so that he could plant his feet against the frame. There was room for someone else; he beckoned Will up. Will followed him up the pole and planted his feet against the frame as well.

“Is your blood rushing to your head?” asked Ethel.

They laughed. “Are you ready?” asked Sergei. Will nodded. “Then let’s push!”

The two men began to shove the aluminum pole down the shaft with all the force their leg and back muscles could muster. The obstruction broke free suddenly and they plunged downward head first. Ethel had to reach up and break their falls. All three gently tumbled off the lander and ended up on the ground, hands out to grab the powder and stop their motion. Will stood up using his backpack’s jets. The three of them slowly climbed back on the lander’s platform.

They grabbed the broken cable and began to pull it upward. The drill bit and a melted plastic sleeve full of cuttings came up easily; the cuttings flew everywhere, since there was nothing to confine them once they came out of the shaft.

“Mission accomplished,” said Will.

“Definitely,” exclaimed Sergei. “Let’s replace this cable and go inside to test the drills.”

“Then we can start exploring Phobos!” added Will.

7

The Valley of Dawns

Feb. 28, 2036

Laura looked at the image of Stickney crater broadcast from one of *Elysium's* cameras. The images from all ten cameras on Phobos were displayed on the walls of the *Cimmerium's* great room; she and David chose which two to send to Earth. She switched to a camera next to the airlock so that Earth's cable audience could watch Will and Sergei step back inside. During the five days since completing the repairs on the two drills, the team had taken their lead from the mission's chief geologist.

They went inside, where Ethel waited, and peeled off their suits. "That was great, guys," said Laura after the team was back in their regular clothes. "So, six days and six seven-hour EVAs. You've explored fossae, several craters, and Stickney. Does one more day look about right?"

"What's the latest with the drillers?" asked Sergei.

"They're fine," replied David. "Both are moving downward at full speed. Drill 1 will hit the 100 meter maximum depth tomorrow or the next day."

"Excellent," said Sergei. "We can return before departure and start a third shaft."

"Yep, shaft 1 will be ready for volatile extraction," said Laura. "So let's schedule our landing."

"You can't wait to get to Aurorae, can you?" asked Will.

"We're bored up here!" replied Laura. "You can drive rovers just so long. I want to feel the reg under my boots. Besides, the Marineris dust storms have finally dissipated."

"I'm satisfied," said Will. "We've explored this moonlet enough to keep the scientists busy for several years, though I'm in favor of visiting again on our way home."

"That's premature," cautioned Laura. "It was originally scheduled if the two Lifters were both fueled and ready to go. We'll see what the second lander does when it arrives in April."

"Let's make the last major excursion that has been proposed," said Sergei. "Then we'll return to the lander one last time and head for the landing orbit."

"We'll start mothballing the ITVs for eighteen months," replied Laura.

The next two days were busy ones. The *Elysium* flew to Phobos's north pole for one last excursion. Then they returned to the automated lander, where Sergei and Ethel removed the drill string from shaft number 1 and moved it to a different location so that it could make a new shaft three meters from the first one.

Then the time to descend to Mars arrived. With excitement and anticipation, six human beings strapped into their seats and fired their shuttles' engines. Will, Ethel, and Sergei watched Phobos shrink behind the *Elysium* with some regret, but excitement about their next destination. Laura, David, and Shinji watched the two interplanetary transit vehicles that had been their home for six months shrink behind the *Olympus.* They could not help but worry whether they would be functioning properly when the six of them returned a year and a half later.

The *Elysium* hit the atmosphere first, but only to lower its orbit and position it for a landing later that day. The *Olympus* headed straight down to the Valley of Dawns. "Okay, here we go, folks," said Laura, as the first wisps of plasma licked past the

windows of the *Olympus*. “Hold on.” She looked down and noticed she was gripping her chair so tightly her knuckles had turned white. She let go and was amazed to see her knuckles relax, then involuntarily stiffen and turn white again.

Their weight built up, the flickering fire outside the windows grew hellish, and the banshee wail from the streaming air waxed fierce. Laura found it hard to lift her hand. A glimpse at the landing profile showed that they were right where they were supposed to be, seventy kilometers above the surface and seven hundred kilometers from their destination. The profile itself, however, was frightening; at four kilometers per second, the surface seemed to be seconds away. The shuttle dropped through the thin atmosphere like a stone. Their velocity decreased as the Martian air rubbed it off, but their altitude plummeted as well.

Deceleration built to a peak of about two terrestrial gees, then began to slacken. The flames diminished as they came out of the hottest phase of entry, their metal heat shield glowing ruddy. The *Olympus’s* velocity dropped to a bit over 1,500 meters per second. Altitude and range from their target decreased fast; landing—a *soft* landing—incredibly was just two minutes away.

One of the screens in front of Laura beeped. “We’ve acquired the landing beacon,” said Laura. “We’re out of the atmospheric entry phase. Deployment of the drogue will commence in six seconds . . . five. . . four. . . .three . . . two . . . one. . .. here we go!”

There was a bang as the mortar in the shuttle’s nose fired the drogue parachute upward. The shuttle jerked as the drogue opened in the supersonic airflow and weight

sharply increased again. Then twenty seconds later the main parachutes were pulled out by the drogue. The shuttle shook twice as two popped open.

And then alarm bells went off. The shuttle had three main parachutes. Laura leaned forward in spite of the gee force pulling her backward to look at the screen more closely. It was clear in an instant that only two of three had opened; deceleration was less than predicted. “We’ve had failure of one of the main chutes,” she reported tersely. “We are compensating.”

The control computer immediately sensed the problem. Landing was possible; their fuel reserves were sufficient for an emergency landing on one chute. But it was risky and they’d overshoot the landing zone. They felt a series of clunks as the computer opened the engine bays doors.

The shuttle bounced around as a result of the partially opened chute; Laura held it as steady as she could. The chutes detached a few seconds later than originally planned and for an instant the weight went away completely and they were *falling.* Then the main engines roared alive, building quickly to full thrust, and gravity returned with a vengeance. She glanced at David and Shinji, who looked much more alarmed than she, and nodded reassuringly.

The shuttle pitched up to vertical and the ground appeared in the windows in front of the pilot, surprisingly close and blurred from the speed. Dawn sunlight cast huge shadows, revealing a land of rocks; much of Mars was a giant stone field and Aurorae Chaos had its share. Laura saw a big boulder—three meters in diameter—ahead of them and steered the shuttle to the right of it; but there was another good sized rock to the right, so she had to bring the vehicle back to the left. Deceleration waned to Mars normal

as the vehicle's last remaining extra speed blasted away just ten meters above the rocks. The *Olympus* was now descending at three meters per second, which dropped to two meters per second at an altitude of eight meters, then one meter per second at five meters. She adjusted their position slightly to avoid a rock highlighted on the screen that would tilt a landing pad, then brought the shuttle down. Four meters. . . three. . . . two. . . one. . . she cut off the engines and the shuttle fell the last half meter. With a thud they landed at a slight angle, followed by a second thud as one landing pad pushed a rock out of the way and the shuttle righted itself.

She looked at David and Shinji. "Whew!" she exclaimed. She glanced down at her hands; they had a slight shake to them.

"Good maneuvering, Commander," said David. His voice quavered.

"*Olympus,* are you down?" called Sergei frantically. "*Olympus,* please copy!"

Laura smiled. "We copy, *Elysium.* The *Olympus* has landed on Mars and we are safe and sound. It's quite a view outside! We're facing east, looking at the early morning sun. We've got a grayish pink sky and a terrain covered with rocks!"

"But where are we?" asked David.

"We've overshot," replied Laura. She pushed some buttons and called up the global positioning system. "We're. . . twenty-two point three kilometers east of the automated cargo landers."

"A long way," observed David.

"*Olympus,* this is *Elysium,*" exclaimed Sergei. "We're coming up on the time of our emergency landing burn. Shall we come down right away?"

Laura looked at the others in the shuttle and then at the controls. All systems were nominal; there was no emergency, strictly speaking, except for the fact that they were twenty-two kilometers from their supplies. The shuttle had all the food they needed for the mission and its cramped module could keep them alive for several years; the buggy could be deployed and take them to the automated cargo landers. But this was not how the mission was supposed to go. The *Elysium's* orbit allowed a landing only once per sol. Normally the *Elysium* would come down the next sol, partly to decrease the stress of two back to back landings, partly to eliminate a media event that would compete for television time with their first steps outside.

The situation was ambiguous. "Affirmative, *Elysium*," Laura finally replied. "We're fine, but if you land in the landing zone you can drive over in the ranger."

"We copy. That makes sense, Commander. We'll prepare for the landing burn, subject to Houston's final approval." That approval was likely; Houston was too far away to maintain a hands-on control.

"We copy," repeated Laura. She turned back to the controls. The engines were going through an automatic deactivation sequence.

"Is there enough fuel to fly us back to the landing zone?" asked Shinji.

David shook his head. "Negative. But after we unload the cargo and convert some of our hydrogen feedstock into methane and oxygen, it can be done. That'll be a month or two, depending on available power."

"We're not going to plug into the landing zone's grid; we don't have twenty-two klicks of cable," said Laura.

"The *Olympus's* own solar array is sufficient if it doesn't have to power anything else," replied David.

"We should get outside," said Laura.

She unbuckled her belt and rose; she was surprised to find that she was stiff and clumsy in Martian gravity. David pulled Laura's pressure suit from the storage locker and handed it to her. He and Shinji had been wearing their suits, complete with helmets and gloves, throughout the landing, so that they were in the position to survive some types of crash landings. But Laura was first diverted by Shinji, who opened the animal locker in the bottom of one of the plant growing cabinets.

"The poor rabbits; they're scared half to death," he said.

"Let me see," said Laura. She walked over. They both took an animal—each shuttle carried a breeding pair—and cuddled it to provide comfort. It was not altogether clear who felt more comforted. David had to content himself looking in on the rooster and two hens in another locker.

Then Laura retreated into the bathroom area to pull off her clothes and put on her suit. The adrenaline shake in her hands was lessening. About the time she had her torso in her suit, the radio crackled and Houston's message congratulating them on a safe landing reached their ears. A minute later they confirmed the *Elysium* should plan an immediate landing; they tactfully avoided the word "emergency."

The three of them spoke little while they donned their pressure suits. For Laura, the emergency had drained the event of the excitement she had expected to feel. David kept glancing out the window at the landscape. *Mars.* He wanted to pinch himself to be

sure it wasn't a dream. Shinji felt dread; he had not walked on the moon before, so for him, this was the first real experience wearing a pressure suit, other than exercises.

They were ready to enter the airlock forty-five minutes after landing, but the time seemed to fly. She grabbed the flags they had stored next to the airlock and entered; David squeezed in behind her. Shinji closed the door behind the two of them and latched it firmly. Laura pressed the "depressurize" button and looked at David expectantly. He smiled back excitedly, all animosity between them momentarily forgotten.

The air in the airlock hissed away and the special plastics in the pressure suits responded, squeezing on their skin to counteract the air pressure inside their bodies. The suits were very flexible; they didn't feel like walking around inside a pneumatic tire. Clothing over their suits compensated for the Martian cold.

Finally, a green light came on; the outer door could be opened. Laura pulled a lever to unlatch the door and it swung outward.

Mars spread out before her; a rolling land of reds, grays, pinks, and browns, and above all, rocks, all the way to the horizon. Her immediate impression was that Mars was covered with a mix of cinnamon and sugar, rather like the topping her mother put on her buttered toast every morning. They were facing north and the horizon was dominated by the impressive mile-high cliffs marking the edge of Aurorae. Layers could be seen in the cliff distinctly even though they were twenty kilometers away. The cliff face was scalloped by landslides and great debris piles rested at its base, invisible over Mars's horizon. The crest was an irregular line, incredibly distant yet sharp in the clear air.

She looked down; they had earlier deployed a ramp that had been folded up against the airlock, forming the shuttle's outer skin. It was short and steep, descending a

meter and a half to the ground. She stepped onto it, grabbing the deployment cable on the right side, which served like a railing. In a few steps she was down. She stepped onto a round, flat rock at the end of the ramp, then put her foot into a small dust drift.

"With this step, humanity attains another world," she exclaimed. "May it become a second home for our species."

She turned to watch David descend next, giving a bit of ceremony to his first step. "Bismullah al-rahman al-rahim," he whispered as he started down the ramp. He touched down onto the rock as well. "L'exploration de Mars commence," he said, then he added in English "The exploration of Mars begins."

Fully aware of the five billion people who were watching, they circled the shuttle while awaiting Shinji's egress. Built into the shuttle's base were three telescoping solar arrays. They moved some rocks and deployed the first one.

The airlock opened and Shinji stepped out. He came down the ramp as well, speaking in Japanese, then repeating in English "May this world symbolize peace for all mankind." He leaped onto the flat rock, then down onto the ground.

"Here, here," agreed Laura. "The nations of the world can cooperate to send people to Mars; they can cooperate to solve their problems on Earth as well."

"Mars is the god of war, traditionally," added Shinji. "It is true in many of our cultures; the red has come to symbolize the blood of conflict. But we will make this the first world where humans live without warfare."

"Let's deploy the flags," said Laura.

There was a spot about ten meters from the shuttle that was flattish and had a deposit of wind-blown drift; perfect for erecting flags. They walked over to it. The

protocol had been carefully negotiated months ago: Laura first pushed the flag of the United States into the ground, and they all saluted it; then David deployed the flag of the European Union, which they saluted; then Shinji planted the Japanese flag and they saluted. Finally, they erected the flag of the United Nations together. Singly and together they posed with the flags.

That done, they deployed the other two solar panels and the buggy, and started to do some preliminary surface science.

Meanwhile, in orbit the *Elysium* was cruising toward its own encounter with the Martian atmosphere. While Sergei piloted, Will confirmed the readiness of Aurorae's ranger to provide emergency support and rescue capability. A bit larger than a humvee, the pressurized cab could seat four abreast, was high enough to stand while wearing a pressure suit, and had space behind the seats for storage and a hammock. Built into the chassis was an array of batteries and methane-oxygen fuel cells; each of its six wheels had its own electric motor with regenerative braking. Rangers had been used on the moon for a decade. Aurorae's first cargo lander had brought it; its bulldozer blade had cleared areas for the deployment of solar arrays and had created tracks between the four vehicles already landed at Aurorae. Last week the crew had used the ranger to pull the portahab—an inflatable wheeled habitation about the size of a terrestrial camper—out of the third cargo lander. It was hitched to the ranger and parked in a safe place.

The *Elysium* hit the atmosphere with a blaze of incandescent air. Ethel endured the build-up of gees stoically; Will sat looking patient, but he was actually silently repeating every Bahá'í prayer he remembered. The drogue and main parachutes deployed normally; Sergei had much a easier piloting job than Laura. When they had slowed to 500

meters per second, at an altitude of 1,000 meters and a downrange distance of 10,000 meters, Sergei detached the parachutes and fired the engines. He brought the *Elysium* down right in the middle of a rock-free landing zone the ranger had cleared. The landing was barely noticeable as a slight bounce, then the engines shut off.

"Wow, Sergei; congratulations!" said Will looking out the window in awe.

"Everything went perfectly. The Doppler radar gave us all the data we needed to compensate for the winds. Under those circumstances, landings are pretty easy," he replied. "What's the local time?"

"A bit after noon," replied Ethel.

"Check the animals, then let's suit up," said Sergei, pushing some buttons to shut down the engine controls.

"Congratulations, *Elysium*," exclaimed Laura over the radio. "We watched you come in. Even twenty-two kilometers away, it was pretty spectacular."

"Thanks," replied Sergei modestly.

Ethel checked the rabbits and chickens while Will and Sergei ran through a checklist. Then they began to suit up.

"It shouldn't take me too long to drive over to the *Olympus*," commented Sergei to Will as he pushed his right and left arms into the top half of his suit, then began to zip up the front. "I see the map shows some smooth areas to drive across."

"Yes, if we bend slightly to the south of west we'll follow the main flood channel, and the last flow carried sand and gravel, so the route should be faster. But shouldn't we wait a few days, for Mission Control to finalize a route and approve the trip?"

"Why? We know where we are, where they are, the terrain in between, and we have GPS."

"But everyone's fine and safe."

"No, everything's not fine; we're separated."

"It'll take you until sunset, Sergei."

He shrugged. "Help me zip the top and bottom halves of my suit together. With GPS I can't get lost and the portahab has enough supplies for weeks."

"I'm not sure I'd want to pick my way through a boulder field after dark, and the *Olympus* is in a bad spot. I should go along, to navigate."

Sergei shook his head. "You stay here with Ethel. I'll manage."

"Are you sure?"

"Yes," he said with an air of finality.

Will opened his mouth to object further, but Ethel, who had come over now that Sergei was suited up, touched his sleeve and shook her head. Will looked at her, surprised, then dropped the matter. He began to put on his backpack.

He and Sergei squeezed into the airlock, closed the door, and began depressurization. In two minutes it was at Martian pressure; Sergei opened the outer door. Mars spread out before them, in richer detail and color than any video or virtual reality. They paused for a moment to look at the world in front of them, struck by its variation and stark beauty. Then Sergei walked down the ramp and stepped onto the ground. "May many footsteps follow these," he said in Russian, not bothering to translate into English.

Will followed. He felt the reg yield under his boot; it crunched slightly. He looked around Mars in awe, amazed to think that he had just set foot on the Red Planet. "A world

of wonders awaits us," he said. It was the best he had been able to think of, but in the context it wasn't bad.

Then his training kicked in. He reached down and picked up a rock. He could feel its cold through the thin, flexible gloves, but it didn't matter. He began to dictate a description of the sample to the geologists on Earth.

"Will, how much should I raise the bulldozer blade?" asked Sergei.

Will looked up. Sergei had walked over to the ranger and portahab, which David had driven by remote control to within thirty meters of the shuttle while they suited up. Will jogged over, careful not to lose his footing in the strange gravity and the still-unfamiliar suit.

"The dirt track clearing standard is to keep it five centimeters above the ground the first time and scrape the ground the second time. But a ranger can advance only about two kilometers per hour that way, and you need to go more than twice that speed to get to the shuttle before dark. I'd raise the blade so that it deflects any big rocks you don't want the tires to hit; maybe twenty centimeters."

He nodded. "Yes, that sounds about right. We can take our time tomorrow and clear the track better."

"We'll be making many round trips, so we can improve it gradually," agreed Will. "Just *be careful*! This is our only ranger. It'd be hard to rescue you with the buggies if you break down in between. *Rocks are the enemy*."

"I know. This isn't that different from driving a ranger on the moon."

"Yes it is. The moon isn't as rocky as Mars."

"Okay, I concede that. I had better go; it's after one."

“I know.” Will reached over and pulled open the ranger’s door. The cab, though filled with oxygen, was at the same pressure as the Martian exterior. Sergei shook as much dust off his boots as he could—dust was a serious problem—and climbed into the driver’s seat, which he pushed backward all the way so that the seat could accommodate his backpack as well.

“I’ll start driving now and stop to take off the suit once the interior is pressurized,” he said.

“Good plan. Take care.”

“Thanks.” Sergei waved, then closed and latched the door. A moment later he activated the ranger’s six fuel cells, raised the bulldozer blade in front to twenty centimeters, and fed power to the six wheels. It began to roll forward. Sergei headed down a dirt track leading to one of the automated cargo landers, which had landed east of the shuttle.

“I dedicate the next eighteen months to exploration of this world and pursuing ways of strengthening international cooperation through it,” exclaimed Ethel. Will turned and saw that she had now stepped onto Mars. She took several steps, then reached down to pick up a small rock.

Will walked over. “Today is not sol 1 for us, so we have no official work.”

“The emergency has blown it away anyway. I suppose we should start by deploying the solar panels.”

“Yes.” The two of them walked to the shuttle. Ethel pulled out a screwdriver and used it to unlatch the end of a panel manually. Will helped; the base of the solar panel array was over her head. A square of the outer hull a meter high and 2.5 meters long

popped outward. They grabbed it and began to pull, slowly unfolding and stretching flat an accordion of solar panels. Soon they had it extended its full twelve meters and deployed a pair of metal legs that supported the end a meter above the ground.

They pulled out and deployed the other two as well, a fairly simple and straightforward task. Will walked eastward toward a dirt track and found the electrical cable that had been extended from the nearest cargo lander; he pulled it to the shuttle and plugged it into the electrical box. The *Elysium* was now part of the electrical grid and had access to over a hundred kilowatts of power. At that point David called Will on a private line—each of them had essentially a cellular telephone number that could be called for private conversation.

"Do you want me to activate the Sabatier on the *Elysium?*"

"Sure. Where are you; inside?"

"For now. We came back in for lunch. You guys will get pretty hungry."

"We'll manage. Sergei will be pretty hungry when he arrives there."

"When he gets here we'll celebrate with a big meal. Tomorrow night all six of us will celebrate together, too."

"Yes. We did it, Daoud! We're on Mars!"

"I know! It's so hard to believe. It's quite a place; fascinating."

"It is. It's growing on me already. But I'll feel a lot better about this place when we're all together."

"I agree."

Will's phone beeped. "Ethel's calling. We'll talk again later." Will pushed a button to switch to her. "Sorry; I was talking to David."

“That’s okay. Can you help me with the buggy?”

“Sure.” The shuttle came with a 250-kilogram buggy about the size of an all-terrain vehicle. It was designed to transport one person but could accommodate two in an emergency; it also could tow a trailer or a disabled buggy. Like the ranger, it had multiple fuel cells and methane and oxygen tanks; the four wire mesh wheels had separate electric motors of the same sort as the ranger. It was solidly reliable and nearly indestructible. The cargo landers had brought two others, so they had three.

They went back inside the shuttle briefly to detach the buggy from its straps and push it into the airlock, then down the ramp to the surface. They checked it out and fueled it with liquid methane and oxygen from the shuttle’s tanks.

“Let’s ride over to the mesas,” suggested Ethel.

“Good idea,” said Will. “They’ve got the best geology.”

“I wonder how Sergei is doing,” added Ethel.

“We can still see him.” Will pointed east. “He’s making good progress.”

“I interrupted you because I sensed Sergei had to make the trip himself.”

“Why?”

“I think in his mind he’s rescuing Laura.”

“Oh? You’re probably right.”

“And I think she wants him to rescue her as well. It’s not a very rational way to start our expedition here.”

“But a very human way,” said Will.

“That’s what worries me,” replied Ethel.

8

Outpost

Feb. 28-29, 2036

Sergei kept up the fastest pace he dared. Mission Control urged him to slow down, though his brief spurt to thirty kilometers per hour had been across an open, flat patch of clay that had no rocks. Where the rocks were thick the bulldozer blades pushed quite a few aside; under those circumstances two kilometers per hour was the max he could manage. At least the work wasn't boring. The terrain was flattish but ever-changing, with signs of aeons-old flood erosion and deposition everywhere. Aurorae Chaos had pooled the water flowing out of the Marineris Valley system and fed it to Simud and Tiu Valles, so the geological deposits were among the most interesting on Mars. In the three and a half billion years since the floods had dried up, meteorites had pocked the surface with craters and blasted rocks everywhere.

The last hour, as the shadows grew longer, the *Olympus* became larger and easier to see. He pulled up to the shuttle just minutes before sunset; Laura and David were outside and literally jumped up and down and waved as he approached. He waved back through the windshield.

"Welcome, welcome!" exclaimed Laura over the radio.

"You made it!" added David.

"It wasn't that difficult. I concentrated on the terrain in front of me and whenever I steered around something I checked my heading. Let me get my suit on." Sergei had taken off his helmet, gloves, and backpack early in the trip.

“How well does that thing drive?” asked David.

“Fine. But don’t drive for long with the life support pack on; it kills your back.”

“Can you bring the portahab’s tool kit? We’re trying to fix the shuttle’s toilet and we could use a second set of tools.”

“Sure.” Sergei rose from his seat. He made sure the flexible, pressurized plastic tunnel to the portahab was still airtight, opened the ranger’s and portahab’s hatches, and passed through. The tool kit was in the rear left, past the sofa that became bunk beds and opposite the tiny galley, but before one reached the bathroom and rear airlock. He opened a storage locker, grabbed it, and hurried back to the ranger. In five minutes he was able to depressurize the cab and step outside.

Laura reached out to hug him; he hugged her in return. They faced each other. “Are you sight for sore eyes,” she said to him over a private line.

“I’m here now,” he replied, a touch of heroic in his voice. “Tomorrow we’ll all be able to drive back to the primary landing area.”

“I want you.”

He was startled by her frankness. “Where.”

“I don’t care.”

David’s voice interrupted. They could hear him, but he couldn’t hear them. “We should probably get inside; the sun’s gone.”

Laura turned toward him, irritated. Sergei saw that the sun had indeed dropped below the horizon, but the solar corona was clearly visible in a pink sky. Martian sunsets were going to be interesting. He pushed a button to activate the general voice channel.

“Okay; I’m starved. I forgot to bring anything to eat and I didn’t want to stop long enough to find the supplies.”

“Everything in the portahab’s dehydrated anyway,” replied David. “Shinji has prepared frozen turkey.”

“Let me close the door,” said Sergei. He walked back to the ranger and shut the door, then handed the toolkit to David. “I had better come back out later, though. I want to familiarize myself with the portahab a bit better.”

“I’ll come with you,” said Laura.

The next morning the four of them headed back to the *Elysium.* Shinji drove; he lowered the bulldozer blade to fifteen centimeters and cleared more rocks as they went. They covered the twenty-two kilometers in a bit over two hours. In a few more sols, as the track got wider and smoother, the trip would take less than an hour.

Rather than wait, Will and Ethel returned to the mesas on the buggies. The sol before they had explored the length of Layercake’s northern edge and circled Boat and Face Rock. Will recognized most of the terrain because of his many hours driving Prospectors. On “Sol 2”—the second Martian day—they climbed up the slope of talus—loose rock—at the base of Boat Rock’s northern cliffs and started to walk along the cliff slowly and systematically, Will westward and Ethel eastward, stopping to examine layers, break off pieces, and describe everything. Sometimes they took samples back to the buggy for analysis by its battery of instruments. David watched very closely from the portahab, coaching Ethel occasionally so that Will could focus on the samples he was

examining. The flow of voice and emails from Earth was fast and furious and he helped answer some of them, or helped Ethel work her way through the technical language.

The ranger headed for the mesas rather than the *Elysium*. Since they were approaching from the south and their colleagues were working Boat Rock's northern cliffs, they had to drive through the notch between it and Layercake Mesa to reach them.

It took ten minutes to exhaust the backlog of geological questions from Earth. Will and Ethel came down from the talus pile and walked over to their friends, who had suited up and exited the ranger. In spite of the suits, everyone hugged each other; they were relieved to be back together again.

"Well, we all made it," said Laura over the common frequency. "We had some scary moments, but we came through them."

"And we now have twenty-two kilometers of Mars 'Route 1' cleared," added Sergei.

"Let's sit down facing each other so we can see our faces and talk," said Laura. She pointed to a rough circle of rocks nearby. They walked over and sat. "We need to plan the sol and review our work schedule for the next week. It's complicated somewhat by the *Olympus's* distance. Until we clear the route better, we'll have to send at least two people back starting about three hours before sunset."

"Until we move the plants and animals," agreed Shinji. "How long will it take to move everything here?"

"Houston says five or six days; or I should say sols," replied Laura. "We need to lighten the *Olympus* before flying it over."

“The delta vee for the launch and landing is substantial; about 1,000 meters per second,” added Sergei. “Every tonne we fly here will take 300 kilos of propellant.”

“What will that do to the *Olympus’s* fuel supply?” asked Will.

“We can strip the shuttle to thirteen tonnes,” replied Sergei. “It’ll also have ten tonnes of liquid hydrogen, for a total of twenty-three tonnes. Flying it here will require seven tonnes of oxygen and methane, which can be made using 400 kilograms of the hydrogen; four percent of the total. We can get the *Olympus* here and still have enough hydrogen to fly her back to orbit. It reduces the supply of wash water and methane fuel for the rangers and buggies.”

“Four hundred kilos is not a problem,” said David. “The three automated landers already here and the three on the way will have two or three extra tonnes of fuel. The *Pavonis* has six extra tonnes of water and eight extra tonnes of fuel, and the *Elysium* has the hydrogen to make the same.”

“And we should have a functioning well in a few months,” added Will.

“We’re in fine shape,” agreed Laura. “Houston wants us to drive solar panels to the *Olympus* to increase its electrical supply, so that it can make the methane and oxygen in a few weeks.”

“But our sol to sol plans won’t be as simple as when the two shuttles are three kilometers apart,” said Ethel. “I’d favor setting up the inflatable habitat and moving the plants and animals on the *Olympus* to the *Pavonis* as soon as possible.”

Laura nodded. “I agree.”

“Will and I found a spot for the outpost,” added Ethel.

“What’s wrong with the spot NASA chose?” asked Laura.

“This is better; we’ll show you.” Ethel rose and walked eastward; the others followed. It took several minutes to reach a wide, flattish, sandy terrace south of the eastern end of Boat Rock. The terrace extended northward to the edge of a depression; beyond the depression the ground was a rolling rock-covered plain all the way to the cliffs marking the edge of Aurorae Chaos.

“Why here?” asked Laura. “The spot by the notch was good; it provides a natural route between the mesas.”

“Why go between them when you can go around them?” asked Ethel. “The notch is interesting as a terrain variation, but so is this.” She pointed at Face Rock nearby. They all looked up and smiled.

“It’s a pretty bumpy face, if you ask me,” said Laura.

“The face of a Martian,” teased Sergei.

“It’s a natural rock formation; walk twenty meters east or west and you can’t see the profile any more,” replied Ethel. “In addition to the Face, there’s also the crevasse separating Face Rock from Boat Rock.”

“It’s pretty cool,” added Will. “It goes all the way through, is barely wide enough for two people to walk side by side, and has a few overhangs that are almost caves. The rovers were never able to go in because of debris blocking both ends, but we climbed over the debris yesterday.”

“So, you’re proposing we move the outpost here because the spot is ‘cool’?” asked Laura, irritated.

“No; we should build here because it is just as good as the other spot, but it’s also cool,” replied Will. He pointed at the depression. “That area is probably a better spot for

a well than the area near the notch. The ground radar shows that just about anywhere you drill, you'll reach the frozen water table at a depth of fifty meters. But that area is about fifteen meters below the average ground level, so it should be closer."

"Where would we put the solar power units?" asked Sergei.

"There." Ethel pointed to a spot east of the depression. "It's flat and less than a hundred meters from here. We have enough plastic tubing to pump heated Martian air from there to the outpost."

Sergei nodded. "That would be a good spot."

"This place has some charm," agreed Shinji. "We should make the decision; we have to live here."

"But we'll also be laying the foundation for a future settlement, so we have to consider posterity," said Laura.

"This is fine for them," replied Will. "This spot has the same characteristics as the other spot, but a bit more charm. We can find solid ground for erecting structures, and spots to drill for water, almost everywhere in Aurorae. We can build our outpost out in the middle of the valley where it's flat and featureless for kilometers if we want. I say, let's build where we have some interesting things to see and hike."

"Okay, you've convinced me," said Laura, abruptly. "I like the idea of being able to see the Face out our windows. It's now 9:45 a.m. You geologists have an appointment with the terrestrial geologists to do research, so you should get started on that. I doubt mission control will object to our moving the outpost to this spot, unless they know something about the geology we don't. I'll walk across the site with my helmet camera so

they can see it all. Meanwhile, Sergei, Shinji, and Ethel, you drive back to the landers and get the inflatable habitat."

"We'll need to prepare the site," added Ethel.

"The bulldozer can do that in a few hours. When can we inflate the hab?"

"By sunset," replied Ethel. "Of course, set up will take weeks."

"When can we live in it?" asked Laura.

"Considering our crazy housing situation right now? I'd say it'd be adequate in two or three sols."

"We should get the inflatable ready as soon as possible," said Sergei. "Considering the near-crash we've experienced and the separation of the shuttles, we need a nest."

"That reminds me; mission control wants us to retrieve the parachutes," exclaimed Laura. "They emailed me last night. They'll give us exact GPS coordinates and the best route to them in a few sols." She looked at the others. "I think we're done."

Will turned to David. "Let's start here, with Face Rock, so we're close to Laura."

"Okay."

Everyone headed to their tasks. Sergei, Ethel, and Shinji unhitched the portahab and drove the ranger to Cargo Lander number 2, plowing a new, direct route from the proposed location of the outpost. Lander 2 had opened like a flower twenty-three months earlier, unrolling its solar panels across the gravely desert; a buggy had plugged it into the power grid so that its electricity could be shared with the other machines scattered across Aurorae's wastes. Still sitting on the lander's platform was a trailer four and a half meters long and four wide with the vacuum-packed eight-tonne inflatable habitat in an enclosed

plastic box. Next to the trailer were three tonnes of life support equipment and plumbing, furniture, and a tonne of hard plastic panels needed to strengthen the inflatable's floors and walls.

They constructed a ramp out of panels and slowly winched the trailer down to the ground. Then they hitched it to the ranger, moved the bulldozer blade to a lower setting to push more rocks out of the way—the trailer had a low clearance—and pulled it back to the construction site. While they moved slowly to the outpost's new location, Shinji began to cook lunch in the ranger's microwave.

They arrived at the site a bit before noon. Laura was staking out the location of the habitat, based on mission control's advice. They all crowded into the portahab and ate lunch while their life support packs recharged.

After lunch Shinji rode a buggy back to the *Elysium* to prepare supper and do his medical work; Sergei and Ethel used the ranger and its bulldozer blade to prepare the spot for the inflatable; Laura helped Will and David with the geology. Two hours before sunset the site was ready. They moved the trailer into place and four of them pushed the inflatable habitat off it while Sergei slowly drove the trailer away.

"It's too late to do anything more today," said Laura. "We need to drive back to the *Elysium*, eat supper, and two of us have to start back to the *Olympus.*"

"Who's going?" asked Sergei. "It can be any two of us." He turned to Laura. "We could go."

"Sure."

There was silence. Will was tempted to say something, but didn't. He caught a glimpse of Ethel's face; she was concerned.

“It’s settled, then,” said Laura. “Someone else can go tomorrow.”

“If someone wants to stay with me, I’ll inflate the habitat in the next two hours and eat supper later,” said Ethel.

“I can stay,” said Will.

“Good,” said Laura, pleased. She looked at the remaining buggy. “The buggy can take Sergei and me back to the *Elysium*. You’ve both got enough oxygen?”

“I’ve still got five hours,” replied Ethel. “My bladder won’t last that long.”

“I’m fine for air and bladder,” said Will.

“Then it’s settled,” agreed Laura.

Sergei and Laura drove off on the buggy and David walked over to the cliff to do more geological work. Will and Ethel set up an oxygen transfer hose from the ranger to the hab and the latter began to inflate.

Not much air was needed to unfold the structure. Most of the inflatable was packed inside two metal boxes that were its airlocks. The habitat was made of layers of Kevlar, nomex, and other plastics; some served as airtight layers while others provided insulation, flame resistance, or puncture protection. As air flowed in, the habitat under the airlocks inflated, lifted them off the ground, and moved them to their positions on opposite sides of the structure. The hab was a flattened sphere—rather like a flying saucer—twelve meters in diameter and seven high. In half an hour the structure had assumed its maximum dimensions, although it had not filled with enough oxygen to support breathing.

Will went back to doing geology. Ethel called him a half hour before sunset. “Come see; we can go inside now.”

He hurried over. She stood outside one of the airlocks on top of a ramp made of plastic panels. They stepped inside, closed the outer door, and latched it firmly. Ethel turned a mechanical valve to let air in. They could hear it hissing in; their suits began to compensate and electrically turn off the mechanical counterpressure squeezing their bodies. “The interior pressure is pure oxygen at 0.15 atmospheres, so set your suit at that presure. Tomorrow we’ll add more oxygen and 0.13 atmospheres of nitrogen to push the pressure up to 0.33 atmospheres.”

“And warm it up; it must be frigid inside,” added Will.

“Indeed.” Ethel tried opening the interior door and it yielded to her push, indicating that the pressure had equalized. They entered and closed the door behind them. They were in a hallway stretching all the way across to the opposite airlock. Natural light filtered into the hab through fourteen windows.

Ethel had been lowering the pressure in her suit and lifted off her helmet. Will followed. They took their first breaths; clouds came from their mouths, then the bone-dry air absorbed the water.

“It looks pretty big,” said Will.

“It is. It’ll be much safer than any other place on Mars. It holds 450 cubic meters of air; a slow leak won’t be a problem for a long time.”

“And with reg covering the roof, we’ll be protected from radiation. Wow, the air’s thin.”

“It is; move slowly.” Ethel moved into the hallway and Will followed. The floor sagged and wiggled under foot; air pressure stretching the hab was holding it taut. Will pushed on a wall with his finger; it yielded.

The hallway opened onto spaces on the right and left. To the right was the elliptical great room, six meters across. It had three exterior windows; the outer wall curved up to form the ceiling, arching to a height of 4.7 meters at the dome's apex. It was punctuated by four skylights. On the left side of the Great Room was the future galley; on the right, the bridge and repair areas.

Will looked into the circular room on the left side of the hallway, the Geobio Lab. Six bedrooms and the sick bay opened into it. Each was a pie slice two and a half meters deep, almost two meters wide at the doorway, and two and a half meters wide against the outside wall; fifty percent more space than their cramped quarters on the interplanetary transit vehicles. Each had a window.

"Wow. This will be a fantastic space."

"It's great. Can you imagine the sunlight pouring in? We can have potted plants."

"So many rooms: six bedrooms, a galley, a bathroom, the Great Room, and four work spaces."

"The attic over the Geobio Lab and basement are for storage. Both have ceilings high enough near the center of the hab for two or three additional rooms."

"I remember." Will walked to the end of the hallway and looked down the open stairway shaft. The area below was unlighted. He looked up the shaft at the attic. "And another of these habitats is arriving next month."

"There will be room for twelve people at that point; plenty of redundancy until Mars grows." Ethel looked up. "But the technology doesn't worry me; the people do."

"What do you mean?"

She hesitated. “Laura and Sergei. Our survival depends on being a team. A romance can disrupt that.”

Will considered. “I see your point, though I don’t see an immediate problem. If they broke up, that would be different.”

“That could be a problem; there’d be no place to go. I can’t see them taking a chance with pregnancy, either. This is no place to have children, and you can’t fly a baby to Earth. But Laura and Sergei are numbers one and two; it doesn’t make sense that they’d both drive to the *Olympus* and leave the rest of us. What if they had an accident and were killed? And what about issues of favoritism in assignments?”

“I agree.” Will considered. “But what can we do? Talk to Mission Control? They must know.”

“I suppose they’d talk to Shinji about it.”

“But he has the wrong temperament to do anything about it. Do you want to talk to Laura?”

Ethel considered. “I’ll look for an opportunity, but I don’t want to make it worse.”

9

Week One

Mar. 1-9, 2036

The next morning Laura and Sergei took the chickens and rabbits from the *Olympus* to the *Pavonis*. They picked up nitrogen, argon, and oxygen canisters, then stopped at cargo lander 2 to pull a trailer loaded with life support equipment, furniture, plumbing, and other items to the habitat.

A long, hard sol of work followed. Will did geology with Laura in the morning, and David with Shinji in the afternoon. In the morning Sergei deployed solar arrays and gas bottles, filled sand bags, and ran an air compressor to inflate the habitat's hundreds of structural support tubes; Ethel continued the work in the afternoon. Each tube had to be inflated individually; eventually they could be filled with self-hardening plastic, permanently hardening the structure.

When they weren't doing geology they worked inside. It started cold—about twenty below zero—so they wore heavy clothing. They set up the atmospheric control and circulation system right inside the airlock; it connected to inflatable air ducts under the floors and air returns built into the ceilings. Outside the habitat they installed the oxygen and nitrogen tanks, which connected to the atmospheric system through valved pipes. Drawing off the solar panels' peak midday power, the unit began to warm the interior environment; by noon it reached the freezing point. The pressure rose to 0.33 atmospheres—0.20 atmospheres of oxygen and 0.13 atmospheres of nitrogen—which was to be Mars standard.

They also installed the energy storage system, a half-ton unit that contained fuel cells, a methane-making sabatier reactor, an electrolysis system, and a methane tank. It went outside the airlock where its waste heat and water could be routed inside the habitat. Sandbags were piled around the oxygen, nitrogen, and methane tanks to insulate and protect them.

The electrical, heating, and atmospheric systems were set up by early afternoon, so they tested the preinstalled pressure, humidity, oxygen, and temperature sensors and placed remote-controlled valves in the ducts so that the environment could be micromanaged. Then the team turned to the kitchen and bathroom. Self-adhesive hard plastic panels were stuck to the floor. Will went into the basement to install vertical braces and strengthen the floor's weight bearing capacity. Before the afternoon ended they were able to bring the stove, refrigerator, kitchen sink and cabinet, bathroom sink, toilet unit, and shower unit inside the habitat. After Shinji and David drove to the *Olympus* for the night, Will and Ethel plumbed bathroom fixtures until 9 p.m.

Sol 4 began early and repeated the pattern of the previous sols. Will and Laura spent the morning at Snow Crater, ten kilometers from the outpost. It was about the size of Arizona's Meteor Crater. They crisscrossed its ejecta blanket and descended to its floor. The impact had excavated a hole 150 meters deep, providing excellent exposures of the strata underlying Aurorae. David and Shinji went to another crater that afternoon.

While the geologists explored, Sergei and Ethel set up a docking unit at the hab's western airlock. The cube-shaped unit was three meters square and had pressure doors in each side, one of which could be latched to the back door of a ranger or portahab. They attached a pressure suit donning facility to the eastern airlock, a four-meter square room

for storing, recharging, and cleaning suits. They set up telephone-booth-sized pressure suit cleaning units to each; a powerful blast of carbon dioxide gas blew the dust and dirt off the suits and exhausted it into a unit that filtered the air, then released it back into the atmosphere. The unit was essential for protecting the habitat's machinery and seals from the dust, which could corrode surfaces and cause leaks.

That afternoon, the ranger pushed loose regolith to the edge of the habitat, where Will shoveled it into the gap under the inflated structure. The bowl-shaped excavation had intentionally been made a bit larger that the habitat and had to be backfilled.

That sol they completed the kitchen and bathroom and installed one of their two refrigerator-sized gray water processing units. Hard plastic panels were placed over the floor of the hallway and part of the great room. The habitat had numerous electrical outlets and plastic boxes with plugs were installed at each.

No one had to go to the *Olympus* that night. Sol 5 included a second visit to Snow Crater, this time by Will and Sergei. Hard "wallpaper" panels were stuck to the walls of the great room to protect them from damage, make them more fire resistant, and to brighten them up. Flooring was installed in the rest of the Great Room, the Geobio lab, and four bedrooms. The furniture from the *Elysium* and *Pavonis* was brought over, making the place almost livable.

At supper Laura said she would go to the *Olympus* that night and before Sergei could volunteer, Ethel spoke up. "Oh, I want to go as well."

Laura frowned. "Really?"

"Yes. I haven't been back yet. So let's go."

Laura opened her mouth, then closed it. The matter was settled. The two women suited up and headed for the ranger. They drove to the *Olympus* in darkness; the track was now cleared of rocks and widened by the repeat trips and was in excellent condition. They were there in a bit less than an hour.

"Say, do you want to try on clothes?" asked Ethel, after checking the plants.

"When have you had the time to download fashions?"

"Last night I spent half an hour scanning several Paris websites."

"You have a funny way of relaxing in the midst of outpost setup! I prefer sleeping!"

"I had only a little time."

Laura shrugged. "Well, I guess we can spend a little time, now."

They sat in front of the large screen in the shuttle's crew module and loaded their personal information into the software. It was strange and fun to watch oneself walk down the runway and model a Paris fashion. But Laura was pleased by several of Ethel's choices. "This one looks great on both of us, I think."

"I agree. Hard to believe, too; we have very different complexions."

"The outfit has enough colors in it; some of them are bound to flatter almost anyone."

"What would Sergei say?"

Laura frowned. "Last time we looked at fashions, we talked about Sergei also, if I recall."

"Well, maybe next time I'll come up with another excuse." Ethel paused. "Laura, I don't want to pry into your personal life."

“Well, I appreciate that!”

“But don’t you think that when there are only six people on Mars, we have to be careful to build a team, and we can’t build a team if there are favorites or if someone’s romantic feelings can be shattered.”

“Favorites? Do you think we all like each other equally? Aren’t you sweet on Will?”

“That’s not what I mean. We all have friendships, but romance is different—”

“Who says we have romance?”

“Oh, come on.”

“Friendship and sex are not the same thing as romance. What are you saying? Are you afraid I might have to choose between Sergei and someone else in a life and death situation? What are the chances of something like that happening? And again, I ask you, can you choose equally among everyone here?”

“The Commander and Vice Commander are responsible for the mission. How appropriate is for the two of them to go off together for the night?”

“Well, I didn’t hear from Mission Control about it,” replied Laura, lying. “I’m Commander. Don’t mind my business.”

Ethel shrugged and said nothing.

“I think you’re jealous.”

“I beg your pardon! I was never motivated by anything like that!”

“Okay.” Laura stood up. “Like I said: drop it. Remember, I’m in charge of assigning the dirty tasks up here. I’m going to bed. Good night.” She walked to her bunk,

pulled the curtain across the opening rather dramatically, grabbed her toothbrush, and walked to the bathroom.

The next morning—sol 6—the women drove back to the outpost in an awkward silence. But they soon plunged into the work with the others. Outside, crewmembers installed plastic hoods around the windows and skylights to keep regolith away from them, then blew dust over the habitat to protect it from the wind, insulate it from temperature extremes, and shield it from radiation. It wasn't windy so the dust mostly stayed put, although their suits required careful cleaning before going inside.

The rest of the floors inside the hab were covered with hard panels. They could now walk around without having the stretched fabric of the floor sink slightly under their feet. Bedroom walls were decorated with wallpaper panels; everyone had selected their own colors and patterns before departure. Cargo lander 2 had brought furniture: desks, chests of drawers, and small closets. The beds in the *Pavonis* were brought into the habitat. The tables, chairs, pots, pans, dishes, and kitchenware, the dishwasher, and the clothes washers and driers were brought from the *Pavonis* and the *Olympus* and put in their places.

"I'm sleeping here tonight," announced Will, as sunset approached. "There's no reason not to test the place out."

"It'd be good to have someone with you though," said Laura. She looked around. "Ethel?"

Ethel shook her head. David leaned forward. "I'll stay. We'll have a slumber party, Moonman."

Will smiled. Ethel looked at him, then said “Saturday’s coming up; or maybe I should say Satursol. The NASA geologists and engineers will be at home. Will’s scheduled to cook dinner, so I was wondering whether he could cook something special.”

“Great idea!” exclaimed Laura. “What do you say?”

Will shrugged. “Sure, but I’ll need to start at 3 p.m.”

“Earlier; it’s time to sacrifice a rabbit,” said Sergei.

“I agree,” added Shinji, the keeper of the rabbits.

“And I’ll help,” added Ethel. “In fact, Will, I wouldn’t mind it if we permanently served as a kitchen team. Whenever either name comes up on the schedule, you cook and I’ll wash.”

“Really? Sure, I can do that. I like cooking a lot more than cleaning up afterwards; though I’m not sure how to kill and prepare a rabbit.”

“Well, I’m the other way around; I’ll clean up over cooking any time. And I don’t know how to prepare a rabbit either.”

Two more sols of set-up work were followed by Satursol on sol 10. That morning Will and Ethel went to the *Pavonis*, where the rabbits and chickens from the *Olympus* had been taken. Each ITV had started with a single breeding pair of rabbits; three months into the voyage one pair had given birth to a litter of eight, which were now mature. They selected two cute, fluffy ones—a male and a female—decapitated them, then spent almost two hours preparing them.

When the hardest, messiest work was over, Ethel said, “This will be easier next time!”

"Yes, we know what to do, or not do." Will looked around. "We may want to use the *Pavonis* exclusively for killing and preparing animals."

"The filters won't have any other smells to deal with," agreed Ethel. "When David and Shinji move the last plants tomorrow, we won't be visiting the *Elysium* at all."

"Just routine maintenance once a month. Say, did you ever talk to Laura?"

"Yes. It was a disaster."

"What happened?"

"I tried to explain that a romance between her and Sergei was not good for the team, but she wouldn't buy it. She even threatened to retaliate against me."

"Did you remind her it's against the regulations of all the space agencies?"

"No. She knows that. I did express concern that the Commander and Vice Commander had deserted their posts together—well, I didn't put it that way—and she said NASA hadn't said anything to her about it."

"Really? I'm surprised. They know where all of us are at all times."

"And monitoring our heart and respiration rates, though I suppose Laura and Sergei remove their ear pieces before climbing into bed."

"They're uncomfortable to sleep with. But there are always the microphones, which theoretically are deactivated unless there's an anomaly."

"Anyway, I made a mess of it, and now she won't want to talk to me about it."

"I was wondering. Maybe a second attempt with—"

"No way, I'm not raising the matter with her again!"

Will nodded and kept thinking. "I wonder whether we should talk to Mission Control."

“I wouldn’t; it could cause trouble. Crew morale is Shinji’s responsibility, not ours.”

“True. I wonder whether he’s done anything? It’s confidential, so he won’t say.”

“He isn’t the type to involve himself in matters like this.”

“Then there’s another approach. You could apologize for hurting her feelings.”

“I don’t want to apologize about something when I’m right.”

“I didn’t say apologize for raising the topic. Apologize for upsetting her. There’s a difference. It may repair the breach without changing positions.”

“You sound like my Presbyterian grandmother!”

“Well, is that such a bad thing?”

Ethel thought a moment, then nodded. “You’re right. That might work, especially if she’s in a good mood.”

“Then tell you what. I’ll make the best meal I’ve ever prepared in space. If that doesn’t prepare the ground, I don’t know what will.”

“Oh, it will help; she loves your cooking.”

“It’s about the only thing I do that she likes!”

“She’s hard to please. In many ways, she and Sergei are a good match; they’re both from a particular place, they aren’t cosmopolitan people, and they’re emotional people.”

“Yes, that’s true.” There was silence for a minute. “How are your parents?”

“Thank you for asking. They’re fine and remain incredibly proud that their daughter was the fifth person to step onto Mars. But their health is not good. I kind of wish I hadn’t come; I’m worried about them.”

“How old?”

“Mom’s 69, but she has diabetes; dad’s 71 and has heart trouble.”

“That’s not good. My mom’s 67 and in very good health.”

“And your dad; he passed on, right?”

“Yes, three years ago. That was rough, especially since it was immediately followed by separation from my wife; or my ex-wife, I should say. Thank God I wasn’t on the moon at the time; it fell between assignments.” He paused to let the emotions pass. “I got a video mail from my mom and sister this morning. They’re incredibly proud of me, too.”

“I thought your mother lived in Connecticut and your sister in Bolivia?”

“Yes, my sister teaches at a university in Santa Cruz. But her son needs a minor medical procedure, so they’re in Connecticut for a few weeks for that. And a Bahá'í holiday period called Intercalary Days just happened, so they were with her for that.”

“What is it?”

“A time of gift giving, family get togethers, charitable deeds, and—this seems particularly important to most Bahá'ís—parties. We have lots of them, usually one every night. It’s sort of Christmas and Thanksgiving with a bit of Mardigras thrown in.”

“Sounds fun.”

He nodded. “It’s followed by the Fast; no eating or drinking from sunrise to sunset, March 2 through March 20. Of course, there are exemptions, including for those performing heavy labor, and it seems to me that being one of the first people on Mars constitutes heavy labor!”

"I agree. That's practical." Ethel paused. "I'm not sure what my Presbyterian grandmother would have thought of fasting."

"Did she observe Lent?"

"In some ways, yes. Catholics are lot bigger with Lent than Protestants."

"This is a little like Lent. Your Presbyterian grandmother's pretty important to you, isn't she?"

"In some ways. She was immensely impressive and a bit awesome to a ten year-old child; that's the year I got to know her best. After that we moved back to Canada for five years, and she died when I was twelve. She's sort of my moral and ethical compass, you might say."

"But not religious?"

Ethel shook her head. "No, not particularly."

They finished cleaning the rabbits and put them in a bag. The parts humans wouldn't eat were put in another bag and some were fed immediately to the chickens, who ate them enthusiastically. Will put the skins in a third bag because he suspected he could do something with them eventually. After they had killed twenty rabbits, they'd have enough fur for a bedspread, coat, or something else warm and attractive. The three bags went into an airtight carrying case.

The two of them suited up and jumped onto the two buggies. They stopped at the *Elysium* to feed more rabbit offal to the chickens there, then headed to the habitat, where Will started cooking. Outside, David was setting up solar arrays; the others were installing floor and wall panels. The sol before they had run a power line to the habitat from the landing zone, so it was plugged into the electric grid.

Soon cooking smells had permeated the entire habitat, causing both positive comments—they were mouth watering—and negative, because it suggested the air filtration system was not adjusted correctly. After another load of furniture arrived from the *Pavonis*, David came to help Will. At 6:30, everyone sat down to an impressive meal.

Laura took one bite of the rabbit and smiled. “Oh, Will, this is good! You have an instinct for cooking!”

“Oh, no. If I had gone by instincts I would have ruined this meal. You can’t rely on instincts when cooking in a third of an atmosphere of pressure; water boils at 72 Centigrade here. You have to go by the book and cook everything long enough to ruin it on Earth!”

Laura laughed. “Well, even that’s an instinct. This is really good.”

“It is,” echoed David. “The flavors are different than on Earth, too.”

“This is a fine inauguration for our new home,” said Laura. “People may be living in this habitat fifty years from now.”

“Children may be born in it,” added Ethel. “I wonder how many people will be living on Mars in fifty years.”

“If you assume an immigration rate of four every other year, about one hundred,” said Will. “We won’t start with that many, but the rate will accelerate over time.”

“It could be more,” added Sergei. “Or if humanity loses its nerve, this habitat could be standing here abandoned in fifty years.”

“Humanity won’t let that happen,” replied Laura. “That’s why the Columbus Project went with reusable vehicles instead of expendables.”

“The foresight is uncharacteristic!” agreed Sergei, and they all laughed.

“We’ll get our money’s worth out of this place, that’s for sure,” said Shinji. He looked around the great room in admiration. “This is going to be very comfortable.”

“Yes,” agreed Will. “And when the second inflatable arrives in a month, the outpost doubles in size.”

“It’s going to make an excellent base of operations,” agreed Laura. “By the way, since we’ve worked so hard and gotten slightly ahead of schedule, tomorrow we rest; no work on sol 11. We’ve got how much work left on this thing; two weeks?”

“That’s about right,” agreed Sergei. “But starting next week, the solar power systems, drills, and greenhouses become priorities, followed by the chemical synthesizing unit and the metal separation and fabrication systems. They’ll take about a month.”

“And then the cargo landers arrive from Earth with even more stuff,” said David.

“Exploration is the focus of the second half of our mission,” noted Laura. “The first half has to set up the outpost, try to extract water from the ground, make sure the greenhouses work, test all sorts of fabrication and synthesis equipment, develop the sunwings, etc.”

“We’ve done some good exploration all along,” added Will. “Two team members explore while four do set-up.”

“I agree,” said David. “And we’re laying the foundation for exploration of the entire planet. Fifty years from now, it’ll be hard to find a spot people haven’t visited.”

“Say, Laura, I hate to change the subject, but that bottle of champagne is getting mighty tempting,” said Sergei. He looked at the counter, where his bottle sat chilling in an ice bucket.

"Okay," agreed Laura. "Let's open it." She walked to the counter, pulled out a corkscrew, and began to work on the cork. It took a few minutes before it popped with great flourish; they all applauded. She carried it to the table and began to fill glasses.

Sergei and Ethel both accepted a glass. David hesitated, then accepted as well. Shinji nodded appreciatively as Laura filled his glass. When she got to Will, he shook his head. "I've got carbonated water."

"So; won't you toast with us?"

"Yes, with the water."

Laura shook her head. "Suit yourself," she growled. She poured herself a glass and raised it. "I had planned to do this toast after supper, but Sergei couldn't wait. But that's fine. 'To Mars, and a bright future for this world and this outpost. Let us build this planet's future as well as we can.'"

"Here, here!" the others said. They all drank.

They resumed eating. After coffee and tea, Will surprised everyone with ice cream. It had required special effort; all they had on board was dehydrated milk.

They lingered over the ice cream and hot drinks, talking about anything and everything. David pulled out his guitar and Laura her keyboard—she was a pretty good pianist—and they sang songs. It was the best time together as a team that they had experienced; no one wanted it to end. Finally, people began to head for their rooms. As Laura went to her room, Ethel hurried to catch up. "Laura!" she exclaimed quietly, trying to avoid being noticed by everyone else. Laura turned.

"What is it?"

"Laura, I want to apologize for upsetting you the other night."

Laura hesitated, as if she was uncertain what incident Ethel referred to. “Oh, that’s okay; forget it,” she replied, then she resumed walking to her room.

10

Boat Rock

mid March, 2036

Will normally remembered very few of his dreams, but Satursol night he seemed to be dreaming constantly and vividly. A range of images flashed through his mind: of Aurorae Chaos dotted with habitats and green domes like a giant Martian suburb; of a climb up the cliff face to the top of Boat Rock; of a hike on Phobos and on an asteroid. Then the venue shifted to Earth. He saw his ex-wife, whom he still loved or at least admired greatly, cooking breakfast in the kitchen; then he saw his mother and sister eating their breakfast before dawn preparing for a day of fasting ahead of them. . .

Will woke up. He sat up in bed and at first was unsure where he was. The bedroom was still unfamiliar and he had not installed a nightlight, but some light filtered in through his porthole-sized window. He stood and looked out. His west-facing window revealed the dark profile of Boat Rock to the left silhouetted against the starry canopy. Balanced on the western horizon was Phobos, ruddy and almost full.

He was startled to see it and thought it was setting; then he remembered that it rose in the west. The fullness of its disk told him something about the sun; it was close to the eastern horizon. He looked at his clock; 5:30 a.m., about half an hour before sunrise.

If he got up then, he could eat breakfast before sunrise. So he turned on the light, pulled on his clothes, and headed for the galley.

Will managed to drink tea, eat two slices of toast with jam—he had made bread the sol before—and have a small portion of scrambled eggs before the sun suddenly popped above the horizon, almost unheralded by twilight. He cleaned his dishes and set

up the coffee maker so the others would have their morning coffee. He was walking back to his room when Ethel appeared.

"You're up early!" she exclaimed. "Sorry I didn't have anything ready for you; breakfast is my responsibility today."

"I set up the coffee," replied Will. "I woke up early and decided to start my sol." He paused, then added, "I had a dream; my mother and sister were eating breakfast before dawn. So I decided that I could fast today, since we have no official work to do."

"Fast? No eating?"

"And drinking. It's really not as hard as it sounds; your body adjusts. All I'm doing today is setting up my room, then going for a walk."

"Geology?"

"No. Well, not primarily. Let's call it a 'poetic expedition.' I need to get a feel for this place."

"Can I come? That would be interesting."

"Sure."

Just then David's door opened. "Good sol," Will said to him.

"What?"

"'Good sol.' If they say 'goo'day' in Australia, we can say 'good sol' here."

"True. Good sol to you, too. Did I hear you talking about a hike?"

"I want to go on a 'poetic exploration' of the area. Geology is secondary."

"Good idea. Can I come?"

"Sure." Will looked at Ethel. "That makes us a threesome."

"Great," said Ethel, and she did seem happy with the arrangement.

Sergei's door opened and out stepped Laura in her bathrobe, heading for the bathroom. "Good sol," Will said.

"What? I've never liked that word, 'sol.' I'd rather think of today as Sunday than as Sunsol. In fact, Sunsol is repetitious, isn't it?" and she headed to the bathroom.

"Yes, I suppose; but pretty soon Sunsol will fall on terrestrial Monday," replied Will.

Laura shrugged and disappeared into the bathroom.

Ethel looked at Will, who looked back at her. David saw the exchange of glances. "There's not much we can do," he said.

"We know; we tried," replied Will.

The next sol—Monsol—Sergei and Laura prepared automated cargo Lander 3 for a short flight. In twenty seconds it rose six hundred meters into the sky, then descended to the ground, touching down gently at the bottom of the depression near the hab just two meters north of where they wanted it. Half an hour later, after the engine had cooled, Ethel and Will approached it, unrolling an electrical cable as they went, which they plugged into the lander. Within an hour both drills on board began to penetrate the ground, making shafts six meters apart. The cuttings accumulated in a ten-meter long plastic sleeve that, once full, had to be lifted out and replaced; Will planned to study each sleeve with great care. A tube carried Martian air down the hole to the drill bit to cool it. Aurorae's relatively soft sedimentary rock could be penetrated at the rate of ten to fifteen meters per sol. Each drill could go down 100 meters; at that point the cable and tubing from one could be transferred to the other, allowing it to drill to 200 meters. When

another lander arrived with another pair of drills, they'd have 400 meters of drilling cable and tubing.

Once the drills were operating, they turned to the outpost's power system. Aurorae already had extensive arrays of 32 % efficient solar panels. But the panels had no ability to track the sun or concentrate the sunlight, with the result that at sunrise and sunset power output was miniscule and peak power output lasted only about six hours a sol. Furthermore, no heat energy was captured, only electricity.

Solar power units or SPUs tracked the sun and collected heat energy. Ethel and Will struggled to pull the half-tonne unit from its box. They oriented it carefully north-south on ground that Laura had smoothed using the ranger's bulldozer blade. They attached an air hose that ran to a tank of liquid carbon dioxide and opened the valve slightly. While Ethel held onto the end where the gas was entering, Will help the structure unroll gently, cushioning every turn that brought a delicate solar panel downward to the ground.

Soon the unit had unrolled to its full thirty-two meter length, revealing a long, flattened cylinder. They plugged it into the power grid, attached air input and output tubes to its heat exchangers, and threaded a cable through a series of loops along the northern and southern ends of the cylinder. Finally, they pulled a cover off the cylinder, stretched it over the prepared ground, and staked it down, making an underskirt.

Ethel opened the valve fully and cylinder began to rise to its full thirty-meter height. The top half rising into the sky was transparent except for a strip of solar panels a meter wide and thirty-two meters long that ran along the zenith of the cylinder. The bottom half was silvered to reflect sunlight onto the strip, except for two parallel strips of

narrow panels running along the middle of the silvered area. Both strips of panels would be warmed by the sun—the panel on top would receive reflected sunlight six times more intense than on the earth's surface—and had a network of heat exchanging tubes behind them through which compressed Martian air would circulate. Electrically rolled along the underskirt, the silvered surface would always face the sun, capturing 160 kilowatts of electricity and 160 kilowatts of thermal energy constantly from sunrise to sunset.

It took two hours for the cylinder to inflate fully. While it filled, Will and Ethel drove four anchors deep into the ground—they used a sledge hammer—and attached cable pulleys and motors to each. Each pulley and motor took at least an hour to set up; when the SPU was fully inflated they had finished the ones on the northwest and southwest corners. They paused to admire the huge object, which now stood thirty meters high and wide and thirty-two meters long.

"Let's roll the SPU toward the sun so the systems can be tested," suggested Will.

Ethel nodded. They each headed toward the eastern end of a cable. The sun was approaching the zenith, but had not reached it yet. By pulling very gently, the entire huge structure rolled slightly eastward until sunlight fell on the entire silvered half and was reflected onto the panels. They saw the power suddenly surge.

"Wow!" said Will. He was surprised by how fast the power output jumped. Because of dust lingering from the recent global dust storm, that sol it could make only 145 kilowatts of power. The SPU was putting out as much power as four tonnes of solar panels!

"And look at the rising temperature of the air flowing through the heat exchanger!" added Ethel. Will orally commanded his computer monitor to switch to the

heat exchanger and was surprised to see that the air was already exiting at 20 centigrade. It rose to 23 centigrade while he watched.

"How high can it get?"

"We hope 150 Centigrade. Above that temperature, the plastic structure could be damaged. The conversion efficiency is 65%; half of that is electricity and half is heat energy. It's worth the hundred million in development costs, I think!"

"I can see why it's been called a poor man's nuke!"

Ethel laughed. "Yes, it's a lot cheaper and has much less mass than a nuclear reactor. But it'll require constant cleaning and won't give us practically anything during a severe global storm. I hope we won't be busy patching holes, either! Time will tell which is better."

"Pinprick-sized holes could be handled by a compressor pretty well. Why did they put two parallel strips of solar panels along the middle of the silvered surface? The strip on top gets all the light."

"It'd make the cylinder top heavy. The pair of strips are opposite the big strip and have the same mass, so they balance each other."

"Oh, of course! You can see why I'm not an engineer."

"The other reason is to get more power from the unit in a dusty sky. That's my worry; today's sky doesn't look dusty, but it's dusty enough to reduce power output."

"If the U.S. presidency changes later this year, we may get a nuke after all."

"We'll see; the Republicans might not have the clout to re-insert nukes into the NASA budget. I'm getting hungry. Let's get the two eastern motors installed so we can get some lunch. We can't have the wind blowing this thing around."

"Okay. Would you like to join me in a hike to the top of Boat Rock after we eat?"

"Late this afternoon? We'll be pretty tired when we finish the cables, and I'd like to test the system further. But we could do it first thing tomorrow morning. Do we have permission to climb to the top?"

"Yes, it arrived this morning. Mission control has approved the route."

"Okay. But we don't know whether you and I will be assigned to work together tomorrow."

"True. But we could request it."

"We could, and I bet Laura will agree. I think she's match making."

"Really?" Will laughed. "Why do you think that?"

"Part of our conversation, last week."

As Ethel predicted, at the brief staff meeting the next morning Laura assigned them to work together again. Will immediately asked whether the climb to Boat Rock could be done that morning and Laura agreed. David looked disappointed.

He and Ethel suited up and headed outside. Their first stop was the SPU. It was rolled over facing the sun, which was still fairly low in the east. The solar panel strip was blazing brightly in reflected sunlight.

"Look at the power output, though," said Ethel. "It's only 142.5 kilowatts."

"Maybe the pointing isn't quite right."

"No." She reached out and ran a gloved finger along the surface of the cylinder. It collected a faint reddish smudge. "Dust. The structure's antistatic coating may not be

working right. We'll have to monitor this closely. This is a pretty big structure to dust off every few sols!"

"That would be a problem," Will agreed.

They descended to the floor of the depression where Lander 3's drills were at work. Each drill's plastic sleeve was full of cuttings; they pulled them up from the shafts, replaced them, and reactivated the drills. They laid the two sleeves on the ground, side by side, next to the two sleeves retrieved just before sunset the sol before. Will was pleased.

"We made a lot of progress yesterday, drilling through five meters of loose drift and ten meters of sedimentary rock." He pointed. "There's the transition from loose drift to arkose. You can see the cuttings get a lot more chewed up and there are fewer small particles."

"I guess the ten million dollar question is, any water yet?"

Will shook his head. "It's too soon; we've got to be down at least ten meters more before the hole begins to give off water vapor. According to the ground radar, the pore spaces are only ten percent ice at a depth of about thirty meters; that rises to ninety percent at one hundred meters. We have to be patient."

"So, sol after tomorrow we should start to encounter a bit of ice?"

"Yes. Maybe even late tomorrow, if we're lucky. After that, every sol will bring us into wetter rock. We should push both shafts as deep as possible before we start water extraction."

"Two hundred meters?"

"Yes. We'll reach that depth in about a month, if everything goes well and nothing breaks. Then we can start piping the SPU's heat energy down both holes."

“And up comes moist air. Sounds like there’s plenty of time to install the condensing units!” She looked at Boat Rock. “Anything else to do here?”

“No. There’s no need to walk along the cuttings and dictate a description of each layer because the guys in Moscow will photograph them with the camera on the top of the driller. Then they’ll email questions and I’ll go over them.” Will pointed to the mesa. “Let’s go.”

The two of them headed toward Boat Rock. The rolling terrain they crossed, like all of the Valley of Dawns, was the rocky bottom of a catastrophic flood channel. Over the three billion years since, it had been cratered, partially burying the flood features under ejecta. Periods of equatorial wetness had weathered the surface and created a hard duricrust of salts and clays in many places. Countless wind storms had sandblasted everything and shifted dunes of fine dust across the terrain.

Will called Laura to request more bandwidth so that both of their helmet cameras could broadcast video back to Earth. They reached the base of the talus slope and walked westward along it for a hundred meters until they reached a spot where an impact crater had nicked the cliff, tumbling rocks as large as bedrooms to the bottom. They began to climb up the boulders, sometimes leaping from top to top, sometimes hiking around them. In a few minutes they got above the area they had already explored and began to describe boulders as they went, stopping to focus the cameras on each one. In some cases they zoomed in closely; the mesa’s bedrock contained occasional laminations of dark shale. Will had already brought some inside the habitat and looked at it closely under a microscope, but had not found any microfossils.

They took their time, working their way up the jumble, staying close and watching each other as they climbed. Periodically they backtracked to answer questions coming from Earth; sometimes the return visit to an outcrop took longer than the original stop, even with Houston vetting the questions.

In two hours they reached the last stretch, a series of cliffs separated by ledges. Will felt for hand and footholds, then pulled himself up to the first ledge; Ethel pushed and helped him balance. He anchored himself well, reached down, and helped pull her up. They walked along the ledge and repeated the pattern to reach the next ledge. From there it was a simple matter of clambering up the last meter to the top.

"We made it!" exclaimed Will, pleased and excited as he took the last step. He scanned the horizon quickly, turned himself much more slowly so that his helmet camera would broadcast a clear image back to Earth. Boat Rock was not flat topped, like Layercake Mesa; it had a hump running down the middle like the keel of a boat.

"Boy, this surface has been eroded!" exclaimed Ethel.

"Yes, your geology eye is well trained," agreed Will. He walked to a circular pit nearby about three meters in diameter and filled with debris. "Here we have a pothole, I think. If we were to excavate the loose stuff we'd find the hard rocks at the bottom that swirled round and round and cut it. We may be a hundred meters above the habitat, but we're still not above the top of the ancient flood waters!"

They both crouched around the pothole and focused their cameras on it, examining the sandstone into which the pothole had been cut, then pulling out small shovels and digging down into the deposit in it. The wind-blown material was layered as

well; they took samples and focused the cameras on each one to get a good-quality close-up shot.

They walked the area, describing the surface, focusing on the layers, working their way toward the keel, which they reached in half an hour. Ethel pulled a small meteorological station from Will's backpack. They unfolded a square meter of solar paneling, then deployed the meteorological unit and raised its wind velocity boom. By piling boulders around the base they guaranteed it would not blow over. They plugged it into the array and data immediately began to be transmitted back.

"Wind speed, 21 kilometers per hour; good," said Will, with a smile. "That's about three times as high as it is at the habitat."

"So, we have potential wind power up here." Ethel looked around. "We could put about twelve MA-2 wind turbines up here, so that's 18 kilowatts of power. Not much."

"Except when a storm front comes through," replied Will. "If the wind speed triples, the power output increases nine fold."

"We'll have to leave that task to Columbus 3."

"Let's answer the rest of these geology questions and take a break." Ethel nodded and they turned back to the geology emails and voice mails. In another fifteen minutes they exhausted the questions in the queue.

Will pointed to a long boulder nearby; Ethel nodded and they sat on it. She called him on his private phone line. "Let's talk without a billion people listening in."

"Good plan. Let them watch commercials." He looked over the terrain around them. She did the same and was struck by the view.

“All this time up here, looking down at the ground, I had no idea we had an incredible view around us!” she exclaimed. “It’s really beautiful!”

“It is! Generally, Aurorae is beautiful, with its magnificent cliffs. But up here the view is spectacular!”

“I love the escarpment. Its color changes as the sunlight and dust levels change.”

“This place is really growing on me. It’s got the exoticness of the moon but the geological diversity of the Earth. And it’s so ancient! It’s a key to understanding the geological evolution of early Earth.”

“Much of your career was based on *the moon* being the key to understanding early Earth.”

Will smiled. “Well, both of them are!”

She laughed. “I like your humor, Will Elliott.”

“Thank you. I like your grace.”

“My grace?”

“Yes. You have style.”

“Thank you. I think we make quite a pair, actually.” The two of them looked at each other. Their eyes met and something passed between them; something that defied the rules against romance. They spontaneously leaned toward each other.

Their helmet bumped. Ethel and Will laughed almost simultaneously. “That’ll teach us to mind the rules!” she said.

“Yes. No kissing outside.”

“And no kissing inside, either. Will, there’s no question about it; we are attracted to each other. You’re really special.”

“You’re special to me, too. And you’re right; the next eighteen months is not the time to develop a romance. We’re worrying about Laura and Sergei getting so close that the team spirit is broken, and we’re in danger of doing the same!”

“As I said, Laura’s playing match maker just to spite me.” Ethel shrugged. “That’s alright, I forgive her! I enjoy my time with you. So, if we can’t have romance, let’s at least be partners in bringing Columbus 1 together. What do you think?”

“What do you have in mind?”

“I don’t know. Things that build more friendship, trust, and rapport among us.”

“Like the meals we planned?”

“Yes. Laura and Sergei certainly won’t do that, or anything like it.”

“No, it’s not their style. David’s part of our group as well, so that’s three of six.”

“Shinji is very quiet and private, but I very much like him,” said Ethel. “I think we can get him involved more. He loves cowboy movies, believe it or not. I think we need to propose some team movie nights.”

“Can you work on Laura more, to get her to loosen up?”

Ethel considered. “Yes, I can talk to her. Can you work on Sergei?”

“Yes; we get along pretty well. But what are we trying to do?”

“Duplicate that great meal we pulled off the other sol. Get people to know and trust each other more. It strikes me as ridiculous that six people can live close to each other and not know each other, and yet be the entire population of a planet!”

“I agree. We’re all from very different cultures, though. That makes it hard.”

“Oh, I don’t know. Laura and Sergei get along. You and I do. You and David do. I don’t think culture’s our problem.”

"You're right. What we need is old-fashioned hospitality and friendship."

"I think so," agreed Ethel.

"Okay, let's do it." Then Will stood. "We've got less than three hours of oxygen. We've got to leave an hour of reserve and it'll take almost an hour to get down, so we have only an hour left to work up here before heading down."

"Yes, you're right. I'm not looking forward to going down that cliff."

"We'll attach a rope permanently to the top and use it to get down."

"Even so!"

11

Greenhouse

late March, 2036

Shinji and Will slowly, almost gingerly opened the airlock door between the docking unit and their newly inflated greenhouse. They peered into the cylinder of transparent plastic, twenty meters long and eight wide.

"There's no reason to stand here," said Shinji, and he strode in. Will followed. They walked the length of the greenhouse in silence, watching their breath steam in the cold. Will touched the transparent plastic structure; it was thick, cold, and taut. It distorted the outside.

"The sky looks red."

"It absorbs some of the blue light, and all the ultraviolet of course," replied Shinji. He pointed to the silvered blanket against the eastern side of the cylinder. "The silvering makes up for the absorption by reflecting downward the sunlight that would pass over the plants. In the morning the silvering covers the western side, of course."

Will nodded. "The cylinders on the moon feed and recycle the wastes for two people."

"It'll do the same here, once it's at its peak."

"I bet you're happy to see this place set up," said Will, seeing his pride.

Shinji smiled. "Thrilled! I'm a biologist and a physician, not a geologist or mechanic. Work like this is why I live!"

"Have the soil chemists settled on a formula for making 'soil'?"

“I’ve sent them data on several dozen samples from nearby deposits and they’ve developed a recipe of alluvial sand, eolian dust, caliche, and crushed basalt. It has no significant arsenic, lead, mercury, cadmium, or selenium, but it does have some salt we’ll have to wash out of it.”

“That’s something we don’t have to worry about on the moon.”

”That’s one way Mars is different. It needs fertilizer—nitrogen and phosphorus in particular—and organic content. Each shuttle brought fifty kilos of living soil. With plant waste, manure, and regolith mix, we can double it every two months. We can have twenty tonnes of living soil about the time we leave.”

“Enough for one greenhouse, but we’ll have two.”

“We’ll plant soil-enhancing crops before we leave and Columbus 2 will maintain the greenhouses remotely. The soil should be pretty good when they arrive. Each one eliminates the need for about a tonne of supplies per year. When will I have more water? I’ll never green more than a quarter of this place with our current supply.”

“We’ve been drilling five sols and we’re down almost fifty meters. The pore water isn’t as good as predicted, but it’s still ten percent of the bedrock by volume and five percent by mass. When these holes are down two hundred meters, they’ll have about fifteen hundred tonnes of water within six meters of them; over a few years we can heat all that rock up and drive off most of the water.”

“We should have plenty of water, then.”

“Yes. If we need more, we’ll just drill another pair of holes. At the rate things are going, Columbus 2 won’t have to bring any hydrogen at all, and only half of its food!”

“Which means Columbus 2 can fly eight people here instead of six.”

“I think so. Of course, the question I’d like to consider is how to make the six of us get along better.”

“Hum. I. . . think we get along well enough for this mission, and I’m not sure we need better relations. I think Ethel should stop bothering Laura about her relationship with Sergei. It’s not something she can change.”

“She knows that.”

“Good. Don’t encourage her. Leave it to Mission Control.”

“I gathered they’re ignoring it, though.”

Shinji shook his head. “I don’t know why you think that. But I think they should ignore it. Our situation is different from the moon’s. If you’ve got six or eight people on the moon for six months, they should be professionals, act like a team, and get the work done they’ve been sent to the moon to do. Romance can interfere with that. Besides, most are going home to spouses and families. No one wants Shackleton Station to get a reputation as a marriage breaker. But Mars is an assignment lasting thirty months. That’s a very different situation.”

“Yes, but it also means this place is more intense and more of a life and death situation. We can’t afford favorites or jilted lovers.”

“Yes, we’re pretty small for either situation.” Shinji shrugged. “Let’s hope nothing happens.”

“Yes, let’s hope,” said Will, disappointed. “What movie would you like us to see tomorrow night?”

“Movie? We’re seeing a movie?”

"That's the idea. I'm cooking dinner for 7 p.m., then we'll watch a movie. I'm downloading it overnight."

"I see. You know what I haven't seen for years?"

"What?"

"*Gone with the Wind.* I remember when I first came to the United States I watched it with some fellow students. I was so impressed by it!"

"That's a great film; I'll see whether I can get it. It's a good suggestion."

The next sol, Satursol, they worked until late afternoon. While David and Ethel set up the second solar power unit, Will and Shinji prepared steak, vegetables, and pasta, and Laura and Sergei made a geological excursion to a catastrophic flood deposit on the route to the *Olympus* for the benefit of geologists in Moscow and Tokyo—it was the wee hours of the morning in Houston—and visited the shuttle to check out a flaky sensor. Will watched on the tv monitors while he cooked and occasionally offered clarifying questions or interpretations to them, but otherwise their geology was excellent.

Everyone was back inside just before sunset. Dinner was another grand success, capped again by a bottle of wine—everyone wondered how many Sergei had—then the movie. They sat together to watch *Gone with the Wind,* which Sergei and David had never seen before.

Several times, Laura seemed agitated. She filled her glass with wine each time. She hurried to the bathroom as Atlanta began to burn, then sat moodily through the rest of the film. Ethel began to watch Laura as much as the movie as the latter drew to an end.

“That movie is just as good as I had heard it was,” said David with a smile as the credits began to roll. He stood up to stretch.

Laura glared at him. “This was your idea, wasn’t it?”

“What?” He said defensively.

“Well, I may be from Atlanta, but I’m not Scarlett O’Hara!” Laura rose and stormed out of the room.

David looked angry; Will was shocked; Sergei confused. “Why would you do such a thing?” asked Sergei.

“We didn’t!” exclaimed Will angrily. “This never occurred to me!”

“Nor me,” added Shinji. “I suggested the movie because the first time I came to the U.S., I saw the movie with a bunch of fellow Stanford students, and we really had a good time together.”

“It wasn’t my idea at all!” added David.

“Okay, I’ll see what I can do,” said Sergei. He followed after her.

Ethel looked at Will and David, then Shinji. “I’m sorry, but this confusion never occurred to me, either. One could see Laura as Scarlet and Sergei as Rhett Butler.”

“Only a little! And what does that make me? Ashley?” asked Will indignantly.

“I suppose I’d be Mamie, then,” growled David. “I hope she plans to apologize.”

“Don’t hold your breath,” said Shinji.

“I guess I won’t.”

12

Escarpment

April, 2036

For the next few weeks, everyone stuck to professional conversations. Laura and Sergei retreated to her room or his for lunch and supper, leaving the other four to socialize. Breakfasts usually involved all six of them, but the conversation remained focused on the work to do that sol. Laura set up a rotating schedule of tasks that often matched Will with Ethel and never matched her with David; she put it on the website and breakfasts were time to review it quickly.

The work of repairing relations fell to Shinji. He held short conversations with Laura, Sergei, and David about the psychological bases of conflict and listened carefully when everyone responded to him passionately. He filed reports with Mission Control and dropped the matter. He was a zero-gravity medicine specialist first and a horticulturalist second; psychology had never been one of his fields, and it ill-suited his personality.

In spite of the difficulties, work on the outpost proceeded on schedule. The habitat was finished one month after they landed, with all rooms furnished and covered with bright wallpaper panels. All pipes and wires were installed and the entire habitat was buried under a meter of sand. Work on the greenhouse progressed. Different materials were hauled to it, sifted into a series of size fractions, the sand and dust sizes were brought inside and poured into plastic troughs for a week to warm up, then the future soil was soaked with water to release peroxides and salts. The water was desalinated and reused. The air was carefully monitored for contaminants and heat was added from the solar power units.

The drills reached a depth of 100 meters and the cabling was transferred from shaft one to shaft two so that it could continue down to two hundred meters, allowing shaft one became the site of an experiment with heated Martian air. The 150 kilowatts of heat output of one of the SPUs was pumped into the shaft in a plastic tube and the hot air flowed back up another tube after heating the rock and picking up water evaporating from the walls. In the first week they obtained half a tonne of precious water, which was essential for the greenhouse set-up continue.

The team finished unloading the three cargo landers, each of which had transported 12.5 tonnes of supplies to Aurorae Chaos. They unloaded the *Olympus* completely to lighten it for its hop to the outpost, but the *Elysium* and *Pavonis* continued to store essentials; by scattering them among several locations, they were protected from possible destruction in an accident.

By April 3, most of the set-up was finished. By then, three more automated cargo landers had aerobraked into orbit, awaiting the command to land. With work one sol ahead of schedule and another month of drudgery ahead, Laura decided it was time for a longer geology expedition: to Aurorae's two-kilometer high escarpment twenty kilometers north of the outpost. Will and David had to go, as the expeditions' two geologists; Laura very much wanted to go; and she decided Sergei would go as well. The four of them set out soon after dawn in the ranger with a portahab attached.

Various short expeditions had already taken them half way to the escarpment with the bulldozer blade down, so they chose a track that took them toward a major canyon that penetrated the escarpment; it might eventually provide a route to the top. They proceeded slowly and scraped a dirt track of fairly good quality so that in an emergency

they could return to the habitat quickly. After three hours, they parked just beyond the massive talus piles at the bottom of the escarpment.

They pulled on their suits and stepped out. The escarpment rose to a height of almost two kilometers and the top was a mere five or six kilometers away; it was as if a gigantic vertical wall cut the surface of the planet.

“There’s nothing to compare this to,” said Will, after a moment of silence.

“It’s about as high as the front of the Grand Tetons,” replied Laura. “But it’s much wilder looking!”

“I can’t imagine what the eight kilometer high escarpments are like farther west,” said David. “Can you picture something four times higher than this!”

“Of course, you often can’t get this close,” added Will. “Because landslides roared down the escarpment and spread fifty kilometers across the canyon floor!”

“Someone will see them eventually,” said Laura. “Sergei, you pull out the laser and set it up. Just make sure you’re aiming at rocks well above our heads!”

“At some point, I should probably zap that house-sized white boulder,” said Sergei, pointing. “It’s probably tuff.”

“It’s from that layer,” said Will, pointing to a prominent light gray band crossing the escarpment half way up. “So zap the rock after we come back for lunch, and zap that layer while we’re exploring. That’ll confirm its chemical similarity to the stratum.”

“We’re going to have communications problems in those rocks,” said Laura.

“We can set up the relay unit on that big boulder,” said David, pointing. “The buggy will be here in another few minutes; we can park it over there and it’ll serve as a relay.” He pointed to a spot where the debris slope had few boulders.

“I’ll tell Ethel to drive it there,” said Sergei. Ethel was in the habitat playing a support role.

“Good. Let’s go,” said Laura. Everyone activated their helmet cameras so the geologists on Earth could see anything they saw in color, five frames per second. The signal, however, had to be relayed to the ranger for retransmission to communications satellites in orbit because their suit radios were lower powered.

Laura, Will, and David loped over to the talus, moving quickly in the low gravity. They spread out, following their usual procedure of stopping in a spot, describing everything thoroughly, answering questions about it, then moving on. Millions watched on cable channels, and sometimes they emailed questions of sufficient intelligence to be transmitted to them.

They looked for as many kinds of rocks as possible. As they picked up pieces, photographed them, described them, and took samples, Sergei was firing the laser at different layers in the cliff to determine their mineral compositions; the laser could later be used on the samples, allowing some samples to be linked to the layers they had fallen from. Most of the escarpment was a mix of conglomerates, poorly sorted arkoses, dune sandstones, and occasional quiet water sandstones and shales, mixed with volcanic tuffs and basalt flows, laced by occasional lenses of evaporite or zones of duricrust, with thick, irregular deposits of crater ejecta abruptly interrupting the sequence. All of it had been chemically altered by ground water. It was amazing to think that in the Noachian era of Mars—the first half billion years of the planet’s history—the area had accumulated at least 2,000 meters of volcanic and sedimentary deposits, all before the formation of the Mariner Canyons. Mars had been far more active geologically in its youth than now.

Anything that formed in water, Will looked at with especial care. But there were no fossils to be seen. This was the enigma of their work: clearly Mars had been a relatively wet, active world, but so far it appeared to have been lifeless.

Will worked his way up the debris slope and in 90 minutes had almost reached the canyon mouth. He stopped and excavated under the ejecta, regolith, and eolian dust to examine a deposit of water-washed sediment; as he suspected, the canyon had once had a flow of water cascading down it. At that point Laura caught up with him. David headed toward a bedrock outcrop across the slope about a hundred meters to the west.

Laura tuned into Will's description of the alluvial fan deposited on top of most of the talus and therefore younger than it; millions of years old, rather than billions. She sat on a rock nearby and rang him up on his private number. "You sound thrilled, Moonman."

"I am! Thanks for proposing this trip. I've been itching to explore the escarpment ever since I was chosen for Columbus 1."

"The geology here is incredible."

"Yes. Rich. It'll take years to exhaust it all." He pointed down. "I wouldn't be surprised if there's ice buried under the talus, too."

"Really?" Laura looked at the canyon mouth ahead of them. "We won't get much farther today; our oxygen's too low. How far up the canyon can we go?"

"Hard to say; the canyon's narrow and filled with shadows, so orbital photography's spotty. One or two places are blocked by slides, but we might be able to get over them. It's fifteen kilometers long; we'd have to pack in oxygen tanks, set up at least one staging camp, then push to reach the end and back."

“It’d be the equivalent of hiking from the bottom of the Grand Canyon to the top in a pressure suit. I wouldn’t try it.”

“Me either.” Will walked over to the rock where Laura sat and joined her. He put incoming messages from Earth on hold. “I could use a rest, too. These vertical climbs are a lot of work in a pressure suit, even in the low gravity.”

“It makes you feel your age.”

“It makes me realize I’m not 25 any more, that’s for sure! I wish we could find some fossils.”

“You yourself said this isn’t the place. We’re in a net erosional environment; we have to find depositional environments instead, like in Gangis Chasma.”

“And parts of western Aurorae Chaos. I suppose there will be time to visit some of those spots later in the mission.”

“I’m working on it. Mission Control is conservative; they want to keep us safe.”

“Of course. I appreciate your effort, Laura. You’ve been pretty persuasive.”

“Thank you. I didn’t know there was anything I had done for this mission that was appreciated.”

Will looked at her. “I’m sorry if I’ve said anything that was misunderstood. I think you’ve done some excellent and highly effective things as Commander. You’re decisive, you have excellent vision for what we can do, you’ve proved persuasive with Mission Control, and we’re a bit ahead of schedule in outpost setup because you made some clever resource allocation decisions.”

“Thank you.” She was impressed. “I’ve done my best.”

"And I've done my best to bring the six of us together, rather than leave us as six autonomous individuals on this vast planet. I haven't tried hosting another dinner party recently. Do you think I should?"

She considered. "Why not this coming Satursol. Two cargo landers will have landed and we'll be pretty busy. At that point, we could use a break."

"Good idea. We could try a movie as well, if you think that might be fun. This time we should let everyone add to a list of movies and scribble notes about whether they like the movie or not. Shinji really meant no harm by proposing *Gone with the Wind.*"

There was a pause. "Yeah, I'm sure that's true."

Will looked at her. "I hesitate to suggest this because I know it is difficult. But if you could find it in your heart to apologize to David, it would make him feel much better. He really was innocent."

Laura looked at him, pensive. "We really have had a problem, for some reason. Not sure how it got started. I guess it's personal chemistry."

Will shrugged and smiled supportively. He wasn't going to speculate about David's French and African ancestry or his dark skin; darker even than Will's.

"Okay, I'll try," she said. She stood up and headed straight to David.

Will watched her go. Then he rose and reactivated the voice and emails from Earth. There were quite a few to deal with.

Laura took her time walking across the loose scree, aware that she might accidentally trigger the area's first landslide in ten million years. David had stopped to describe a basalt flow. The base of the ancient lava flow had streaks of green; malachite, a common copper ore.

She felt his excitement and got excited as well. This was a significant find; not as important as fossils, but important. He had found a few samples that were a significant percentage of copper carbonate.

“Congratulations,” she finally said to him, after he finished dictating his description. “This appears to be our big find of the sol.”

“Maybe. I figured you and Will had listened in and come over; where’s Will?”

“He’s still exploring the alluvial fan deposit that came down the canyon mouth and spread out on top of the talus.”

“That’s pretty important, too.”

“Yes. This has been a day full of surprises.” She looked at the status of her connection with David; she had called him on a private line, but he was replying on a public line. “Actually, David, I came over to have a private conversation with you.”

He was startled. “Oh?” He immediately switched to a private connection.

“I want to apologize for accusing you of trying to embarrass me with the movie feature, a few weeks ago.”

She saw a surprised—shocked—expression spread across his face. Then he nodded. “Thank you, Commander, I appreciate that.”

They explored until oxygen ran low, then went back to the portahab to eat and recharge their backpacks, then all four of them walked back up the slope until afternoon shadows grew long. Will and David managed to get a kilometer up the very narrow and steep canyon—they called it ‘Little Colorado’ in honor of the Grand Canyon—at which point they lost radio contact. They would have to try again at a time when a communications

satellite was looping overhead, or bring along a few communications relays. Will didn't mind a half hour of radio blackout, but everyone else freaked out.

They returned to the habitat very tired but very happy. The energy was different; Ethel felt it right away. "What happened out there, today?" she whispered to Will as she was approaching the bathroom and he was walking away from it.

"Laura and I had a heart to heart talk, and she apologized to David."

"Really? How did you do that?"

"I'm still not sure."

"Congratulations!" She leaned over and kissed him on his ear; a playful, funny gesture. He laughed.

He walked back to the table, happy. Shinji had cooked a pretty good meal. They were all sitting around the table in the great room, relaxed, talking about the rapidly deepening economic recession and its possible implications for the space program.

Ethel returned from her visit to the bathroom. Laura raised her coffee cup and drained the last drops from it. "Okay, folks," she said. "We all know what tomorrow is, don't we?"

"Tomorrow everything starts all over again," replied Shinji. David smiled.

"I suppose you could put it that way," said Laura. "Cargo Lander 1 is cleared to land at 6:45 a.m. at landing zone 5."

"It's got ranger 2?" asked Will.

Laura nodded. "And surface exploration equipment, and the second sunwing. If we start unloading it by 8:30, we can probably finish by sunset."

“And the next sol we get habitat 2,” exclaimed Sergei. “Followed, the sol after, by greenhouse 2, the second portahab, and more chemical and metal fabrication equipment.”

“And four or five weeks to set them up,” added Ethel. “We’ve got a lot of work ahead of us.”

13

Birthday

May 2036

The next three sols were filled with adrenaline. Someone was in the bridge at all times monitoring the three landers and making last-minute corrections; Earth was seven light-minutes away and unable to make snap decisions. But all went well and all three landings were perfect, the vehicles touching down near the centers of the hundred-meter pads that had been cleared for them.

The cargo on the three new landers was nearly identical to that on the three old ones, so that if a shuttle missed the prime landing zone, an entire set of mission supplies could accompany it. They deployed the second ranger first and used it to excavate the dish-shaped hollow for habitat 2 a few meters north of hab 1. They inflated it and attached a docking unit and a pressure suit donning facility to its eastern and western airlocks. One of the docking unit's doors was attached to the far end of greenhouse 1, providing a connection between the two habitats on their eastern side; greenhouse 2 was inflated to provide a second connection on their western sides. Thus the design of the Outpost was of two circular habitats connected together by two rectangular greenhouses, one on each side. It was capable of infinite expansion, producing a network of greenery connecting buried housing.

Their spare docking unit was attached to the northern door of the eastern docking unit and they "docked" their industrial modules for making chemicals and metals to it. Everything was surrounded by sandbags to protect them from explosions.

The next Sunsol they opened all the doors and held a footrace to see who could run the length of greenhouse 1, across hab 2, back up greenhouse 2, and across hab 1, an eighty-meter round trip. It was a great antidote to cabin fever. But otherwise, the month of April consisted of twelve-hour sols of hard work, installing floors, setting up life support units, and running pipes. They did undertake two departures from the original plan; they moved the geo-bio lab to habitat 2's Great Room, tripling the space for equipment and samples, and moved the repair facility from its cramped room in habitat 1 to the geo-bio space in habitat 2. Everyone continue living in habitat 1, but they made habitat 2 their work area.

In late April the question of the next priority for their work arose. "So, is this sol the sol we can set up the chemical synthesis unit?" asked Ethel, after pouring her morning tea. "We've got the water and electricity it needs and it can make the plastic panels we'll need if we decide to fix up the basement and reinforce this floor." She tapped the floor under foot.

"But Will and I wanted to get a sunwing put together," replied David. "It's essential for the surface exploration program. We've got six Prospector rovers to fly to their proposed deployment sites. If we can get them into the field, before we head for Earth the sunwing can fly out and retrieve their sample canisters."

"I know. I understand. But even half a sol of work by four or five of us will get the chemical and plastic synthesis unit running. The sooner, the better; the equipment roster for Columbus 2 will be simplified by our successes."

"Ditto with the metallurgical refining equipment," added Sergei. "But it needs meteoritic nickel-iron, too."

“Anyone can do that,” said David. “We have two rangers.”

“How long will these projects take?” asked Shinji.

“The chemical and plastic synthesis unit is the simplest; a few person sols is plenty,” said Sergei. “The carbonyl synthesis unit is a bit more complicated because its fractionation tower has to be assembled; it was too tall for the lander. The sunwing is by far the most complicated; it’ll take several weeks of assembly.”

“A sixty-meter wingspan doesn’t fit in a launch fairing either,” quipped Will.

Just then Laura entered the Great Room. “Shinji, Greenhouse 2’s beginning to smell.”

“It’s going to smell pretty bad for the next six months; the sewer digesting bacteria have to get fully established in the sand bed. We’ve got two months of accumulated sewage solids for them to convert into soil.”

“So, I should walk through Greenhouse 1 for the next six months?”

Shinji nodded. “In a few weeks we can lay some pipes from our gray water processing unit here in Hab 1 to Greenhouse 2, so that facility can convert shower and toilet water from either habitat.”

Laura nodded. “Yes, make it so. I don’t particularly like walking to the other hab to take a shower. If we can use this shower more intensely, we can avoid the hassle.”

“We were just debating other uses of our collective time,” said Ethel. “I want to get the chemical and plastic synthesizing unit running so we can determine whether we can make useful compounds or not. If we can, Columbus 2’s cargo roster is very positively impacted. But Sergei wants to get the carbonyl units installed and our geologists want to assemble the sunwings.”

"Only one of them," corrected David.

Laura looked at her colleagues. "Cost-benefit analysis. The chemical and plastic synthesis unit requires the least set-up work and needs its results the soonest. So let's get it operating right away. I suspect we can have the carbonyl unit functioning by midnight tomorrow if we turn to it next. On sol three some of us will start on the sunwing, whether the carbonyl unit is working or not. Shinji, how much can you contribute to this effort?"

"You mean from the medical and ecological research? Assuming you're asking us to work twelve hours, I can give you five."

"Good. Daoud and Moonman, what are your minimum geology commitments? Let's say we give the folks in the geology control rooms a two-day vacation; how bad would that be?"

"Today's Sunday on most of Earth, so we have no commitments," replied David. "As for tomorrow, I suspect if we said we weren't going out, most would be relieved. They're burning the candle at both ends to keep up."

"I'd make it a three-sol moratorium, so that we can get substantial work done on the sunwing," suggested Will. "They'll understand that; they can't wait for us to fly the six rovers to their designated excursion sites."

"Okay; it's vacation time for the geologists," agreed Laura. "I'll talk to Mission Control about it in. . . eight hours, when the staff arrives for the day."

Work began after breakfast. The carbonyl unit was set up in the suit donning facility attached to Habitat 1, and the chemical and plastic synthesizing unit was placed in the similar space attached to Habitat 2. Both units started with carbon dioxide and

hydrogen—the latter made from electrolyzing water, of which they now had plenty. The carbonyl making unit combined them in equal quantities, yielding carbon monoxide and water, and combined the carbon monoxide with ground up metals at low heat—110 Centigrade for iron—to make carbonyls, such as iron carbonyl ($Fe(CO)_5$). Iron carbonyl was a liquid at room temperature, allowing it to be poured into molds. Then it could be heated to 200 Centigrade to drive off the carbon monoxide and the liquid became a piece of molded solid iron. Nickel-iron meteorites were abundant. The sifter they used to separate sand from other size fractions had a magnet attached to it and already had accumulated fifty kilograms of iron fragments.

The chemical synthesis unit started with three times as much hydrogen as carbon dioxide, which produced water and ethylene or C_2H_2 under the right temperature and pressure conditions, in the presence of the right catalysts. Ethylene was useful as an anesthetic, a ripening agent for fruit, an agent that speeded germination of seeds, and as a fuel for rockets and welders. It was also the starting chemical for polyethylene, polypropylene, and many other very useful plastics. Both units could turn out only a dozen kilograms per sol; they were experimental units about twice the size of a refrigerator. But that was plenty to determine, through experimentation, how larger units could be used. Furthermore, both units produced oxygen as a “waste” gas.

They postponed lunch to 2 p.m., at which point the chemical synthesis unit was ready to be tested. That afternoon Ethel turned to it and Shinji to his work while the other four continued assembling the carbonyl unit. Sergei and Laura were still hard at work at midnight, at which point the unit was ready to be hauled to its place near the chemical synthesis unit for final assembly.

Breakfast the next morning was late. David took advantage of the quiet to ask Will a question. “How well did your fast go, back in March?”

“Okay, I guess. People adjusted to it. I assume you’re asking about their reactions and not about my stomach.”

“Exactly.”

“Why?”

“Ramadan begins in a few months. I can always postpone the entire fast to a later date, and I always figured that’s what I’d do. But your once-per-week fast was a good idea. I’d have fewer days to make up later and it would be something I could do in solidarity with my family and Muslims around the Earth.”

Will nodded. “I’d do it. How long will you fast every sol?”

“First light to last light, just like on Earth. The Martian day’s a bit longer than Earth’s, but twilight’s a lot shorter.”

“It’d amount to the same. When you say your obligatory prayer, which direction do you face?”

“I face roughly toward Earth. In practice, that means facing toward the sun, because the Earth’s always within about forty-five degrees of it. Right now it’s about thirty degrees west of it, I think.”

“Ah, so you use the sun. Clever.”

“I asked an imam. He said that most interpretations of Islamic law indicate that when you aren’t sure which way Mecca is—because you’re traveling, for example—it is permissible to face anywhere within ninety degrees of Mecca. That’s half the horizon!

Since the Earth is always much closer to the sun than that, I figure the sun is a reasonably good indicator of direction. Why?"

"Because Bahá'ís have an obligatory prayer, and we're supposed to face our qiblih, too. Since it's on Earth, I think I'll adopt your practice of facing the sun!"

David smiled. "It works for me."

Just then Ethel entered the room, followed by Shinji, Sergei, and Laura. "Has anyone heard the news?" she said, angrily.

"Do you mean, the Dow's down another ten percent?" asked Will.

"No. I just got a videomail from Heather Kimball. She says that negotiations are underway to cut Columbus 2 in half: one ITV, one shuttle, and a crew of four. And no cargo landers. It'd save five billion dollars."

"And cripple capacity here." Will shook his head. "Haven't they learned any lessons from history? ISS was practically useless for years because it was limited to a crew of three. Whenever they cut Shackleton to four, half the university geologists doing lunar science have to twiddle their thumbs."

"They still haven't recovered from your departure, Moonman," added David. "What about safety? They had better not miss the Outpost, or they'll be dead."

"We'd load the shuttle remaining here with a ranger, portahab, and supplies, so that it could be flown to them in an emergency," replied Laura. "But even the interplanetary cruise needs backup. Furthermore, the lunar fueling system costs the same, whether you fuel Columbus 2 or not."

"How could Columbus 2 arrive without cargo landers?" asked Shinji.

“Everything Columbus 2 needs is here, including hydrogen for making return fuel, except for minor supplies.”

“If shuttles don’t have to bring nine tonnes of hydrogen along, they can carry fourteen tonnes of cargo,” added Will. “That’s a lot for four people for eighteen months.”

“But once this outpost is set up, it takes two and a half full-time staff to run it,” said Shinji. “A team of four will have less than half its time available for science.”

“And if they sent eight on Columbus 2, think of the results!” exclaimed Will. “Wait until the Mars Colonization Society hears about this.”

“Yes,” said Laura. “I’m sure that’s why they’re keeping it quiet.”

“Who; pro or con?” asked Sergei, and they all laughed. The Mars Colonization Society had an unscientific, popular, and slightly fanatical reputation; it was not clear which side would benefit from their loud opposition to the cuts.

“It sounds like our manufacturing experiments may take on more importance,” suggested Ethel. “This habitat would be two tonnes lighter if the structural members had been made here. The greenhouse would be a tonne lighter.”

“Let’s figure it out,” agreed Laura. “Let’s get the carbonyl unit set up and running as soon as possible. Can we delay the sunwing by a week?”

“Is that really necessary?” asked David. “Look, Laura, if this is that important, let’s lengthen our work week for a few weeks.”

Will nodded. Laura looked at the others; only Shinji looked hesitant. “Okay,” she said. “We’ll work a full sol Satursol instead of half, and make the official work sol twelve hours instead of ten. That gives us seventeen extra hours of work per person per week. Can we handle that?”

“For a week or two; it’ll be worth it,” replied Will.

“We’ll give it a try and revisit the schedule next week,” said Laura.

That settled the matter. It reminded Will that they had only thirteen months left on Mars. How much could the six of them still accomplish? He was finding Mars more and more interesting all the time.

They finished their meals and headed for work. Ethel cornered Laura near the bathroom for a moment. “Will’s birthday is Satursol,” she said. “I thought we should start celebrating birthdays here. It’ll be his 35th.”

“My fortieth was a few months ago.”

“I know; now. I didn’t know then, Laura. I think we should celebrate everyone’s birthday from now on.”

Laura nodded. “Okay; I agree, it’s a good plan. Are you trying for a surprise?”

“That hadn’t occurred to me. Maybe we could manage it if he’s outside all sol and there are two of us—maybe Shinji and I—doing the cooking. I think we have all the ingredients to make a birthday cake.”

“I’ll assign him to work on the runway that sol. I think you’re already scheduled for Satursol lunch and David for supper; maybe I can switch the two of you around.”

“Thanks, Laura.”

Concerned about Columbus 2, the crew redoubled their efforts. By Satursol they had made their first carbonyl and had produced an iron bar, a nickel ingot, a cobalt blob the size of a silver dollar, and a tiny bit of platinum. Ethel also devoted two long sols to making her first batch of polyethylene. It was rather soft, but it was a start.

Progress on the sunwing was the most exciting to watch. It was a biplane with wings 2.25 meters wide and sixty meters from tip to tip. The wings were staggered—the lower wing was one meter behind the top one—so they both received sunshine. The wings' 270 square meters of surface was covered with solar cells that had an impressively high efficiency (40%) converting sunlight shining above and a 20 % efficiency converting stray light shining on it from the bottom. Peak energy production was forty-four kilowatts at noontime. The prefabricated five-meter sections had to be carefully bolted and wired together; a small propeller and motor had to be attached to each section of upper wing and tested.

Equally complex to assemble was the sunwing's fuselage with its computer controls, fuel cells, methane/oxygen storage tanks, and its hot carbon dioxide takeoff and landing system. A cylinder filled with fifty kilograms of beryllium bearings could be electrically heated to 1700 degrees Centigrade and liquid carbon dioxide—compressed by an electric motor from the Martian atmosphere—could be pumped into it, producing a rocket strong enough to affect a vertical takeoff or landing. In this way the vehicle could deploy or pick up probes up to 200 kilograms without the need for a runway.

The crew assembled the sunwing with great anticipation. It could be used to drop off Prospectors, pick up their sample canisters, provision expeditions, and provide low-level surveillance and communications relay service. Riding the winds, sunwings could achieve ground speeds up to three hundred kilometers per hour; far faster than surface transport. Larger models might be used to move even heavier cargos, such as ore. If sunwings proved reliable, they could even be supplied with a light-weight passenger capsule for two.

After a long sol's work assembling and testing, Will and David came inside, washed up, and enjoyed the supper prepared for them. When the birthday cake came out—minus candles, for none existed on Mars—Will was quite surprised. "What's this?"

"Happy birthday to you. . ." The others all sang to him, and he sat with an embarrassed smile on his face.

"There are no candles to blow out, so you'll have to cut the cake instead," said Ethel when they finished.

"Sure. Thank you, everyone." Will leaned over to shake hands with Shinji and Sergei and patted David on the back. He shook Laura's hand as well and kissed Ethel on the cheek.

"Oh, thank you!" Ethel replied, very pleased.

"Ethel did all the work and deserves the credit," agreed Shinji.

"Will wasn't planning to kiss you anyway," Laura replied.

"You baked the cake?" Will asked, surprised.

She nodded. "It really wasn't bad. Shinji said to ignore instincts and stick to the recipe, since instincts formed in Earth kitchens are all wrong here. And I didn't have any instincts to ignore!"

"I hope the result is good," said Laura.

Will dished out slices of the rich cake, strawberry with chocolate frosting. Since their strawberry plants had started to bear again, the cake had real berries; real eggs from their chickens as well. Will took a bite and nodded. "Congratulations."

"Really?"

"He's right; it's very good," confirmed David.

Ethel beamed.

"So, Moonman, have you any wisdom on the other side of the great divide?" asked Laura.

"Thirty-five? I assume you can offer advice from across another divide."

"I can; I just passed forty. But today is your day."

"Hum. Well, I've always found years divisible by five to be my lucky years. I first walked on the moon when I was thirty."

"Of course, you got your PhD at 27 and joined the corps at 28," said Ethel.

"Yes; not everything fell on a year divisible by five," agreed Will. "And this is the year I've first felt a bit of slowness and a few pains."

Sergei laughed; at age 43, he was the old man on board. "I assure you, it won't be the last! I'm beginning to understand the idea that it's all downhill after age thirty."

"Especially forty," agreed Laura, with a sigh. "David, how old are you?"

"Thirty-seven, like Shinji."

"And I guess I'm the baby on board," added Ethel. "I'm still thirty-four."

"By just a few months, though," said Will. "Watch out, I'll plan quite a culinary response to this!"

"Good; then we'll all benefit!" replied Laura, and they all laughed.

14

Sunwing

late June, 2036

"I don't think I'll ever forget this trip," exclaimed Will from rear of the ranger. "No matter how many times we revisit it, this first trip will always be burned into my memory."

"I agree," said David. "The name 'Little Colorado' is well chosen. It captures the grandeur."

"Not to mention the colors; 'Colorado' means 'colored' after all," added Ethel. "I want us to go farther up it, next time."

"Two more day trips, and we may be able to make it all the way," replied Will. "It's getting pretty narrow and steep, though."

"The key is getting a lander with an overnight shelter and oxygen up there," said Laura. "And 'the Bench' you explored today is the best place to put one down."

"Absolutely," agreed Will. "Our suits won't accommodate a thirty-two kilometer hike, round trip, even with three hand-stocked resupply stations. But will mission control risk a lander in such terrain?"

"Sergei's good at piloting them remotely. He brought lander 1 down within a meter of its target and last week he brought the *Olympus* down just two meters from the center of the landing zone after a twenty-two kilometer flight. The beacon you set up gives us a radio target."

"I'm impressed that they're letting us take chances like this," added David. "Here we are, just four months into the mission."

“Sending four of us up the canyon and setting up resupply points reduces the risk significantly,” replied Laura. “The canyon floor requires serious rock climbing in only two spots.”

“And the benefits of the effort are incredible!” added Will. “We can sample the whole escarpment bottom to top and can explore the highland plains above. I’d like to see us improve the trail as much as possible. If we can dynamite the two cliffs, I think someone could build a road up Little Colorado.”

Laura looked at him skeptically. “That would be an incredible amount of work. Just clearing a ramp up the talus slope and alluvial fan materials at the bottom will take weeks. I doubt anyone will try it in the next decade.”

“It’s the only possible route to the highlands north of here.”

Laura shrugged. “So, we’ll explore other areas of Mars first. It’d be faster to drive a thousand kilometers out of the way to get up there.”

The Outpost’s exterior lights, triggered by their approach came on. Two round humps of Martian reg and dust punctuated by holes for the windows and connected by greenhouses were dimly visible. They were home.

Ethel and Laura put on their helmets and gloves while Will and David retreated into the portahab and sealed the tunnel. Laura began to depressurize the ranger’s cab and pointed the two rear cameras at the docking mechanism. Ethel opened the cab’s rarely used passenger-side door and stepped outside to assist with the docking. Once they were both ready, Laura slowly backed up the ranger and portahab until the latter’s docking tunnel contacted the side of the outpost. Ethel latched the transit tunnel in place and made sure the seal was permanent and airtight. She and Laura headed for a nearby airlock.

“Don’t forget the samples,” reminded Laura over the radio. Will and David picked up the airtight bags and opened the hatch. Sergei and Shinji were waiting to greet them.

“Welcome home; supper’s ready,” said Shinji.

“Congratulations on the best trip yet,” added Sergei. “We’ve been listening to the banter in Mission Control. They’re still thrilled. I think the geologists haven’t left yet, even if it is in the wee hours of the morning in Houston.”

“They’re in awe,” agreed Shinji. “Four live cameras and four running commentaries on the geology; it was incredible.”

“The sunwing provided a great relay,” said Will. “What were our ratings?”

“We haven’t heard, but a lot of people tuned into the web channel,” said Shinji.

“That’ll help,” said Sergei. “Laura, you have some sort of urgent message from Kimball. She even called me to tell you to listen.”

“It’s probably about Columbus 2. She thinks Mission Control’s just about convinced to restore the second vehicle. Columbus 1 is incredibly popular worldwide.”

“The Brazilians want to buy a seat, I hear,” said Ethel.

“Well, we need at least two sponsors, preferably three,” said Laura.

“I’ve got to run back to the sunwing controls,” said Sergei. “It’s still gaining altitude and should enter a zone of strong winds in a few minutes.”

“How’s it doing?” asked Laura.

“Fine, ever since we got the bugs out of it,” replied Sergei.

“It’s time to use the sunwing to fly the first exploration package to Gangis,” reminded Will. He had been advocating the effort all week.

Will, David, and Ethel went to the Geology Lab in Habitat 2 to deposit the bags of samples, then they headed to Habitat 1. They passed through Greenhouse 1, which was mostly bare ground; only ten percent of the trays, at the high end of the structure, had vegetables growing in them. Another twenty percent had plant matter and animal waste mixed with the reg, and was moistened daily; bacteria and even worms had been introduced to begin the creation of soil. The rest of the reg was lifeless, except for anything carried in by the trickling irrigation water.

Some sat in Habitat 1's Great Room and ate toasted bread while others took showers. Just before they sat to eat supper, Laura appeared. "Here's the latest," she said. "A blue-ribbon panel is proposing that four be flown here on Columbus 2, but that two of the four make a commitment to stay two cycles; fifty-six months. That's how they propose to solve the problem of staff shortages."

There was a pause as they considered the idea, then they all laughed. "Are they trying to create more divorces?" asked David. "My wife can barely tolerate thirty months! My kids are suffering!"

"I can't imagine anyone wanting to stay more than thirty months," agreed Will. "This place is interesting, but not *that* interesting."

"NASA's sure it can find volunteers," said Laura.

"This outpost needs continuity," agreed Shinji. "When we leave, there will be no one to maintain the greenhouses, rangers, and life support equipment for nine months."

"I agree," said Ethel.

"Kimball suggests that all of us get involved," said Laura. "She thinks we should do a series of interviews with reporters and mention how unhappy we are with the plans

to cut back Columbus 2. We can put it out on the social media, too; most of us have occasional blogs and Facebook pages. We're becoming popular and we can make this mission even more media-friendly. She thinks that we should."

"What about Mission Control?" asked David.

"They would certainly be opposed. But they can't control us. We have plenty of direct access to the media via the web."

The others looked at each other, then everyone nodded.

The next morning Ethel and Will rose earliest because they had breakfast duty. Shinji was always up early; he sat, coffee in hand, reading the *Asahi Shimbun* newspaper on his attaché and occasionally translating news of international importance. David came out of his room shortly thereafter; he lent a hand to making some scrambled eggs. "So, when are we going to eat a chicken?" he asked.

"Give them another month to grow," replied Shinji, without looking up from his paper. "Now that the greenhouse is producing plant matter, we can finally let their total biomass increase."

"I wish Columbus 2 would bring a dairy cow," exclaimed Will. "Powdered milk is not a great substitute for the real thing."

"If all goes according to the original plan, Columbus 3 will have two miniature cows," replied Shinji. "There will also be a separate animal raising facility. But now they want to cut the several hundred million for it."

"That's a lot of money per liter of milk," agreed Will.

“What’s that?” asked Ethel, suddenly looking up. They all paused; there was the muffled sound of discussion—argument—coming from Sergei’s bedroom.

It grew louder, though it was still incomprehensible. Sergei and Laura were arguing about something.

Then the bedroom door opened. “Get out of my bed! Get out of my room!” shouted Sergei.

“You get out of my life!” shouted Laura in reply.

A door slammed, then another.

Silence.

Ethel looked at the others. “That doesn’t sound good.”

“Sounds like a rift,” said Will.

“Just what we need, with six of us living in three hundred square meters of space,” said Ethel, shaking her head.

“This is why romantic relationships are improper,” added Shinji. “It’s hard enough to be discrete when they’re working alright, but a break up is a near disaster. As the flight physician, I am tempted to declare both of them temporarily unfit to serve as Commander.”

Will raised his eyebrows, surprised that do-nothing Shinji was now speaking up.

“Let me go talk to Laura,” said Ethel.

“I’ll talk to Sergei,” added David.

Ethel walked back to the bedroom doors, which opened onto the now-empty geo-bio lab. She knocked on Laura’s door. “Can I come in?”

A pause. “Sure, Ethel. Just a second.” There was a rustling sound, and Laura opened the door. Ethel entered and closed the door. “I guess that was pretty loud,” said Laura.

Ethel nodded. “It was hard to ignore. How are you doing?”

“I’ll be alright in a little while. I need some time.”

“Shall I bring you breakfast?”

“Ah. . . yes, my usual coffee and whatever we have.”

“Some scrambled eggs, toast, and jam. I can get you a plate full.”

Ethel headed back to the kitchen, made a cup of coffee for Laura, prepared a plate of food for her, and brought it to her room. Laura was beginning to lay out clothes for the day when she entered.

“Thanks,” said Laura.

“No problem. Is there anything else I can do?”

“No, not right now.”

“Do you need an ear?”

“Maybe later.”

“Have you guys broken up?”

Laura sighed. “I think so, permanently. He’s so selfish. He won’t take my feelings into account.”

“It sounds like this was pretty serious.”

“Well, I was hoping we’d get married. But no, he doesn’t want a commitment of any sort, not after the divorce.”

“We’ve all been burned. I guess it takes time and patience.”

“Well, I’m not going to be patient any more. I’ve been try to make this work for eight months.”

“I’m sorry, Laura.”

“Thanks.” She smiled at Ethel. The two women hugged.

Ethel hurried out. Meanwhile, David had gone to get Sergei’s breakfast as well. He returned to Sergei’s room.

“This is ridiculous. I can’t let her lock me in my room.”

“She’s in her room, too. I think this is a cooling off time.”

“I won’t let her deprive me of my freedom of the outpost.” He shook her head. “All she ever wants is sex. And attention. She’s insatiable.”

David nodded but said nothing. Finally, he went back to the great room to eat his breakfast in silence. No one was in the mood to speak. Finally, Will said “Where’s the sunwing?”

“I checked while you guys made breakfast. Last night it flew over two thousand kilometers,” said Shinji.

“Two thousand kilometers!” exclaimed Will. “My God, the winds must have been strong!”

“Sergei got it into that fast jet stream. I was thinking it was just about time to bring it down to a low altitude where the winds run east to west—downhill through the canyon—and get it back here. But it’ll need two sols to come back.”

“So much for loading the first remote exploration package on board,” said Will. “I guess we use the next few sols to set up sunwing 2.”

“Makes sense. We can’t explore Little Colorado again for at least a week,” agreed David. They had left four half-exhausted oxygen bottles at the two recharging stations. It would be a week before the bottles were refilled with oxygen made from CO_2.

“I’ll bring the sunwing back,” said Shinji. “I can do that in and around the greenhouse work. There are a couple of areas to photograph; I’ll monitor that as well. I can whip up lunch so the three of you have all sol to work on sunwing 2.”

“There’s also an ITV flyby of Deimos about 4 p.m.,” said David. “Sergei said he’d do it. If he’s not available, I can do it. We need the laser data.”

Will looked at the others, then nodded. “Okay, that’s what we’ll do. Except I have a television interview scheduled for 11-12:30 this morning.”

“So do I,” added Ethel.

They finished breakfast and turned to their work. They still remembered how they had assembled sunwing 1, so sunwing 2 went faster. Will and David drove to Cargo Lander 4 and retrieved all the parts. They bolted the main cargo pod together, then started on the twenty-two wing sections. Meanwhile, inside the hab Ethel tested each electric motor, the fuel cell power system, and the sunwing’s main computer. Sergei assembled motor pods and Laura suited up to bring them outside and attach them to the wings. Sergei and Ethel soon ran into a snag; the plastic shell of one of the tiny radioactive heaters that kept the computer at a constant temperature had cracked. They had to remove it and replace it with another unit, a relatively simple task because the alpha radiation it emitted was not dangerous.

Lunch was a strange experience because few wanted to talk. Conversation focused on their work. The afternoon’s tasks went quickly; the first wing sections were

attached. The fuel cells and the computer were brought to the work site installed. By sunset the sunwing was beginning to look familiar.

Supper was also quiet and uneasy. Afterward, Sergei went to his room with David. “I’m not going to stay in a room next to Laura any more. I’m moving to Habitat 2.”

“Why don’t we switch rooms? That’ll put you on the other side of this area.”

Sergei shook his head. “No, I’m moving to Habitat 2. Besides, it’s better that we’re not all sleeping in the same hab.”

“Why don’t I move too, then? It’ll look less strange if two of us move.”

“Suit yourself.”

David went to ask Will for help. He was helping Ethel wash the dishes, but she agreed he could help them instead. Shinji pitched in as well. By 11 p.m. both men were moved to Habitat 2. Laura came out of her room occasionally to watch.

“Well, this is one solution,” Ethel said to her.

“Yes,” said Laura. “It’s not going to do our social life much good.”

“The breakup sank that.”

Laura looked angry, but didn’t say anything at first. “This will heal. Give us a couple weeks.”

Ethel nodded sympathetically and hoped Laura was right.

15

Breakthrough

early July, 2036

"That is a remarkable and strange stratum," said David, looking over Will's shoulder at the television image from Gangis Chasma. A Prospector telerobotically operated vehicle was sitting as close to the base of the talus pile as it could get, a hundred meters from the spot where they had deployed it the sol before. Its two cameras were trained upward at the cliffs, which exposed two thousand meters of lake deposits. It was zoomed in on a blackish layer one hundred meters up.

"It sure looks like carbonaceous shale," exclaimed Will. "It seems to be about two meters thick. That's a lot of carbonaceous shale."

"I wouldn't jump to conclusions too fast. The low albedo—it is pretty black—could be caused by magnetite or some other iron mineral. Carbon would imply life."

"Not necessarily. Maybe inorganic process or organic but non-biotic processes could fix carbon in the clays."

"We don't even know whether it's clay, though."

"No, we don't. I think we should send the sunwing back with a laser. A few zaps, and we'd know."

David considered, then nodded. "It'd take a sol to get it there and a sol to bring it back. While the sunwing's there, it could take detailed photos of the talus as well, and using them we could see whether any black rocks are within reach of the rover."

"A shame it can't climb rocks."

“Even with all this automation, our robotic explorers still can’t accomplish simple walking tasks that six-legged insects and three year old humans can do. Maybe another decade. Meanwhile, we humans are still needed.”

“And we can be grateful for that.” Will looked at the images. He magnified the stereoscopic images to their maximum again. The black layer was simply too far from the cameras to resolve in detail. “The sunwing’s cameras can do a lot better.”

“Yes. The photographs the sunwing took of the Gangis South Escarpment still have the guys in mission control in ecstasy. We need to photograph this entire pile of sediments in detail, centimeter by centimeter. A two-kilometer pile of lake sediments: it’s an incredible opportunity.”

“And a high priority for a visit.” Will smiled at the thought.

“Definitely for Columbus 2. They wanted to put the outpost there, but the canyon was too deep and narrow for automated cargo landers and the floor was too rough.”

“It’s a thousand-kilometer drive,” acknowledged Will, sadly.

He moved the rover along the edge of the talus pile, stopping to look at rocks in great detail, placing the alpha backscattering instrument against the surface of a rock to see what its chemical composition was, zooming in so that crystals as small as one millimeter in diameter were clearly visible, activating an infrared light, then an ultraviolet light to capture an image of the rock in those wavelengths so that the crystal compositions could be determined. Much of the actual analysis would be done on Earth; the outpost’s computers did quick, crude analysis for him so he knew more or less what he was looking at. That enabled him to make informed decisions and move on to another rock quickly. He could move the rover five hundred meters a sol, five to ten times as

much as a trained driver on Earth, and make a far more thorough examination as well. It was almost as good as being there in a pressure suit.

The intercom beeped. “Attention all staff,” said Laura. “Please assemble in the Great Room immediately. Thank you.”

“Immediately?” said David. “Sergei and Ethel are outside; it’ll take them at least fifteen minutes to get inside.”

“I know. Let’s go find out.” Will switched the rover to automated operation; it would examine the rock itself, running through a pre-programmed examination sequence, then use its software to select another rock, roll to it, and repeat the procedure.

They rose and headed for the Great Room. Laura was waiting. “You guys can come back when everyone else arrives. I just told Shinji that, too.”

“Okay,” said Will. Uncertain what to do, he and David headed to Greenhouse 1. There they could admire the greenery while watching for Ethel and Sergei.

Much of the greenhouse was now growing, in spite of its poor soil. Shinji had a collection of “soil preparation” species. Some had done reasonably well in Martian clay; others had failed to thrive because of salinity, low nitrogen, low phosphorous, or some other factor. Each square was labeled and a camera mounted in the ceiling sent close-ups to Earth continually, allowing the biological team to monitor the experiments. A few squares were positively lush; those squares had received sewage sludge and ground up plant matter. Gradually they were learning what grew well under Martian conditions and what did not. But no square was growing vegetables yet; they were still relying on the plant growing cabinets for them.

“This must be a pretty important development,” said David. “Laura hasn’t called a staff meeting in two weeks.”

“Not since she and Sergei broke up,” agreed Will. “This is important enough to override that.”

“Important enough for her to function as Commander again! For the last two weeks, the four of us have set priorities together, then she and Sergei have plugged in, in such a way that they don’t have to work together.”

“It’s been very strange. If I were in Mission Control, I would not be pleased.”

“It’s what they get for having an affair in a small place with only a few others around,” said David. “At least the other four of us have been knit together more tightly.”

“Yes; it’s ironic!”

David pointed. “Here comes Ethel and Sergei.” Through the plastic they saw the other two approaching the outpost. They waved; Sergei and Ethel waved back. They walked over to the airlock to greet them when they entered the outpost.

“What’s this all about?” asked Ethel.

“We don’t know,” replied Will. “It must be important.”

“It better be; we’ve just about got sunwing 2 set up and ready for its maiden flight!” exclaimed Sergei, angry.

The four of them headed inside Habitat 1. Shinji, hearing them enter, came out of the medical lab. Laura was waiting for them in the great room.

“I just got this from Earth,” she exclaimed. Then she pushed a button and a text appeared on the wall screen. The title was “Why NASA Can’t Get Anything Right” and they quickly discovered that it was an attack on the Mars program.

“Ouch!” exclaimed David. “‘NASA is chronically unable to screen a crew psychologically, with the result that we see a dysfunctional team trying to explore Mars.’”

“It gets worse,” replied Laura.

“‘A team riven by personal jealousies and punctuated by soured love affairs’; this person had access to some misunderstood insider information,” noted Will.

“Except he says you and I have been sleeping together!” exclaimed Ethel to Will, outraged.

“Oh, yeah,” said Will, reading further down.

“Y’all should have slept together after all,” commented Laura, wryly. “The article implies I’ve been sleeping with more than one man, too, and that I dislike everyone.”

David wasn’t going to comment on that. He kept on reading. Laura asked if everyone was ready for page 2; she switched to the second page.

“And the conclusion to all this is ‘stick to robots’!” exclaimed Ethel, shocked when she got to the punch line.

“Shortsighted,” pronounced Will. “In a few weeks we’ll have six new Prospector rovers scattered across the surface. We can run them ten times faster than a team on Earth *and* do our own exploration. We’re sending back a hundred times more data than a single machine controlled from Earth.”

“And there’s the excitement of people on Mars,” added Ethel. “The public’s fascinated. Has the writer no appreciation for that?”

“Certainly not!” replied Laura. “Psychological motivations, as far as this author is concerned, are all wrong.”

“Where did this appear?” asked Will.

“The *Washington Post.*”

“Ouch,” said Will.

“This author has access to a lot of insider information,” said Shinji. “It looks like this is a reaction to our media campaign to strengthen Columbus 2.”

“An insider reaction,” said Will, nodding. “Yes, that makes sense.”

“This is retaliation,” agreed Laura. “The author is one of the *Post’s* regular space correspondents, though he’s a critic of NASA most of the time.”

“So what do we do?” asked David. “Some of this is hard to deny!”

“And we have no idea what audio or videotapes the critics have,” said Shinji.

“Then maybe we should try to get this team back to normal,” suggested Will. “The best response is to clean up our act.”

“How will we do that?” asked Laura, defensively.

“Let’s get back to daily planning meetings,” said Ethel. “More mealtimes when we’re having fun together. And we could meet with some psychologists by video.”

“How would that work?” asked Sergei, scowling.

“Not well,” asserted Laura. “Interplanetary meetings are torture because of the time delays. I know, I have to sit through lots of them.”

“I think we should try,” replied Ethel. “This report makes Mission Control look bad, too. They’re going to want to do something.”

“They’ll be under pressure to act,” agreed Shinji.

“I wonder whether this could result in the cancellation of Columbus 2.”

“It makes a skeleton crew a lot more likely,” growled Laura. “We’re going to land on Mars, then abandon it, just like with Apollo.”

“Let’s not jump to hasty conclusions,” replied Will. “The manned exploration of Mars has a lot of political and economic momentum.”

“But this doesn’t help the momentum!” said David.

“True,” agreed Will.

“Let’s face it; we are not a very good team,” said Ethel, looking at the others. “We’ve had our tensions. We’ve been together eleven months, four on Mars. We really have not gelled very well. Maybe we can do something about it.”

“Like what?” asked Laura.

“Let’s talk through some of the troubles. Maybe we can let go of some of them; they happened a long time ago. Shinji and I both have psychological training.”

“And some of this is common sense.” added Will. “We need to work through things. Some of it can be resolved one on one, or with one other person to serve as a kind of arbitrator. This article is a wakeup call. We have to do something.”

Laura looked at Sergei. She seemed terrified that their relationship would be discussed. “I don’t know. This is getting pretty complicated.”

“Well, if neither the Commander nor the Assistant Commander can do this, they are not fit to command,” replied Shinji. “I’m the mission physician; I can certify them unfit to command. The fact is, over the last two weeks, neither of you have been commanding. The four of us have been meeting every morning and dividing up the tasks, and the two of you have then plugged into that effort in such a way as to minimize your contact with each other. This is an inappropriate way to run a mission.”

“The mission physician does not have the authority to declare someone else Commander,” said Laura, pointedly. “That’s the responsibility of Mission Control.”

“Maybe the Mission Physician should call Mission Control and express his opinion, then,” replied Shinji.

“You wouldn’t dare!”

“Try me.”

“I’ll assign you kitchen duty for the rest of the mission!”

“You can’t,” replied Will. “Because no one else can do the tasks Shinji does.”

“Besides, you haven’t been assigning anyone tasks, lately,” exclaimed Ethel. “If you start assigning tasks arbitrarily, Mission Control would relieve you of command.”

Laura said nothing; she knew Ethel was right. “Well, I should resign as Commander, then.”

“I think that’s too drastic,” replied Will. “Remember the conversation we had at the Escarpment, when I mentioned your leadership qualities? I meant every word of that. You can lead, Laura.”

“Then I guess I’d better do something,” said Laura. She looked at Sergei. “Maybe you and I need to talk about a few things.”

He nodded.

“Maybe all six of us need to talk, too,” suggested David. “Not now; I think we need to think. Can I suggest that Ethel coordinate that discussion?”

Laura looked around. “Okay, let’s meet this evening. I’d better call Mission Control. Let’s take the rest of the afternoon off. We’ve got other things to work on.”

Mission Control couldn't be ready for a big meeting by the evening; they wanted two psychiatrists to sit in. The crew agreed to postpone their meeting to the next morning. Meanwhile, Laura and Sergei talked for several hours. Afterward, they were able to sit together comfortably.

The next morning the psychiatrists were ready, so the crew sat in the Great Room and Ethel coordinated the discussion. Mission Control assured them that the signal was going only to one room where the two psychiatrists and the two Cap Coms—Heather Kimball and Jerry McCord—participated. Even so, they were uneasy; they could not be sure who might see the video, either live or as a tape later.

"My impression is that over the last eighteen hours, we've already made progress," said Ethel. "Maybe we should start by letting people speak their mind, if they have anything to say." She knew Laura did. Sure enough, Commander Laura Stillwell raised her hand. Ethel nodded.

"Well, I'm not sure what I want to say. It isn't easy to speak at all, frankly. I've felt like I was in an almost impossible position. I suppose I can't blame anyone but myself; maybe it's all in my head. But NASA was under a lot of pressure to send a woman as well as a man, and Will, everyone says, was a natural to send because of his incredible geological talent. So I've always felt like I was second choice. And as Commander, and as a woman, I've felt tremendous pressure. It's been very difficult." She shook her head, then looked away in order to hide the tears.

Everyone looked at her sympathetically. "Laura, the decision to choose me as the American man to fly has nothing to do with their decision to choose you as the American woman to fly. You're an immensely talented professional."

“Will if NASA could have chosen two men, someone else would have flown and been Commander, not me.”

“You don’t know that,” said Ethel.

“Besides, you’re Commander now,” added Sergei. “It does no good to speculate about what might have been.”

“It’s easy for you to say that,” replied Laura.

“This is something to let go of, I think,” added Shinji. “Or maybe it’s something Mission Control should apologize for. We’ve got eleven months left here on Mars. You’ve got plenty of time to be our Commander.”

“You are our Commander, and no one has said they think that should change,” exclaimed Will.

“Shinji suggested that a change might be necessary.”

“If you continued to let things drift; but it appears that you aren’t,” replied Shinji.

“Let me ask a question,” said Ethel. “Will, David, and I get along quite well. We get along well with Shinji, too, though socially we haven’t been as close. We get along with Sergei well. I haven’t talked to Will or David, but I can say, speaking for myself, that I don’t want us to be a little clique inside this team. So, what can all of us do to prevent the formation of a clique?”

“Keep including everyone,” said Sergei. “You and Will have made real efforts to pull us together as a team, with the dinners and the movies. I’ve really appreciated it.”

“And I think it’ll work better, now,” added Laura.

“I would hope that Sergei and David would feel comfortable moving back to Habitat 1,” said Will. “It makes the place a bit crowded, but I think there’s a wisdom to all six of us sleeping in the same hab. It’s part of being a team.”

“We’ll move back,” agreed Sergei. “I’ve been thinking about that, too.”

“David?” asked Ethel.

“Yes, I agree. I moved when Sergei moved because I didn’t want it to look like he had abandoned us or that we had abandoned him.”

“What do you think we have to do to build a stronger team?” asked Ethel.

“I agree that we all need to be in one place,” continued David. “And I agree that the team spirit that some of us have—I wouldn’t call us a clique—needs to spread out to everyone. And I don’t know why it can’t spread out, if all of us try to do it.”

“What’s been the problem, up to now?”

David looked at Ethel, alarmed. “Well, Laura has been quite eloquent about her difficulties, and I’m very appreciative of that. She and I haven’t gotten along so well sometimes. I’ve tried and it hasn’t always worked. Laura has tried, too. Maybe now we can close the gap.”

“I think that’s important,” agreed Laura.

There was a silence. The videophone light was on; the psychiatrists at the other end had asked a question, though it would have been at the beginning of their conversation. Ethel reached over and pushed the play icon.

“So far, we’re very impressed by your open communication,” said one doctor. “But we hope that the question of small groups or cliques within the team can be discussed.”

“We just did that; that’s what happens when questions are seven minutes old,” said Laura, irritated.

“Then let’s move on.” Ethel pushed a button to get the next question.

“I hope the matter of the various romantic relationships can be discussed,” said the second doctor. “How have all of you felt the relationships have interfered with the creation of a team? What can be done?”

Laura and Sergei looked at each other awkwardly. “There isn’t much to say,” said Laura. “Sergei and I have had a romantic relationship from shortly after we left Earth. Perhaps it has occasionally distorted our judgment.”

“The time the two of us went to the *Olympus* overnight,” agreed Sergei.

“And now we’re both hurting from the relationship,” added Laura.

“It was a difficult time for us,” said Sergei. “My wife divorced me just as we left because I was going away for thirty months. Laura felt enormous pressure as Commander. The relationship really helped both of us.”

“Until it hurt us.”

“But it’s over now. Isn’t it?”

Laura looked at him and nodded. “But we’re adults and we can deal with each other professionally.”

“Let me know whether I can help,” said Shinji.

“Thanks, Shinji,” replied Laura, a bit dismissively.

“We’ll try on fashions together,” suggested Ethel, and Laura nodded to that.

“Ethel and Will, you need to answer the question as well,” continued Shinji.

“I’m not sure we have a relationship,” said Will. “Ethel and I have not had a romantic connection. One reason is because we felt what Laura and Sergei was doing was unprofessional and improper, considering our circumstances. I suppose that means we felt excessively righteous, and I apologize if it has come across that way.”

“I think it has,” said Sergei.

“How would you characterize the relationship the two of you have?” asked Shinji.

“Well. . . I really like Ethel, deeply admire her character, and would like to get to know her better.”

“I’ll say this,” exclaimed Ethel, looking at Will. “I think I love you, Will Elliott. And I suppose that has shaped the dynamic of the six of us; if it has been a problem, I apologize. It was the main reason I pushed to organize the birthday party for Will, and why I arranged for the two of us to do meals together.”

Will looked at her, startled. The others didn’t look startled; they knew.

“I appreciate your honesty,” said Shinji. “Because it isn’t easy. You’ve made yourself vulnerable.”

“I suppose I have,” she replied.

“And I proposed a few walks so we could have some time together,” added Will.

“I think it has been a tension among the six of us,” added David. “I’ve felt competition for Will’s attention. We’re really old friends, after all.”

“That’s been a tension as well,” said Laura. “Because I’ve always known that if either you or Will suggested a geology effort, there was a very high likelihood the other one would agree immediately. I’ve always felt it was two against one whenever I’ve had to deal with you guys.”

"I think this shows the limitation of this line of concern," said Sergei. "We will never all like each other equally. It's impossible. I'll always have a warm spot in my heart for Laura. Will will always have a warm spot in his heart for Ethel and for David. But that's alright. We have to accept that."

"I agree," said Shinji. "Our goal cannot be to make us all equally friendly. We'll always have stronger or weaker ties. I am not very close to any of you, and I feel sad about that, but there are cultural and personality differences. The old doctor, clearly, fit into the team better, and I've always felt like I was trying to fill someone else's shoes. That's been hard for me."

"I agree, some differences like this are inevitable," said Ethel. "But when the differences cause friction, we have to talk them through. That's what we haven't been doing. Thank God we're doing it now."

"Maybe we need to get together and let our hair down every month or two," agreed Laura. "It was hard for me to get to the point where I could do this, but now I'm glad we did it. We'll all be a lot more comfortable together."

They talked all morning and half the afternoon. The psychiatrists were sometimes helpful by asking questions that kept the discussion focused on specifics; but they were unable to ask the questions at the right time, and sometimes the specific question disrupted the trend of the discussion among the six of them.

It was 2 p.m. when they finished lunch and their discussion. Will and David headed to the GeoBio Lab to resume control over the Prospector in Gangis. Since they

had stopped working twenty-four hours earlier, terrestrial geologists had managed to move it twenty meters.

"I'm glad to be back to work," said David. "This intimate stuff is hard on me."

"It was hard on all of us, especially Laura. She had more to fess up to."

"Note that she still hasn't apologized to me."

"No, but I think that's all water under the bridge, now."

"I hope so; I'll try to relate to her better. It's hard; our personalities are not well suited. And it sounds like you and Ethel have to talk more."

"Yes, but first I've got to think about what she said. I'm still surprised."

"I'm not. The two of you relate to each other very well, I think."

"I think so, too. Hey, maybe I am in love with her. But she and I have to talk. And now we have to open communications to the folks on Earth, so let's switch topics."

Okay."

Will pushed some buttons and opened the communications line to Earth; a two-way audio and a simple, ten frames per second video connection, sufficient to see expressions. "Where's the sunwing?"

David checked the console. "About a hundred kilometers east of here. Sergei's scheduled to land it here in three hours, then Ethel goes out and installs the laser. With any luck, that'll be done before sunset and the sunwing can start back to Gangis."

"Good. I wonder whether we can get at this black rock here?"

David looked at the aerial photo taken by the sunwing. "Doubtful, but give it a try."

“I will.” Will turned to the Prospector’s controls. The last twenty-four hours of diminished activity had recharged the electrical system. He got himself oriented; the black rock was sitting on the edge of the talus slope about fifteen meters away, but not visible because another rock blocked the view. Will moved the Prospector along the edge of the debris pile, occasionally steering around rocks that had fallen onto the rough ground. Finally he spotted it. “I don’t know,” he said doubtfully.

“It’s too far up slope,” said David.

Will rolled toward it, stopping just two meters away at the base of the slope of rocks and boulders. He looked for a way up that was smooth enough, but there were too many loose rocks and obstacles.

He maneuvered a bit closer, bumping the front of the Prospector against an obstacle. He zoomed the two stereoscopic cameras on the black rock. “God, even this close and there’s nothing to see!”

“It looks like a fine shale. It must be a quiet water deposit. It reinforces the theory that Gangis was once filled with a lake.”

“One with quiet water, alternating with alluvial fans and maybe debris flows off the escarpment,” said Will, nodding. “The cliff has five blackish layers, not three like we thought yestersol.”

David looked at another screen; the terrestrial team had prepared a preliminary map based on the sunwing’s horizontal photos taken three sols ago. He nodded. “You might be able to reach the rock with the arms.”

“I was thinking of that.” Will stretched out the left-hand arm; it was slightly closer to the black rock than the right side. But it fell short by several centimeters. “So close, and yet so far.”

“I wish *we* were there instead of a Prospector.” David projected a false-color image of the area onto a screen near him. It was set to emphasize compositional differences between the rocks, based on their ultraviolet reflectivity. “It looks like the next black rock is at least a hundred meters away; I don’t see any in this frame, do you?”

“No. We should probably concentrate on the other sedimentary rocks, then, and see what we can see.”

David frowned, then pointed to a small rock about twenty-five meters from the talus slope. “Look at this. It seems to have the same spectral response as the black rocks.”

“But where did it come from? It couldn’t have rolled down the slope.”

“No; it’s float. But at least it’s a sample.”

“Yes, maybe it’s a good start.” Will looked at the image closely, popped up the GPS coordinates for the rock, then turned the Prospector around and headed toward the small sliver of black material. It was only twenty centimeters long and half as wide and was partially buried. The Prospector’s cameras were about as far above the ground as the head of a man, so that helped orient them to the scene; but a Prospector could roll only about a kilometer per hour—a fifth of walking speed—so it was slow.

It took a few minutes to cover the distance, slowly, threading around rocks as they went. Several rocks they passed appeared worth a return visit. Finally they spotted it. Will rolled the Prospector right up to the rock and lowered the rock examination unit

until it touched the surface. “Very nice,” he said. He activated the alpha backscattering instrument to measure its composition and a microscopic camera to peer at it closely.

“Black flakes; it sure looks like unconsolidated carbonaceous shale to me,” said David.

Will nodded. He zoomed closer. A few scattered grains began to become visible; they appeared to be sand grains mixed in with the ancient clay. That was to be expected. He zoomed in even closer; the camera was able to reveal objects as small as a fortieth of a millimeter across, or about a thousandth of an inch. Unfortunately, at that magnification it had very little depth of field; most objects were out of focus. But as they moved the minute focus around the rock, it would autofocus constantly, so that a small area in the middle was always sharp.

At full magnification they could see some of the larger clay particles; the rock was shale. But there were also blackish flecks that presumably were carbon particles; they gave the sample its dark color. When Will zoomed in on one of them at maximum magnification, it looked like a puckered ball. “What the heck is that?” he said. A chill ran down his spine and he looked at David. Shocked, David looked back at him.

“Find another one.”

Will nodded and moved the focus toward another dark blob. It popped into focus as well. It was squashed between two clay grains like a flattened football. It had some broken plates on the outside. “My God,” Will said. “That could be a dried up, partially fossilized cell membrane.”

David nodded. “Let’s not forget that there could be nonbiological explanations,” he said, calmly.

They wandered another twentieth of a millimeter around the rock and focused on a third dark fleck. It appeared to be better preserved; it was a sphere with vague geometric patterns on the outside, like a tiny geodesic dome. “Amazing,” said Will.

A light began to flash on David’s console. The alpha backscatterer was finished with its analysis. David pushed a button and pulled up the data. “Look! The rock’s eight percent carbon and 0.25 percent nitrogen!”

“What?” Will looked at the screen. The figures were unmistakable. The oxygen figure—about fifty percent of the atoms—said nothing, since clays always had plenty of oxides in them. The hydrogen figure was also of little use because the clays were hydrated, but it was notable anyway; three percent. But eight percent carbon!

“I think we had better call Laura and the others,” said Will. “This is a historic moment.”

16

Fossil

mid July, 2036

The six of them gathered around the rover controls as they examined one spherule after another. Some were hopelessly crushed; a small number, attached to or wedged between sand grains, looked almost pristine. Some came in pairs or trios. After an hour of searching the rock they came across a ball of six spherules.

Questions began to flood in from Earth, especially from Paris and Moscow; it was 3 a.m. in Houston. Shinji was the biologist; he dictated descriptions of the objects, trying to avoid biogenically loaded language. Within an hour they were beginning to run out of new data to gather. “We’ve got to fly this sample back here,” said Shinji. “We can run a battery of tests on it that we can’t run at Gangis.”

“Okay,” said Laura. “Sergei, can you get the sunwing here a bit faster? We had better change the methane and oxygen bottles so that it can fly faster.”

“Okay.”

Laura looked at Ethel. “The two of us can go out together to get it ready to take off before sunset.”

“The high altitude winds should get it back to Gangis by tomorrow morning,” said Sergei.

They continued to search the sample millimeter by millimeter until the rover’s batteries were nearly exhausted; they had to shut down their exploration until dawn. By then, sunwing 1 had landed at the Outpost and Laura and Ethel had gone out to replace its

spent methane and oxygen bottles. As the sun was setting at Aurorae, sunwing 1 took off. It did not have the laser they had fetched it for; it was on a sample return mission.

They all gathered in the great room for supper. “This sol has been a historic sol,” said Will. “We probably found proof of life on Mars.”

“No one will care about the issue of team unity any more,” said Laura. “Still, I’m glad we hashed through everything. Now we can move forward together.”

“What will this do to the demands to cut Columbus 2?” asked David.

“We’ll see,” said Laura. “But if the data continues to support the idea that these are fossils, no one would dare cut Columbus 2.”

“They’ll need to add a biological facility to the cargo landers,” added Shinji. “That raises the issue of biological contamination. Should we bring the sample inside here? Will we get sick? Will the greenhouses get contaminated?”

Laura looked at the others. “We were not looking at hibernating cells,” said Laura. “We were looking at smashed and desiccated remnants consisting of carbon and maybe a few complex organic compounds. There’s nothing in that sample to reproduce.”

“That’s my opinion,” said Shinji, nodding. “They’ve been dead billions of years.”

David and Will nodded as well. “The surface of this planet is sterile; we’ve proved that again and again,” added Will. Sergei looked at them, then nodded.

“That’s that,” said Laura. “We’ll be guinea pigs, but the result will be some confidence that the samples can be returned to Earth. I think the sunwing’s going to be making lots of flights back and forth.”

“If we can get at the rocks,” exclaimed Will. “The problem is that the carbonaceous shale fragments very easily, so when pieces fall off the cliff, they break

into little slivers and fall between the rocks on the talus slope. So the rovers can't get at them. If we want lots of samples, someone has to drive there and collect them."

"How far?"

"Seventy hundred fifty kilometers."

Laura whistled. Then she shook her head.

"A ranger with a portahab has a range of a thousand kilometers," said Will. "But we can set up a supply depot half way with solar panels and tanks to store water, methane, and oxygen. The ranger sets up the panels, leaves water behind to be converted into fuel for the return trip, and continues. When the ranger returns the crew packs everything up and drives it home."

"I know the plan," replied Laura, with a scowl. "We're talking about a Columbus 2 mission. We have the equipment, but the purpose of our mission is to check it out and make sure it's working properly. That'll take months."

"We've got eleven," said David. "With the well and both solar power units working, we have plenty of water and power to explore beyond our nominal mission."

"I understand that," replied Laura. "I won't exclude the possibility we can go to Gangis, but it's premature to make a plan. We can get a few kilos of samples here by sunwing. We have to start with that. For all we know, there may be an outcrop of carbonaceous shale thirty kilometers from here. Noachian Lake Gangis drained right through here; there may be samples in the deposits in this area. Let's exhaust the other possibilities first."

They all rose early the next morning. Columbus 1 was front-page news around the world; the possibility of Martian life was electrifying. As expected, the controversies about the Columbus 1 team were submerged, at least temporarily.

"Maybe now people will understand and appreciate the importance of this world," said Will. "It takes something sensational to do it!"

"What do you mean?" asked Ethel.

"It's very simple. The moon tells us how the Earth formed. It provides a window into the first hundred million years of the Earth's history. Mars tells us how Earth developed in the next seven hundred million years or so; how it was bombarded, how its crust formed, and now maybe it'll tell us how life arose on Earth. There's almost no crust left on Earth from that period, and the bits of crust are so smashed they can't tell us almost anything."

"And don't forget Venus," added David. "It may tell us about Earth's future, as the sun heats up."

"We do have the pieces of ancient Earth found on the moon," said Ethel.

"Yes," agreed Will. "But sometimes we can't date them reliably, and we have no idea where on earth they formed or what their crustal context was. Here we have huge stretches of ancient crust, so we have the context. And now we apparently will have fossils; maybe fossils that are older than anything we have on Earth. Mars may preserve precellular life; pre-prokaryotic life; maybe even the organic precursors of life."

"Life could have originated here and been transported to Earth by meteorite," added David. "Mars cooled faster than Earth and would have been hospitable to life sooner. It may very well be that we are really Martians."

“Or Venusians; Venus probably had oceans and life in its early years, and life could have originated there even if Venus cooled last,” said Will. “It’s incredibly exciting! Moments like this allow us to explain it to large numbers of people.”

“And justify the expense,” added Laura. “So, where’s the sunwing?”

“Almost all the way to Gangis!” replied Sergei. “I got it up into a westward airstream last night, and it was a strong current. Unfortunately, the sunwing was also blown almost two hundred klicks too far north, so now I’m bringing it back to the landing zone. I’ve also found the boulder we need to use for the sample capture.”

“Boulder?” asked Will.

“I need a big, prominent, visible object to fly toward about thirty meters from the rover. You’ve got to move the rover about seventy-five meters to get it in position.”

“Well, let’s go!” said Will. “I can finish my breakfast there. I bet the scientists are already gathering in Mission Control, even if it is 8 p.m. in Texas.”

They hurried to Habitat 2 and its computer screens. Sergei showed Will and David where to put the rover; they drove it there, then continued to examine the sample. The carbonaceous shale had rich spots with lots of spherules, but no area had none.

By mid morning the sunwing was ready to make its approach. Will transferred the sample to the recovery canister and raised its ten-meter whip into the air. It deployed correctly, to everyone’s relief. Sergei aimed for the boulder, cut back on the wind speed to twenty kilometers per hour—too low to keep the sunwing in the air, so he had to activate the heated carbon dioxide thrusters to keep it aloft—and brought its altitude down to twenty meters. He deployed a boom with a hook on the end. It skimmed above

the ground, one camera trained on the boulder to keep the forward direction roughly correct and one on the ring at the end of the whip. Will watched from the rover.

The first pass was a miss. Sergei turned the sunwing around for another pass while David brought the various images together. “Altitude was perfect,” said David. “But you were forty centimeters too far to the right.”

“Okay, I’ll move left.”

Sergei brought the sunwing around and made another pass, farther to the left. The hook lined up with the ring and caught it, yanking the sample canister from the rover.

“You got it!” exclaimed Will.

“Let me reel it in,” said Sergei. He pushed a button and the canister very slowly rose toward the sunwing. In a few minutes it disappeared into the cargo pod; Sergei closed the door. “Heading back to Aurorae,” he said. “It’ll be here tomorrow afternoon.”

“Let’s resume our search for more shale samples,” exclaimed Will.

The next sol was devoted to a continuous exploration of Gangis. There was no interest in exploring any other area of Mars, even though they had rovers in three other localities, plus one wandering around Aurorae. Some of the work was carried live over cable and millions tuned in, at least for a few minutes.

An hour before the sunwing reached the Outpost, Will received a surprising email from a geology graduate student via mission control. He turned to David. “Look at this! They’ve turned loose an army of graduate students on our existing body of data, and this kid says he found fossils in one of our catalogued samples!” Will clicked on the attached image.

David looked over Will's shoulder as the picture popped up on the computer screen. It was a sandstone and it had a few very tiny black specks at the limit of resolution.

"Could be; we could have overlooked them. Let's see; sample 032521036. I'll get it." David jotted the number down on the screen of his attaché, then hurried down the stairs to Habitat 2's lower level, where samples were bagged and labeled. He hurried back up the stairs a few minutes later with a fist-sized chunk of grayish rock. They took it over to a stereoscopic microscope and put it on the tray, then looked. Will laughed. "I think he's right!"

"Let me see!" David looked through the microscope, moved the rock around, then nodded. "I think so, too. Where did this come from?"

"I checked while you were downstairs. We pulled it off the gravel bar the outpost is built on! It could have been transported thousands of kilometers down the Mariner Canyon system."

"Even Gangis."

"Who knows. I'll get this thing in the scanning electronic microscope. By the time we get the sample from Gangis, we'll have some data."

They broke the sample into smaller pieces—it was too large for the scanning electronic microscope —and examined slivers while one piece was in the machine. Sergei prepared to bring the sunwing down; Ethel and Laura suited up to bring in the sample. With a fairly strong wind flowing eastward down the Marineris canyon system, Sergei was able to bring the gossamer craft down quickly and easily. The two women removed the sample and handed it to Shinji, who drove it over to the outpost. Laura and

Ethel installed the laser sensor, replaced the methane and oxygen bottles to augment the sunwing's power, and checked a motor that had been overheating. Then they went inside and the sunwing took off again, heading back to Gangis to provide more aerial data and drop a replacement sample return canister.

They stayed up most of the night. The small sample was broken into fifteen pieces and each one was slowly and carefully examined. Columbus 1 had brought six Prospectors and two were still at the outpost. Earlier in the sol they had been set up just outside the outpost and plugged into its electrical system. Now their microscopic cameras and sensors were pressed into service. Since the spherules permeated the sample, there were thousands to image.

By dawn the scanning electron microscope was revealing even more details. Some spherules appeared to have the remnants of interior structures, though what the structures were, no one could yet say. The remnants certainly looked biological.

They rotated who went to sleep so that the work could continue non-stop. For the next three sols they scanned samples using every instrument available to them and sent the data back to Earth, where hundreds of scientists participated in the analysis. A special issue of *Nature* magazine was prepared to get the initial results published by the official team so that specialized research by others could begin.

Laura declared Sunsol a sol of rest because they were exhausted. The terrestrial scientists claimed to be disappointed, but they needed to rest as well. Everyone slept late, then headed to the Great Room to eat and to the washing machine to wash their dirty laundry. Will ran into Ethel there.

"How many loads are ahead of mine?" he asked.

"Three. It's been quite a week; lots of dirty laundry to wash."

"It's been unbelievable. We still don't have sunwing 2 assembled or any other rovers deployed, but we've probably found life on Mars."

"It's been exciting; almost too exciting."

Will nodded. "I'm sorry we haven't had time to talk. I haven't been avoiding you; we've just had too much to do!"

She looked surprised. "I didn't think you were avoiding me, don't worry. I didn't say anything that required you to talk to me."

"Even so, I thought we should talk. Would you like to go for a walk later on?"

She smiled. "Sure. That would be nice."

After lunch Will and Ethel suited up and headed to the top of Boat Rock. They hadn't been up there for several months; the route had been cleared one Sunsol by David and Shinji and was now easier, with actual stair steps broken into the two small cliffs. In twenty minutes they followed the path to the rounded top. A set of boulders near the prow gave a view of Face Rock, the crack separating it from Boat Rock, the Outpost, and the eastern expanse of Aurorae Chaos. They sat there admiring the view. Their communicators were set to each other's cellular numbers, so they had a private line.

"Ethel, I've been doing a lot of thinking about your comment last week that you thought you loved me. I feel bad that I said I admired you, because I really do feel attracted to you. I don't know, maybe I love you, too. We haven't dared find out."

"No, we haven't, and for good reason." She looked at him. "But please don't torture yourself about this, Will. I don't want to hurt you and cause us to have some sort of emotional breakdown, which could be just as bad as sleeping together and having a

falling out. I've been doing a lot of thinking in the last week, too, especially about my priorities in life. The fact is that I love my career. I didn't apply for the astronaut corps to make it a temporary phase in my life; I want it to be a long phase, at least for another decade or so. Of course, it's hard to say what will happen after we return to Earth. It may be awkward for Columbus 1 veterans to apply for stints at International Space Station 2 or Shackleton. We may be in demand for speaking engagements. And I suppose all of us will be pressured to retire from active duty and serve on various NASA and ESA commissions about space flight and Mars exploration. And you'll always be the Moonman; radiation quota or not, you'll want to go back to the moon. Space travel has proved incompatible with marriage, at least for many of us. So, I look at the situation and say: Will, I love you, but I don't think I had better marry you, because we'll just hurt each other."

Her voice quavered and her words cut him. He was surprised they hurt so much. He looked at her, then looked away a second to collect his thoughts and bring his voice under control. "Yes, you're right. It's certainly true that having a family would be impossible; we'd be flying too much. Of course, once we're back from Mars, as you said, we will be in a different situation. We may be able to dictate our schedule to our space agencies."

"Maybe. There are now monthly flights to ISS; it might be possible to get short shifts there. But not the moon."

"No, the moon will be served by long shifts for at least another decade. You're right. Of course, there's a lot I could do telerobotically."

“True, but Will, you’re trying to abandon your career, or at least drastically modify it—something you love dearly—for something that might or might not work out. And I don’t have the same telerobotic options you have; most construction and manufacturing is done live.”

“But you’re abandoning something more drastic than career; you’re abandoning love.”

“That’s true, but it hasn’t worked out as well as my career anyway. And maybe ‘abandon’ is too strong a word; ‘postpone’ may be better. In ten years or fifteen years I may feel differently.”

“Yes, that’s true.” Will thought. “So, you don’t see anything developing between us?”

“Not for a decade or so. I want to stay close to you, but as a friend, Will Elliott.”

“Okay.” He swallowed. He was not completely satisfied or happy about the idea, but he could see that Ethel had thought her position through.

17

Conjunction

late Oct. 2036

Sunwing 2 approached the landing area at the outpost, flying into the wind. Will and Ethel watched as Sergei, controlling it from Hab 1, carefully set down the flying wing in a cloud of dust and expelled carbon dioxide. Then they hurried over to it while Sergei cut the propellers.

Will opened the cargo bay; inside was a sample return canister with ten kilograms of rocks from Charitum Montes, the rugged mountain ring surrounding half of the Argyre Basin some four thousand kilometers to the south of them. Pleased, he grabbed the canister with one hand and freed it from its restraints with the other. He put it down on a nearby rock, then turned to help Ethel, who was struggling with a methane bottle.

"Darn thing," she said. He moved the refill to get it out of her way. He knew better than to try to take over; she was better with mechanical problems than he.

"There!" she pulled the bottle free and handed it to him. He took it and handed her the replacement, which she snapped smoothly into place. "Let's get out of Sergei's way, so he can get her back into the air. It's supposed to be windy tonight; we don't want her to stay here."

"Okay." Will picked up the spent bottle; Ethel walked to the rock and grabbed the sample canister. They loped back to the ranger while Sergei fired the carbon dioxide rockets and blasted the sunwing diagonally back into the air.

"So, how old are these?" asked Ethel.

“They should be lower Noachian; say, 4.3 or 4.4. Just about as old as the Martian crust gets.”

“Great! More stuff to fly home.”

“I’m beginning to wonder when we’re going to start making selections. As of this sol we had two tonnes of samples, and David and I have more cataloging to do.”

“We’re still inside the theoretical limit of the shuttles.”

“Yes, but I doubt NASA will want us to haul back to Earth more than two tonnes per shuttle.”

“But that’s still two tonnes more than we have!” said Ethel. “And we’re at the halfway point of our stay; eight and a half months over, eight and a half months to go.”

“It’s hard to believe the mission’s half over.”

“We left Earth sixteen months ago.”

“I know, and will return in about fifteen months. But our first four months here were mostly devoted to setup, and even the second four months involved lots of set-up. Now we have all the rovers deployed, we’re recovering samples from them, and we’re about to embark on our first lengthy excursion. Samples should accumulate twice as fast, between now and late June.”

“Then we’ll have about six tonnes, and that’s still within the shuttles’ limits.”

“That’s true. Oh, it does no good to argue with you!” And he laughed.

“You know what they say; women are always right.”

“No, they say wives are always right, and you’ve opted out of that status for the foreseeable future,” Will teased.

“Okay. As a woman, but not as a wife, I stand corrected.”

He smiled and put his hand on her pressure suited shoulder. In the last few months they had started to touch outside; but never inside.

They reached the ranger and turned to watch the sunwing shrink into the distance.

“Where’s it going now?” asked Ethel.

“A long way; to Alba Patera and the rover that’s been exploring there since 2031. It’ll spend a week making low-altitude observations, then pick up the sample return canister and fly it back here. Then it heads for the rover in Tithonius Chasma. By then, conjunction will be over.”

“A couple more sols.” Ethel glanced at the setting sun and contemplated the Earth, hidden behind it. Then she looked higher and pointed. “Hey, there’s Venus! We can see it during the day!”

“It’s close to maximum brightness and to maximum eastern elongation, so it’s just about as visible as it gets. Thank goodness for the Amazon 3 spacecraft.”

“It’s better than nothing,” For the last two weeks, they had been relaying their data to Earth via the Amazon 3 spacecraft orbiting Venus. It was adequate for basic communications, but no live video feed was possible. Consequently, they had been staying around the Outpost doing additional analysis, which they could relay to Earth via email, and had been catching up on inventories. Even the rovers had been used little.

They climbed into the ranger and drove back to the Outpost. The sun was setting as they backed slowly up against the airlock to which the ranger could dock. Ethel got out and locked the tunnel into place, so they could return to the ranger without suits later, but both entered the outpost via the nearby airlock. Will headed through Greenhouse 1 to take the samples to the Geo-bio Lab. In the last month the greenery had advanced

significantly and now covered almost half the floor, thanks to Ethel's help. Shinji had been so busy with the study of the Martian fossils—*Spheruloides Gangii* of the Kingdom *Monaria,* so named because its members lacked a nucleus like terrestrial monera—that he had neglected the greenhouses. Consequently he had given the responsibility for number one to her and she had planted carrots, beans, and wheat whether the "soil" was ready or not. It had provided adequate and the plants were growing slowly. In a few months, after harvest, the plant matter would be chopped up, partially composted, then returned to the soil, providing adequate organic material for a worm population and a more vigorous second crop. Some samples would be subject to exhaustive chemical analysis to make sure they had safe levels of lead, cadmium, selenium, and other dangerous elements.

Will deposited the samples in the processing area, then headed to Habitat 1. It was suppertime. Laura was cooking and the prepackaged meals were just about ready. Everyone sat and she pulled them out of the microwave oven as soon as the timer beeped. "Real" cooking was limited to weekends.

"A bit of news," said Laura. "I received an email from Kimball a little while ago; she was attending a NASA Planning Committee meeting on my behalf. The decision is pretty much final to send the Mars Life Research Facility with Columbus 2."

"Good!" exclaimed Shinji. "What we have is totally inadequate. But a facility will be useless without staffing. I hope this means they plan to send eight?"

"I think it has to mean that," replied Laura. "Mars biology is the rage, now. Money is pouring in. The public will bore of it eventually, but we have another six months of excitement, and Congress will finalize fiscal 2037 by then. And if my

candidate wins the presidential election next week, he'll commit to supplying the Outpost with a nuclear reactor in four years."

"In and around banning abortions for the second time?" asked David.

Laura scowled at him. "In a dozen years the liberals will make it legal for the third time. Kimball said that no automated cargo landers will accompany Columbus 2."

"Really? What if a shuttle goes astray?" asked Will.

"If one misses the Outpost it'll explore its landing site until the other crew mounts a rescue effort from here. Each shuttle will carry fifteen tonnes of cargo and no hydrogen."

"They're coming with only thirty tonnes of cargo?"

"No. There will be one automated cargo vehicle, but it'll deliver its fifteen tonnes of cargo to Mars orbit. A shuttle will fly up to pick up the cargo, then the ACV will return to earth for reuse. That saves several billion. They're talking about two Columbus 2 crew staying for two cycles, too."

"Really? Permanent habitation?" said Will.

"Good. This place is already too big to abandon for nine months," said Ethel.

Laura nodded. "Our successes have accelerated a lot of planning. If the money continues, Columbus 3 will expand the Outpost to ten."

"That would guarantee a serious exploration effort," said Sergei.

"Of course, if we want the sort of research effort that Antarctica sees, we'll need hundreds," noted Will.

Laura laughed. "Dream on, Moonman! Late this century. Transportation costs will have to tumble quite a lot first!"

"The new commercial tourist shuttle seems to offer exactly that possibility," replied Will.

"And you think NASA will swallow its pride and use it?" replied Sergei, laughing.

Two sols later Earth moved out from behind the sun enough to allow direct contact. They all cheered; it meant much better quality interaction with terrestrial co-workers and better entertainment at night, because they'd be able to receive their favorite tv programs. That evening four of them sat in the Great Room to watch an episode of *Sutter's Mill,* a western series they particularly liked. They had missed three programs while the sun blocked transmission.

The next sol they planned their first lengthy expedition: two rangers with portahabs and three crew members would clear a route westward along the escarpment, hopefully as far as the mouth of Gangis Chasma three hundred kilometers away. It was a logical expedition to propose because eventually a route would be needed all the way along the Mariner canyons. The sunwings had already taken extremely detailed photographs, enabling Mission Control to plan the dirt track meter by meter. A month-long trip would enable slow, careful exploration and clearing of a wide, smooth route; crucial if an emergency return to the Outpost became necessary.

By the end of the sol, the six of them and the planning team in Houston had a good proposal ready for Mission Control. With any luck, approval would take a week and they'd leave a few sols later.

Then at 3 a.m. Ethel received an emergency videomail from Earth. Within minutes she called Will. The phone rang three times before he answered sleepily.

"Hello."

"Will, this is Ethel. I'm sorry to wake you, but I just got a message from my father. My mother just had a heart attack and passed away."

Will was instantly awake. He sat up straight. "Ethel, I don't know what to say. I'm terribly sorry. Shall I come over?"

"Ah. . . yes, that might help."

"I'll be right there." Will deactivated the audio line and pulled on his clothes as fast as he could. Then he hurried over to Ethel's and knocked on the door.

"Come in."

He opened the door. She was sitting on her bed, dressed. "I'm in shock, I think."

"Well, of course you are!" he replied. He came over and sat next to her. She turned toward him; he reached out and put his arm around her back. She leaned her head on his shoulder.

"Her health wasn't very good. She had diabetes. But she was only 69; she could have lived another ten years at least." Tears began to fill her eyes.

"I know." Will pulled her tighter to him. "My dad was 67 when he passed, and I felt the same way. But we don't choose the time for these things. When the time comes, it comes. It's a terrible shock."

"I don't know what dad will do." She began to cry.

Will said nothing; he just held her. He looked out the window where he could see Phobos rising in the west, three quarters full. Its strangeness made the experience harder.

“And here I am, literally on the other side of the solar system.”

“The time delay is as bad as it can be. But I suggest you talk with your dad and sister as much as you can anyway. It’ll help.”

“You’re right.”

“I’m not sure what I can say. A cousin of mine told me after her dad died that it left a hole in her heart, and that the hole gets smaller and smaller every year, but it’ll never close completely. I think that’s true for me, too. I miss my dad, and I think of him often.” Will felt tears well up in his eyes.

“Yes,” said Ethel, and she put a hand on Will’s hand. “She was so proud of me.”

“My dad was proud of me, too. And I feel his presence with me, sometimes.”

Ethel looked at him. “Really?”

“Well, not literally. But I believe he’s present. The next world is not another place; it’s another plane. It can be here at the same time we’re here.”

“I don’t know what I think about afterlife and heaven.”

Will sighed. “I’m not sure I can help, either. When I was a teenager I didn’t believe it, either. Then one day, when I was 23, I suddenly realized that I took it for granted that there was a next world. There was no moment of convincement, no moment when I acquired faith. At some point I got beyond a sort of adolescent scientism; I realized that not only was there no scientific evidence in favor of the afterlife, but that there was no scientific evidence against it, either. That basically meant that I either took Bahá'u'lláh’s word for it, or not. And since I already trusted Bahá'u'lláh on a lot of other matters, I decided I’d trust him about the next world as well. I’m not a very good Bahá'í in many ways, but that was that.”

“Does it help to believe in it?”

“Yes, I think it does.”

“You sound like my Presbyterian grandmother.”

Will chuckled. “Maybe I do. Just think, she’s there in the next world to greet your mother.”

“I wonder what that would be like! They didn’t always get along!”

“It’s been many years since she’s seen your mother, and I’m sure she’s delighted to be reunited with her.” Will’s voice choked a bit. “Because remember, our grief of separation is their joy of reunion.”

“Well, it still feels like grief to me. I suppose I had better call my dad.”

Will stood up. “I’ll wait outside.”

“No; please stay.”

He nodded and sat. Ethel went to her desk and touched the screen of her attaché, bringing it instantly alive. She touched the icon for her father’s message and the reply icon, then recorded a message back to him; touching, sweet, supportive, but not quite tearful. She sent it, then started on a message to her sister.

As she was preparing the second message, one arrived from her sister; it sounded desperate, concerned, and disjointed. Just before she hit reply, she turned to Will. “Come stand behind me, where Gina can see you.”

Will came over and faced the screen. Ethel hit reply. “Gina, don’t worry about me. Will’s here, and he’s been through this with his dad. You go take care of dad, okay? I’m not quite a live presence, but I’m not going away. Call me and talk to me if it’ll help. I’m always available. Bye.” She sent the message.

"I take it you're the strong one in the family."

"I play that role sometimes. I don't feel very strong now."

"You should tell them you'll attend the funeral by video. NASA will do that, so I suppose ESA will as well."

"That's a good idea. But I suppose that means giving some sort of eulogy for mom."

"It's hard, but I did it for dad. I felt better afterwards. He died while I was out in the field. I barely got back for the funeral; I never thought it could take three days to cross the Earth, but there are still some places where travel is slow."

"I'd better arrange that."

"Do you want me to call Mission Control? I'd like to do something."

She smiled. "You're sweet. Thank you."

It was close to dawn when Will finally stepped out of Ethel's room. Laura was heading for the bathroom and saw him.

"Ethel's mother just passed away."

"How is she?"

"She's dealing with it, and in touch with her dad and sister. She asked me to come help. I'm composing an e-mail to Mission Control. She wants to watch the funeral."

"When's that?"

"October 30, 11 a.m. Edinburgh time. I still haven't tried to figure out the time here."

"Probably about 11 p.m. for us." Laura looked at the door. "Should I go in?"

“Knock and ask.”

Will headed to his room while Laura went to Ethel’s and entered to offer her words of condolence.

A half hour later, the sun popped above the horizon and it was day. The others began to get up. Ethel was supposed to prepare breakfast, but Will took care of it. When she came out of her room, they all rose and embraced her one by one.

“I’m so sorry,” exclaimed Shinji.

“My deepest condolences,” said Sergei.

“It’s never easy,” added David. “What can we do for you?”

“Oh, nothing, please! You’re all so very kind; thank you.”

“What would you say to the idea of all of us attending the funeral with you, by video?” asked Laura.

“That would be very nice,” said Ethel. “I think it’d make a real statement to my dad and sister, too.”

“Then we’ll do it,” said Shinji. “It’s nothing, really. We need to do something more.”

“I was thinking we should organize a service for her here as well, for the six of us,” exclaimed Will.

“How would we do that?” asked Laura.

“It wouldn’t be hard. A few readings from scripture or other appropriate texts. Maybe there’s something Ethel would like all of us to sing together. Laura could offer a few words.”

“I suppose I could.” Will looked at Laura, surprised; he figured she would not want to attempt a eulogy.

“That would be a good thing,” said Ethel. “I’d appreciate something like that. Will, could you organize it?”

“Sure, I’d be glad to.”

“Work is optional for everyone this sol,” said Laura. “And it’s banned for Ethel, of course. We’re here for you.”

“Thank you. You’re making me cry!” said Ethel, as tears came to her eyes.

The funeral was late in the evening three sols later. The six of them wore their dress uniforms and sat together so one camera could take them in, with Ethel in the middle. Ethel taped a beautiful five-minute eulogy that was played at the funeral. Before the service, everyone filed up to the television screen to transmit their respects to her; when the service ended her responses had reached them.

The next evening at 9 p.m.—which was morning in Scotland—they held their brief memorial service, attended by video by Ethel’s immediate family. Sergei delivered a reading from the Old Testament, Laura from the New Testament, David from the Qur’án, and Will from the Bahá'í scriptures; Shinji read a Japanese text on a related theme, translated into English; Ethel spoke briefly about her mother again; Laura spoke briefly about eternal life and did a fairly good job; then, on Ethel’s request, they all sang Amazing Grace, a hymn her mother had loved. It was over in 25 minutes; the first religious service conducted on Mars.

The next morning, Will knocked on Ethel's door before breakfast. "I want to talk to you about something after breakfast. Outside."

"Oh? What?"

"It won't take very long."

"Okay."

They both ate breakfast quickly; both had tasks outside that sol, as Will had to move the driller to start on a fifth two-hundred meter deep shaft and Ethel was adding more sandbags and rocks to the semi-enclosed "hanger" they were building for the sunwings. After they stepped out of the airlock, Will pointed up. "Let's go to the top of Boat Rock."

"Oh? Alright."

They hiked up quickly; the path was now well worn and they reached the top in fifteen minutes. There, Will led them to the eastern prow where they could see the Outpost and the chaotic southeastern edge of the Mariner system. "I was thinking. Maybe the six of us could move the rocks around and build a little circle of stone benches up here, and name it for your mother."

"What; here?"

He nodded. "The Mary McGregor Memorial Overlook."

Ethel smiled. "What a marvelous and kind idea, Will Elliott!" She embraced him

18

Gangis

Nov. 2036-mid March 2037

Their first major expedition was postponed a week by the funeral and then by construction of the overlook. Will had once learned how to build dry fieldstone walls and his experience proved valuable; Martian stones fit together just as well as terrestrial ones. In two sols they had a very nice semicircular stone bench with a low wall along the cliff, six meters in diameter.

The expedition's goal was to reach the mouth of Gangis Chasma; the sample site was too far for a single round trip. Will, David, and Sergei left the Outpost on November 7 with both rangers and portahabs. They bulldozed fifteen kilometers of dirt track eastward per sol, staying close to the escarpment except when an interesting feature invited a detour or a massive landslide necessitated one. They explored several craters that punched through the sedimentary rocks filling Aurorae Chaos, allowing them to study the sequence of catastrophic floods layer upon layer. They also shot the escarpment with the laser to measure the chemical composition of various strata, and recovered samples from the boulder pile at the base.

On December 1 they reached the entrance to Gangis Chasma, an immense gash in the Martian crust seven hundred kilometers long, two hundred wide, and two to three kilometers deep. They explored its northern escarpment for twenty kilometers, then crossed the valley mouth—only sixty kilometers wide at that point—to explore twenty kilometers of its southern escarpment. Five sols later they headed home. They stopped at a choice spot near the chasma's mouth to set up a supply depot with a tonne of waste

water, five hundred kilos of solar panels, empty methane and oxygen bottles, a small electrolysis unit and methane-making Sabatier reactor. The water, with atmospheric carbon dioxide, would be slowly converted to methane and oxygen for their next trip. Then they hurried back to the Outpost, stopping only to pick up plastic bags of samples that they had dropped off on their way. The rangers returned to the Outpost the afternoon of December 7.

They took a week off to rest and recuperate, then devoted the rest of December to a variety of tasks. The rangers and portahabs needed only minor repairs; they had held up extremely well under Martian conditions. A tonne and a half of samples had to be cataloged. There were requests for x-ray crystallography, scanning electron micrography, microscopic photography, and elemental analyses of specific samples, keeping four of them busy constantly. The quantity of data they generated was so great that several publishers of articles about Martian surface science said that henceforth they wanted papers that involved more analysis; too many papers describing individual rocks or short field stops were being submitted.

December was also the occasion to plan their second long field trip, which began after they celebrated New Years 2037. It took Will, Ethel, and Sergei deep into Gangis—within a hundred kilometers of the carbonaceous shale deposit—then back to the Outpost. They hauled another half tonne of solar panels to the supply depot, raising its output of methane and oxygen, and left yet more water there.

They returned to the Outpost from their second expedition on January 26 and devoted a month to follow-up research, repairs, and rest. On February 28—the first anniversary of their landing—Will, David, and Laura set out on mission three, to reach

the fossiliferous deposits in central Gangis some seven hundred-fifty kilometers from Aurorae Outpost. The first three hundred kilometers were routine; they had already traversed the route twice. The supply cache had a tonne and a half of methane and oxygen waiting for them, more than enough to replace the fuel they had burned to get there. They refueled, pushed to the end of the route they had cleared previously, and proceeded forward at twenty-kilometers a sol—about as fast as one could go—making very few daily geology stops. In a week they reached the two-kilometer-high pile of rocks located in the middle of Gangis, a remnant of the highland plateau left behind as the rift valley opened to the north and south of it; a record of 600 million years of deposition of sheets of impact ejecta, volcanic eruptions with their lavas and ash, crudely sorted deposits of sand and gravel left by flash floods and steady trickles of water, evaporites and hematite in salt marshes and temporary salt lakes, and layers of dune sandstone and loess. The thickest ejecta deposits often were followed by the thickest fluvial deposits, suggesting that impact heating had temporarily increased the supply of running water and disrupted the drainage patterns. The entire 2,000 meter stack had six significant lenses of carbonaceous shale, representing temporary quiet water conditions where life was able to thrive.

Laura drove one ranger, David the other. They made straight for the nearest known pile of carbonaceous shale debris on the talus slope below the cliffs. They excitedly suited up and climbed the rock pile to get access.

“We’re finally doing something the rovers never could do!” exclaimed Will, scrambling over the last few boulders between him and a huge, smashed pile of black shale. He jumped over a rock, then bent down and grabbed a piece. He held it up

triumphantly, then brought it to his helmet. He pushed a button on his suit and a magnifying lens swung down in front of his right eye.

"Does it have spherules?" asked David. He was a few paces behind Will.

"Oh, yes; lots of them! It doesn't take a rocket scientist to recognize them!"

"Hey, watch the rocket scientist crack," joked Laura. She was coming up the debris slope as well, just a few seconds behind David.

"Ah!" she and David said almost simultaneously as they began to examine samples. "Looks familiar," she added.

"No question," agreed David. "We've got to check a lot of other sample types as well; we've found spherules in just about all the strata, here."

"Except this is the first time we've confirmed the spherules in the shale from this outcrop," reminded Will. "The samples we had access to, until now, were all float of uncertain provenance." Will stood up and looked at the smashed mess of shale around them. A chunk the size of a bathroom had broken off high above, broken into a few large pieces on the way down, then shattered on impact. "You know, I bet some of the float below came from this source."

David scanned the ground beyond the talus slope. "Maybe. The nearest piece was found sixty meters or so from here. That's a long way to fly through the air."

"But this chunk could have broken off pretty high up," said Will. "And a sliver could have been propelled laterally."

"That might be possible," agreed David. "The guys in science control will figure it out. I wonder how many tonnes of this stuff we have to take back to Earth!"

“They’ll advise us about that,” said Laura. “I think we’ll be loading the shuttles pretty full!”

“You know, this stuff could be sold to Mars fans for the price of gold,” said Will. “That could raise a lot of money.”

“Dream on, Moonman,” replied Laura. “NASA would fear that its reputation for science would be compromised.”

“One reason they never seem to have enough money,” exclaimed Will.

For two weeks they drove along the sedimentary stack in the middle of Gangis, circling it completely, then returning eastward along the southern escarpment of the canyon and its associated chaotic terrain. They had to fill up with all the fuel at the cache because they had almost three tonnes of samples with them. Every piece was filled with millions of microfossils. Analysis would take at least six weeks even when they skipped many steps and left many rocks unexamined until they were brought back to Earth.

The first afternoon back, Will, David, and Laura had routine physical examinations and gave Shinji blood samples. The next morning—a sol off—Will and Ethel walked up to the overlook.

“You know, it’s incredible that we’ve built so much in fourteen months,” said Will, looking across the outpost.

“While you were away, Sergei and I sprayed ten tonnes of water on each habitat,” added Ethel. “They’ve now got a nice, thick ice coat; excellent radiation protection. And the sunwing hanger is finally finished. I made the last polyethylene roof supports and anchored them into the sandbags, then tied down the parachute roof sections.”

“That’s for only one sunwing though, right?”

“We can pull the second one up against the first one and tie it, so we have shelter for two if we need it. Of course, they can stay in the air for months at a time, so it’s easiest keeping them aloft.”

“Not after we’ve left Mars. It’s not clear both can fly for nine months.”

“We can cover them both with parachutes before we leave. We won’t be able to launch and land them.”

“I’ve been thinking about that,” said Will. He looked at Ethel. “I have a proposition for you. It’ll take a minute to explain, so you’ll have to bear with me. Everyone calls me Moonman, but over the last thirteen months I think I’ve found a world more interesting than the moon. And I’m under the impression that you’ve found a pretty interesting place as well.”

“Here?” Ethel nodded. “The Outpost’s been fascinating. It’s been fantastic. I’ve been making more items than I’d ever make at ISS2 or Shackleton, repairing a wider variety of things, working on the greenhouses—much more interesting than I thought—and there’s even a view!”

“That’s my feeling, too. I’m thinking that you and I might consider staying another two years. And getting married.”

“What?” Ethel looked at him, startled.

“Well, where else in the solar system can two astronauts be married together, do their careers at the same place, and not be separated for months at a time? We could stay two years, or even four if we wanted to; then when we’re ready to retire from active duty, whenever that is, we can return to Earth.”

“Huh.” Ethel considered. “This is a rather shocking suggestion. Or maybe I should say suggestions, because there’s staying *and* getting married! I’m not sure which is more far-out.”

“Well, the first suggestion fixes the problems of the second suggestion.”

“Maybe. It’s not a very romantic approach!”

“Like I said, bear with me. I don’t think I have ever gotten to know a woman under stranger circumstances than this mission. We have very little private time together, except outside like this, and we have no physical relationship at all. Right now I can’t even kiss you! But Ethel, I’ve thought about you a lot. I miss you when I’m not with you. I want to be with you and do things for you. In short: I love you.”

“I love you, too.” She laughed. “This has been a strange situation to be in, not even holding hands. I wonder whether NASA would want a married couple on Mars. The problems of uneven team-building and favoritism remain, and there’s always the worry about children.”

“We’d have to find out about NASA, and we’d have to be very careful about children. Because this would be a very strange and difficult place to have a child.”

“We don’t even know whether it would be possible. The rabbits and chickens are having healthy-looking offspring, but their biochemistry may not be completely normal; we don’t have the instruments for detailed testing. And in the last month, sitting inside, going outside very little, Shinji says I lost about one percent of my bone density, based on an x-ray he took. Unless one exercises a lot, the gravity here is not good for one’s cardiovascular and skeletal systems.”

“Unless one exercises a lot, terrestrial gravity is not good for them either.”

“Good point,” said Ethel, chuckling. She looked around. “This would be a lonely place with only two.”

“It would be. We’d have to be careful. No field trips, and we’d both have to go out together when we went outside. But there’s plenty of work to do inside the habitat for nine months; we have tonnes of samples to study, six rovers to drive, and two sunwings to fly.”

“And we could provide support when Columbus 2 arrives, if anything goes wrong. I wonder whether NASA would consent to our staying?”

“There’s only one way to find out. They might agree to it. They’re recruiting Columbus 2 based on the idea that at least two crew would stay an extra two years. Until we have faster space vehicles, crews can’t overlap each rotation unless some people stay two rotations.”

“But you were talking about staying even longer.”

“Who knows? If we decide to get married, it’ll be a mutual decision. I’m open to staying longer, but I don’t know how I’ll feel in two years. And I still don’t know how you feel about marrying me.”

“Well, I love you, Will. I said that to you last July. Balancing my love for you and my career is the tricky thing. I could be tempted to return to Earth and marry you there even if it is risky to both the relationship and the career. Mars might be less risky to both, but it’s not an ideal environment, either. And while we don’t want kids now, what if we want them in the future?”

“There’s still time. We’re 35. If we stayed here even five more years, it wouldn’t be too late to start a family.”

“Though we might need some pretty powerful fertility assistance to do it! We could certainly stay two more years, though. Will Elliott, you’ve made my simple life so complicated!” She laughed.

He took her gloved hand in his. “Well, sometimes life is complicated. Feelings make it complicated.”

“They do.”

“So, what do you say?”

“Give me a few hours to think about it. This is too sudden and too big to make a snap decision. I need to think.”

“Okay. I understand. I was up all last night thinking about it.”

“You were?”

Will nodded. She smiled; it was romantic.

They both rose and headed back to the Outpost. They could see Laura and Sergei transferring propellant tanks from two automated cargo landers to a third one to increase its total transport capacity. Laura and Sergei had spent the previous night together; they still did occasionally.

Will and Ethel entered Habitat 2, where David was hard at work on the samples from Gangis. Ethel headed to her manufacturing area. She looked at the bars of iron she had made from meteoritic material, two meters long and a centimeter in diameter. They were sitting on the floor; some had been used to reinforce the hanger’s walls of stone and sandbags and a few others had been used to support the floor of Habitat 1, which was sagging. They reminded her that the carbonyl separation process had recovered some platinum and related elements. She opened the carbonyl unit and looked at the top tray; it

has a shiny, silver coating on it. There should be more than enough to make two wedding rings. That was something to think about. She looked at the greenhouse nearby, the less lush of their two but still greening quite nicely. Two greenhouses could feed four people once they were mature, and they would be mature in a few months. Wheat, corn, tomatoes, lettuce, green beans, soybeans, peas, cucumbers, squash, eggplants, strawberries, peppers, mint, cilantro, basil, mushrooms, chickens, eggs, rabbits: a small range of foods, but nutritious and tasty. Coffee and tea were running out, but mint tea was a pleasant substitute. From wheat they could make pasta, bread, couscous, and cakes; from soybeans, soymilk, soy ice cream, tofu, and soybean oil. Even with advanced food processing equipment, fresh foods were labor intensive, but they had better flavor than the frozen foods imported from Earth.

That reminded her: Shinji was having the time of his life studying the fossils. Ethel headed for Habitat 1; he was in the medical area analyzing the blood samples he drew the sol before.

"Good sol."

He looked up. "Good sol."

"I have a strange hypothetical question for you, one you cannot talk to anyone about except Will and me."

"Really? If it's about birth control pills, I've got plenty left."

"No, that's not the question, though it may lead to that question. Shinji, it seems to me you really love your work here. If a group of us were thinking of applying to NASA to stay an extra two years, would you be interested?"

"Staying? Who's thinking of staying?"

“Will and I.”

“You and Will. And me. I doubt NASA would agree to it.”

“Maybe not, but let’s say we asked.”

“Hum. Maybe I’d stay two more years. I’m not sure what I’ll do when I get back to Earth. I haven’t thought about it much, but I want to continue working on these fossils. The facility being sent will be quite advanced; the size of an entire habitat. I’ve helped design it, too.”

“Do you want to work in it?”

“That’s the question, I guess. It would be very interesting. Let me think about it. I would be interested.”

“Let me know.” Ethel walked back to her work area. She headed straight to the platinum; she wanted to make Will a wedding ring. As she pulled the tray out of the unit, she realized she was convinced. She would stay and marry him.

Meanwhile Will went through the motions to do his work, but he was unable to concentrate. “Come on, Will, I need some help,” said David, gently.

“I’m sorry. I didn’t sleep last night.”

“No? You did fine on the trip.”

“I just asked Ethel to marry me.”

“Really? I thought she said she didn’t want to give up her career.”

“I asked her to stay here on Mars with me.”

“Really!”

Will nodded.

“What did she say?”

“She has to think about it.”

“That’s a lot to think about! This isn’t the Australian Outback with a mall a twenty-hour drive away. It isn’t Shackleton, four days’ flight from Earth.”

“I know. This is an entire planet. A fascinating, complex, ancient planet. An isolated, lonely one, too.”

“Not to mention a planet that can kill you in ten seconds.”

“I know.”

David stared at him. “I don’t know what to say. I don’t know whether it’s a great idea and very courageous, or crazy.”

Will shrugged. “I don’t know, either! And I don’t think Ethel knows.”

“Wow. This means we won’t be exploring the moon together any more, Moonman.”

“Maybe not. But who knows, twenty years from now we might both be going there still.”

“I suppose that’s possible. Malika and I have been talking. Once I’m back, we’re moving the family back to Paris.”

“I thought she didn’t want to live there.”

“She fears for the kids; it’s a seductive place. But if I’m with her, she’s willing to live there. That’ll allow me to work for the Mars Project office there. So we may still be working together. I wonder what NASA will say.”

“If Ethel says yes, I guess we’ll find out.”

They went back to work. Having talked through some of his feelings, Will was able to concentrate a bit better. A bit before noon Ethel came in, smiling. Will saw her

and turned toward her. She walked over to him, picked up his left hand, and slid a ring on his finger. It was rather loose. “What’s this?”

“My crude attempt at a wedding ring.”

“Oh?” Will smiled.

“Congratulations!” exclaimed David.

“It’s platinum, from the carbonyl unit. It’s way too big, I see; I was guessing the size.”

“I wonder whether we can use NASA’s platinum.”

“This is temporary; I thought I’d make us rings. By the way, I will stay here with you and marry you.”

“I figured!” Will took her in his arms and kissed her.

Ethel smiled. “Thank you, even though we are on duty.”

“I won’t talk,” replied David. “I’m really happy for both of you. You’re two of my favorite people in the world.”

“Who’s on kitchen duty today? Shinji?” asked Ethel.

David nodded. “I think so, and all he has to do is heat up leftovers from last night’s supper.”

“Let’s stop at the metallurgical facility on our way to lunch,” said Ethel. “My ring’s still cooling. And I want to measure your finger so I can adjust yours.”

“No, it’s fine! It’s not that too big. I can add something to it to make it fit better.”

“I can melt it down and make it again; it’ll take an hour this afternoon and then it’ll be right. Come on.”

Will nodded and walked with Ethel to the metallurgical unit, where they picked up the other ring. Then they strolled through Greenhouse 2, arm in arm, into Habitat 1. Laura and Sergei had just come through the airlock and were taking off their suits. They saw Will and Ethel with arms locked and were startled. Will and Ethel just smiled and kept walking.

A few minutes later all six of them were in the Great Room, so Will decided it was time to make the announcement. “Okay, attention everyone! Ethel and I have news to announce!”

“What?” asked Laura, sensing what was coming.

“We’ve decided to get married,” exclaimed Ethel. She held up her wedding ring; so did Will.

“Wow; congratulations!” said Laura.

“Great, congratulations!” added Sergei.

“Where and when will the ceremony be? On Earth?” asked Laura.

“No; it’ll have to be here,” replied Ethel. “Because we’ve decided to volunteer to stay two more years.”

Laura was startled. “You’re kidding! I don’t think you can!”

“We can ask,” said Will. “The habitats are rated for fifteen years. We’d have two portahabs and at least one shuttle, so there would be plenty of life support. We’d have two greenhouses to supplement our food supply—which is enough anyway—and plenty of electricity to make water and oxygen. We have all of Columbus 2’s equipment and supplies. Everything has proved extremely reliable. There’s no significant danger.”

“But do you really want to stay here another two years?” asked Sergei. “You’ve said you didn’t. I know I wouldn’t want to. I’ve enjoyed my stay and the work I’ve done, but I’m also looking forward to going home.”

“Me, too,” added Laura. “I’m looking forward to a tickertape parade in New York City.”

“I’ve really enjoyed the work, and I’d like to stay another two years,” said Will. “I’m not sure after that.”

“The same for me,” agreed Ethel. “This has been the best assignment I’ve ever had. If Will and I get married and go back to Earth, we’ll be flying on different missions and won’t see each other very much. Here, at least, we’ll be working together.”

“That’s true. But this is no place for kids,” said Laura.

“We’re not planning to have children while we’re here, if ever,” replied Ethel.

“But just two of you; that’ll be lonely,” said Sergei.

“I’m willing to stay as well,” exclaimed Shinji. The others were startled; Ethel hadn’t mentioned her conversation to Will.

“Really?” Laura said.

Shinji nodded. “Yes, I’ve been thinking about the idea all morning, after Ethel and I talked. You’re right, Ethel; staying another two years is a unique opportunity for me. This is the beginning of the real biological exploration of Mars. Columbus 2 is arriving with the essential equipment that we don’t have. I’ve already identified three species. With enough time and the right equipment I can identify a lot more.”

“Three personnel; NASA will be more willing to consider the request with three, especially when one is a physician,” said Laura. “You know, I think the marriage plans

and the plans to stay are really two separate issues, especially with Shinji wanting to stay as well. My suggestion is that this afternoon the three of you and I tape a message to Mission Control where the three of you volunteer to stay and I endorse the idea. I wouldn't say anything at all about getting married. They consider it their business, but I think we should treat it as none of their business. Let them decide about your request to stay, first; then announce the wedding."

"What if they ask? They might," said Will.

"I wouldn't lie to them, but I'd start by saying that's not relevant to the question of staying."

"NASA cannot deal well with questions of love and marriage," agreed Sergei. "We've already seen that on this trip. Their policies make sense for short missions, but not for long ones."

Once the wedding is announced, you'll probably want to emphasize the decision not to have children here," added Shinji. "Mars is no place for children, and won't be for a long time. Having children here raises all sorts of mythic issues of radiation damage and kids with two heads."

"I agree," said Will.

"Are we sure staying another two years is possible?" asked Sergei.

"We have the parts and consumables to keep the life support systems of both habitats running throughout Columbus 2's mission," replied David.

"We'll want to stay close to the outpost," added Shinji. "We could send out two on an expedition of a few sol's length if we really had to, but it'd be better to stay here."

“There’s plenty to do here,” agreed Ethel. “There are tonnes of samples to analyze, rovers to run, and I can make furniture and basic items needed for Columbus 2, which means when they arrive everything will be ready for them. We don’t need to go more than a kilometer from here.”

“If we can keep the wells going for nine months, when Columbus 2 arrives we’ll have enough water for several years,” added Will. “The wells are maturing and putting out more and more water vapor all the time. Pretty soon we’ll be getting a tonne per sol. We’ll also have a hundred thousand tonnes of rock heated to two hundred centigrade by then; even if we get a bad dust storm that cuts off the sun for three or four months, we’ll be able to extract heat from the hot rock during the entire storm, so the outpost will stay warm.”

“And the greenhouses will be in much better shape if they’re kept functioning nine months,” added Shinji. “Rather than killing all the rabbits and chickens before we leave, we’ll be able to keep the species going. That means Columbus 2 can bring other species.”

“The argument for continuous habitation is pretty strong,” agreed Laura. “Mothballing the Outpost for nine months is not optimum. The dangers are the unexpected; an explosion that kills one and injures another, for example. There probably won’t be explosions in a mothballed outpost, but an active one could have one.”

“If eight arrive on Columbus 2 and there are three here, that’s eleven people on Mars,” said Will. “The habitats are designed for six each and a third one is coming, so we have sufficient capacity.”

“My main suggestion would be that they bring two more greenhouses instead of one, so they can raise food for up to eight,” said Laura. She looked at David. “Can you update the inventory? I want to know whether there are shortages to deal with.”

David nodded. “We should think about what changes to Columbus 2’s inventory this will require,” added Will. “So, this afternoon we’ll call Mission Control about the proposal that three of us stay.”

“And say nothing about the wedding,” agreed Ethel. “We better not talk to our parents yet, either.”

19

Decisions

April, 2037

That afternoon Will, Ethel, Shinji, and Laura called Mission Control and talked to Heather Kimball, Sebastian Langlais, Armando Cruz—Heather was the main capcom, Sebastian was commander of Columbus 2, and Armando was Columbus 2's physician—about staying twenty-six more months. The three Houston folks grilled them extensively. David completed the inventory toward the end of the discussion, showing that existing supplies could run both habitats for one year and either one for two years at nominal maintenance rates; if filters and other replaceable parts were cleaned and reused both habitats could be run even longer. Much of the discussion turned to the agency's natural conservatism, which had kept NASA out of trouble many times. But in this case the opportunities possibly exceeded the costs of caution.

By the next morning, the story had leaked and the world knew about the request. It debated the idea hotly as well. Emails and videomails poured in from the media. The Columbus 1 crew said nothing; NASA had told them to, and they had learned from their earlier experience not to disobey. Besides, they could not predict how their comments might be manipulated.

A new problem became clear to all six of them by breakfast the next morning; Will and Ethel's relationship was changed forever. The platinum rings on their fingers meant they looked at each other differently, and the others treated them like a couple.

"When will you get married?" asked Laura as she poured a second cup of coffee.

“We don’t know,” replied Will. “The rest of April is supposed to be a period of rest, inventory, and supplemental research. May will be dominated by our first expedition to the southern chaotic terrain. June is devoted to packing and mothballing the outpost for blastoff on June 20.”

“The logical time is early June,” said Ethel. “Will will be back from the chaos, we’ll get married, and there will still be plenty of time to prepare for blastoff.”

“A wedding won’t be hard to plan,” said Sergei. “No invitations, no wedding dress, no gifts; just a wedding cake and a ceremony.”

“But I suspect my mother will want to host something at her house in Connecticut,” said Will. “She’ll need time to plan. So we don’t want to wait too long to let our parents know.”

“And it looks like NASA will take its time in deciding,” said Laura. “They may need a month. So be patient.”

“How can they take a month?” asked Will. “We’re less than six months before Columbus 2’s launch!”

“It’s already too late to add things to the nominal cargo manifest,” replied Laura. “The *Syrtis* and the *Solis* are on their way up from low Earth orbit to Gateway. The *Hadriaca* has arrived, but the *Apollinaris* left International Space Station 2 a month ago and won’t reach Gateway until late August. The automated cargo vehicle is loaded and will reach Gateway in July, when it’ll be launched to Mars. So the entire mission is already in flight. Every tonne sent to Gateway now has to be pushed by chemical engines, which is expensive, but there’s six months to do it.”

“They could still push five to eight tones to Gateway with an ion engine,” commented Sergei. “The ion tugs need six months to push sixteen to twenty tonnes there; a lighter load could get there faster.”

“They’ll need to ship an extra two or three tonnes of consumables,” said Will. “We’ll need new suits and computers and probably a thirty kilo allotment for personal items for each of us. There may be additional equipment they’ll want to send knowing that three more hands are available to do work here.”

“Never mind; this is premature,” said Laura. “Everyone has their work assignments for this sol?”

Everyone nodded.

“Good. We need to work hard and be very careful. Right now any kind of accident or mistake will undermine confidence in the safety of the outpost and weaken the case that three of us can stay safely. So keep safety uppermost in your minds.”

Everyone nodded. Laura’s morning pep talks had gotten better

They all headed to work. Ethel went back to the plastic and metallurgical area to make metal supports for the two habitats’ floors. Shinji returned to the fossil research. Will and David continued to run tests on samples. Laura and Sergei headed to the landers to continue transferring fuel tanks to one lander from two others, thereby boosting its total flight capacity. They also planned to service a sunwing that was landing later that sol from Chryse, where it had retrieved a sample canister.

Will was busy checking sample numbers, entering them into the computer, and matching them against descriptions when his videophone line beeped. It was a message from Sebastian Langlais, who would be his future commander. He knew the German

slightly from a one-month overlap at Shackleton. He was nine years older than Will and notoriously precise in his words and control over missions.

"Good morning, Dr. Elliott," he began. "I've been thinking about our conversation yesterday and a few questions come to mind. I've seen you work on the moon. Your love for lunar geology is extraordinary; you were the most published author in the field after only six years of work on the moon. I suppose you've found a new love in Mars. That surprises me; your dissertation was on impact and volcanic features, not fluvial, glacial, and lacustrine processes that are so important on Mars. Are you really prepared to give up lunar geology? Are you sure you can handle the place another two years? Conditions are crowded inside and the environment is hostile outside. Four years is a long time to deal with those situations. Looking forward to your replies. Good bye."

Will was not pleased by Langlais's questions. He hit reply immediately. "Let me start with the second question, Sebastian. I hope you don't mind me calling you Sebastian. First of all, the interior is not that crowded. We have five hundred square meters of pressurized space, including the greenhouses. That's more than Shackleton, and during the day only four people work in it. At night all six of us are inside, but we have our own private rooms. So we're not rubbing shoulders.

"As for the outside, I wouldn't exactly call it 'hostile.' The suits keep us very comfortable; more so than moon suits, because there's a cold atmosphere to remove extra heat. There's no danger from micrometeoroids and less from radiation, compared to the moon. We all go outside an average of four hours every other sol, which is sufficient to counteract cabin fever. It also provides adequate exercise; with the suits, our weight is 2/3

our weight on Earth and we have to exert ourselves a lot to move in them, so our skeletal and cardiovascular systems are doing much better here than on the moon.

"As for your first question, geologic work is different here than on the moon in two ways. First, this world is more like Earth; it has an atmosphere and water has been very active in its geology. I've published two papers about geology on Earth, one just two years ago. I find myself constantly making three-way comparisons involving the Earth, Mars, and the moon. My six years of lunar research were essential preparation for my work here because it gave me a feel for half of Mars's geological processes. The Earth gives me a feel for the other half.

"The other way geology here is different is a function of our isolation. A six-month trip to the moon involved close work with a geology team for several months beforehand, face to face, in Houston; then the trip to the moon was made and one interacted with them live; and finally one flew home and coauthored papers with them. Here there is no face-to-face interaction and no real coauthoring. Instead, we have to serve as everyone's hands and eyes, and later as their lab assistants. We're working for—not with—hundreds of geologists instead of with four or five. So I haven't published a single paper of my own since landing here. My name has been listed as coauthor on about forty papers—I'm not even sure what the total is—but I've never been a primary author.

"If I stay, that will change. For nine months, the three of us will have to remain very close to the Outpost. I still haven't taken a month of vacation. I'll probably take it then and use the time to write. And then you will see how much I love the geology here. I've got a dozen papers in mind and I've outlined a few. I'm looking forward to the time to write. I hope that answers your question. Bye."

Will sent the reply and returned to his work. Clearly, Sebastian had more questions in mind; his next message arrived forty minutes later, just three minutes more than the round trip transmission time. “Thanks, Dr. Elliott. Actually, I’d prefer ‘Dr. Langlais’ for this current exchange. I think you are right about how well the alternation of inside and outside duties works to maintain psychological and physical health. I suspect the aesthetic setting helps, too. I’m looking forward to seeing all your research, but I suppose you could write most of it after you returned to Earth just as easily, and you’d be in an ideal position to take the lead in sample analysis. I’m also glad to hear you’re willing to work in support roles.

“However, another question has occurred to me. The six of you have had your ups and downs in the last eighteen months. What makes you think that you, Ethel McGregor, and Shinji Nagatani will get along for another twenty-six months? The rumors about romantic ties between you and Ethel make the whole issue even more complicated. There’s the problem with interfacing with my eight-person team as well. We’re becoming a smoothly working team. I’m curious if you’ve thought about that subject.”

Will frowned as he listened to the question. It would be complicated to answer because a lie, if revealed, might jeopardize everything. “Dr. Langlais, I think there are two questions to ask, not one,” he replied. “One is, how well will the three of us get along for the nine months before Columbus 2 arrives; the other is, how well will we get along after Columbus 2 brings eight more people here. I don’t see why the three of us will have a relationship in the next nine months any different from the one we’ve already had for eighteen months. We get along well, and there’s no reason that should change. The second issue is unpredictable. There will be an adjustment when two crews merge into

one. We will do everything we can to meet the challenge." He paused, then decided that was all he'd say, and hit send. Maybe the romance issue was finessed sufficiently.

It seemed to be. Forty-three minutes later, Langlais called back. "Thanks, Dr. Elliott. My worry is integrating eleven persons into a team responsive to the priorities and duties set in Houston and by the Commander of Columbus 2. I appreciate that you have pledged your full cooperation and support to me. Good bye."

Langlais's face faded on the screen and Will wondered what his future commander thought they had agreed to do. He turned back to his work, pondering the conversation. Then Shinji appeared at the door of his office looking crestfallen. He had heard Shinji's voice occasionally from the other side of the wall and it sounded like he was talking to Langlais as well. Shinji shook his head. "I don't think I can stay, Will."

"What? Why?"

"I've been talking to Commander Langlais. He's been rather hostile to my staying. At one point he asked 'Couldn't you continue much of your research on Earth?' And then he said in a latter conversation 'I suppose we can find something for you to do, but Armando's coming as mission physician, Monica's our exobiologist, and Lisa's our horticulturalist, so I'm not sure what position would be left for you.'"

Will's eyes grew large. "Who does he think he is? He can't use another exobiologist, physician, and horticulturalist? Of course he can! The more, the better!"

"There's plenty of work for two exobiologists. That's where I'd put my time, but I can always provide backup for the other two. Yes, I can write up the research I've already done here from Earth; but there's plenty of new research to do here!"

“He said something similar to me, so don’t worry about it. If you want, I can complain to mission control, but I think we’re better off waiting. We’ve been here over a year and we have seniority, after all.”

“True. I agree, let’s drop it. Thanks.” Shinji went back to his office.

Will tried to ignore the persistent knock on his bedroom door. It kept impinging on his dreams. Finally he awakened. His clock showed the time: 2:15 a.m. “Who’s there?”

“Will, it’s Laura. I’ve got Dr. Lassen on the line and he wants to talk to you, Ethel, and me immediately.”

Lassen was the Director of Mars Mission Operations. Will bolted out of bed. “Okay; I’ll be there right away. Where are we meeting?”

“The Great Room. I’m inviting Shinji, too. They know about your wedding plans; Lassen was upset we didn’t tell them. That’s why he’s calling.”

“Oh, great! Alright, I’ll be there in a minute.” Will pulled on his clothes quickly, combed his hair, and wondered whether he’d get any sleep the rest of that night. But when they were awake, Lassen would be asleep—the clocks in Aurorae and Houston were out of synchrony at the time—and he was the one who was mad.

Will walked to the Great Room. Laura and Shinji were already there; Ethel arrived a moment later. “They’ve been listening to our private conversations,” said Laura.

“I thought the audio and video never went farther than the ITVs,” said Will.

“Unless they call for it. They did; I just checked.” Laura shrugged. “We don’t have the ability to block it, and we know they can do it.”

“At least we wouldn’t have sounded too conspiratorial,” said Will.

"I'm not so sure. Let me play his message."

She pushed a button to play his videomail. Lassen's face appeared on the screen and he looked stern. "Commander Stillwell, I hope you are still up because we need to speak immediately. I have been informed that Elliott and McGregor plan to get married. This was not mentioned in their request to stay on Mars. I need an immediate explanation of this discrepancy from them and from you. Goodbye."

"Well, let's sit and explain," said Laura. "There's no reason to coordinate our responses because they can listen to the coordinating. I'll go first." The four of them sat facing the wall screen and the camera above it. Laura checked the image to make sure it included them all, then began the recording. "Dr. Lassen, here we are; I just awakened everyone so we can talk with you. We haven't stopped to plan our responses because I see Mission Control has been listening to our conversations of the last few sols. Under such circumstances we have to be frank and spontaneous. I think we also have to be honest with you, and not try to hide our motives.

"We didn't mention Will and Ethel's decision to get married because it really has nothing to do with the issue of their staying on Mars. That was my decision and I accept responsibility for it. Yes, one can say that NASA needs to know whether they want to be married or not. But we were planning to tell you after the request to stay was resolved. You would have known. Would it really change your decision? Will, what do you say?"

Will looked at Laura, then at the screen. "Dr. Lassen, I love Ethel and I love Mars. I've explained how I love Mars to Sebastian Langlais. This is an incredible world and I want to study it for at least two more years; maybe four. As I think you know, I have developed a fairly good technique for communicating with scientists on Earth; they

get a good idea of what I am looking at and what I think it is. The moon and Earth are two end members on a geological spectrum with Mars in between, and there is a vast amount of work to do to understand that. So I want to stay. And I love Ethel; over the last year and a half we have grown very fond of each other and very close. Ethel and I did not plan to fall in love; it just happened. I'm sure you know how that is; you're married. NASA's policy of no romance makes sense on ISS2 or even on the moon; people are together a few months, then they go home to their families. But this is a thirty-month expedition, and if anyone stays a second cycle they're away from Earth fifty-six months. I'm afraid one can't expect no romantic involvement for that length of time. It would be wise to send married couples on future expeditions. I'm not sure what else there is to say. Ethel?"

"I love Will. I figured that out last summer and said so when our team was meeting with the counselors. They heard it; it's on videotape. Will was surprised and so we talked about it and decided that since we're both divorced and we both love our work, we couldn't get married. The pressure on astronauts is too much; too many of them are divorced. The pressure is far worse when both spouses are astronauts. Needless to say, our relationship all this time has been Platonic, and it remains Platonic. But we would like to get married. I think at this point we'll get married whether we stay here or not, and take a chance that we can make a marriage work in spite of mission schedules. But Mars provides an ideal opportunity to continue our professions and be married. The work here has been incredible; if you talk to my ground support team, they'll tell you how hard I've worked and how much I love it. So the situation is really very simple: we are providing the space agency with an incredible opportunity to build the human presence on Mars far

more than could have been imagined. And for Will and me, it's a chance to do the work we love together." She turned to Shinji.

"I've explained my motivations for staying extensively for the last two sols," said Shinji. "And I'll be glad to continue if it is helpful. I am a biologist and a physician, with a Ph.D. and an M.D. I don't think I can begin to explain how exciting it's been to study Mars's first fossils. We've identified three species so far and we'll soon have three more. The equipment here is not designed for microfossils, but if one is patient it's adequate to do very important work. An additional nine months will allow a lot of research, and I want to be part of the team using Columbus 2's Mars Life Science Facility. As a horticulturist and physician, I bring a lot of valuable skills to the Outpost. I hope I can stay, and I'd be delighted to stay with Ethel and Will, since they're good friends."

He turned to Laura. She looked at the screen. "That's the story, Dr. Lassen. Let us know what else you want to know. Bye." She pressed send, then rose. "Who wants coffee? If you want to lay down, I'll wake you when his reply arrives."

"Coffee," said Will and Ethel simultaneously.

They were up half the night while Lassen—who was sitting in his office and getting many other tasks done—was listening to their comments, formulating another question, sending it, and getting work done. Finally about 5 a.m. he said "I appreciate your time in answering these questions frankly. I'm not trying to grill you, but obviously this is a big step and not one to take lightly. We'll get back to you in a few days about this."

So they finally went to bed, and slept late the next morning. After breakfast, Will walked Ethel to the greenhouse, where she was working that sol. There they had privacy, verdure, and a view of the Martian terrain. “What do you think of last night?” she asked.

“I don’t know. I think it’s unlikely we’ll get a green light now. Thank God we were honest; if we had lied to Lassen, the whole plan to stay would be dead.”

“You’re pessimistic, then?”

He nodded. “But I may be wrong. Langlais doesn’t want us.”

“That was my impression, and certainly was Shinji’s. But he doesn’t get to decide, and the advantages for NASA to our staying are immense.”

“I agree. We’ll see. Typical of NASA, to ask us to spend this entire evening talking to psychiatrists.”

“Yes. That will be unpleasant. They want spontaneity and get frustrated by the forty-minute time delay!” Ethel sighed. “I think I’ll videomail dad this afternoon and tell him. It’d be nice if you could join me.”

“I’d love to! I don’t know your father.”

“Well, it’s hard to get to know anyone by videomail.”

“True. Did I tell you that we need his permission to get married? It’s a Bahá'í law.”

Ethel frowned. “Really? No matter how old the child is?”

“Correct. It’s a Bahá'í law to bind the generations together and create family unity. Unity, as you probably know, is the main teaching of my religion.”

“Interesting. Dad will be flattered. Are there other regulations?”

“Only one; in addition to anything else we do in the wedding ceremony, we have to say the Bahá'í marriage vow: ‘verily, we will all abide by the will of God’ in front of at least two witnesses.”

“That’s pretty simple. Shall we call your mother, too?”

“Let’s call mom tonight, in between rounds of questions from Houston.”

She nodded. “Okay.”

“So, you’re going to marry me even if we can’t stay?”

“Yes, I think I will, Will Elliott. You’re too good to get away.” She smiled.

He leaned over and kissed her on the cheek. “You’re too good to get away, too, Ethel McGregor. If we can’t stay here, should we get married here anyway?”

She sighed. “I’d be in favor; I don’t want to wait until December when Columbus 1 gets home. I’d rather be living with you.”

“I feel the same. We’ve already staked our reputation on being chaste, so we can’t back out of that unless we get married!” He looked at the exteriors of the habitats. “If we stay, where will we live? The bedrooms are pretty small.”

“We could cut away a wall and convert two small bedrooms into one big one. There are some other options; leave that to me.”

“Alright. I’d better get to work. Do you want help with anything?”

“If you want to come and kill a chicken for me, that’d be nice! I always hate killing them. But besides that, I’m planting a new square of wheat and harvesting vegetables. Shinji will come here for an hour this afternoon and we’ll mix soil—complete with worms—into another square. It’s pretty routine stuff.”

“I’ll stop by right after lunch to dispatch the chicken, how’s that.”

Ethel smiled. “Thank you, that’d be very nice of you.”

It was a rough evening with the psychiatrists, who wanted to talk to Will and Ethel separately and asked a battery of invasive, personal, and often seemingly irrelevant questions. The unpleasant evening was followed by a surprise the next morning. “I just had a conversation with Kimball,” Laura said when she came out for breakfast. She glanced at the camera and microphone built into the ceiling, then at the others and lowered her voice a bit. “She just met with Lassen, who had just met with the Administrator. Lassen told her to leak your marriage plans anonymously to the media.”

“Why?” asked Will. And then he smiled.

“What is it?” asked Ethel.

“They’re cowards,” he said.

Laura laughed. “You may be right. The majority of NASA bigwigs don’t want to accept your offer to stay. Some are cautious. Some are jealous of the three of you. Some, like Jerry McCord, want to command a future mission. Many fear you’ll end up dominating Mars exploration and become difficult to manage. But if the plan to marry and stay becomes public, the public will probably love it.”

“And want it approved,” said Ethel.

“Most likely,” agreed Laura. “Public opinion could be turned against the idea; if so, NASA would have an excuse to turn it down. But the public will probably support the idea, so NASA will have to accept it, the internal opponents will have to give in, and NASA will be off the hook if you get into trouble.”

“Cowards,” repeated Sergei.

"So I think it's settled," said Laura. "The six of us have three months left together and Columbus 2 arrives in exactly one year."

"We'll be taking one shuttle and one ITV back to the Earth, right?" asked David.

Sergei nodded. "That's the plan. We'll fly the *Pavonis* and *Olympus* to orbit. We'll transfer the *Pavonis's* rock samples to the ITV *Cimmerium* and the *Pavonis* will fly itself back to the Outpost. We'll leave the *Ausonia* here in orbit and take the *Cimmerium* and the *Olympus* home; the latter needs to be checked to figure out why the parachute didn't deploy. That way, whenever Will, Ethel, and Shinji want to go home, the *Ausonia* and *Olympus* will be available."

"I wonder when that will be," said Will.

20

Wedding

early June, 2037

Will, in the lead ranger, kept his eyes focused on the northern horizon. He drove down the dirt track as fast as he reasonably could—almost fifty kilometers per hour—occasionally slowing when the ranger's on-board computer began to beep because it detected a rough spot or curve in the road ahead.

It was nearly sunset and they hoped to get back to the Outpost before dark. The two rangers and portahabs had explored the southern margin of Aurorae Chaos for most of May, penetrating deeply up channels, exploring partial caves, and walking through natural bridges, seeking to understand why millions of square kilometers of Mars had collapsed into heaps of water-weeping sediment. They found a dozen lenses of carboniferous shale full of fossils. In some ways it was their greatest expedition; the geology certainly was the most important. It would have been impossible for non-human explorers to accomplish. They were returning with a tonne of samples.

Layercake Mesa and Boat Rock hove into view. A few minutes later they could make out Face Rock as well. Will, Sergei, and David had been alternating behind the wheels of rangers 1 and 2 since dawn and had made the entire return trip in one sol, thanks to the good track their bulldozer blades had cleared on the way up.

"Ah, there it is," said David, pointing.

"Where? I don't see."

"The white top of the habitat, just to the right of Face Rock; see it?"

Will shook his head, then a moment later nodded. "You're still Eagle Eye."

“I sure am, Moonman. There it is; home, sweet home.”

“Especially for me.”

David nodded and patted his friend on the back, who looked forward to a wedding next week and an additional two-year stay. The white top of habitat 2 could be seen now; both had been capped by white parachutes material covering sandbags, dirt, and twenty-five tonnes of ice. The habs were now well insulated from cold and radiation.

As the sun set, Will backed portahab number one up against an airlock and docked to it. Sergei did the same with portahab number two at another airlock. David went out to secure a hard dock for both vehicles. They pressurized the tunnels, opened the doors, and were greeted by Laura and Ethel.

“Welcome home!” they said almost simultaneously. Will stepped out and hugged Laura, then kissed Ethel. After three weeks, it was very good to see her again. Just then David came in through the airlock. He hugged Shinji, who had gotten used to the very un-Japanese custom.

“Our last big trip was quite a success!” said Laura. “We’re celebrating with chicken tonight, and it’s just about ready. So let’s head for the Great Room!” She led everyone inside Habitat 1.

Ethel walked in with Will, hand in hand. “Thank goodness you’re home.”

“I missed you.”

“I missed you too, in spite of nightly calls. I’ve got something to show you.”

“Oh?”

She nodded and led him down the hall to the staircase that led up to the attic and down to the basement. She started up, so he followed.

At the top of the narrow stairs he was surprised to see a wall. The attic level had been a large, open space that extended from the apex of the dome to the point where it curved down to touch the attic floor. Only the central area had a ceiling high enough to stand. The floor had been a plastic membrane stretched tight by air pressure, but now it was covered with hard polyethylene sheets. Walls of similar material closed off a room.

Ethel walked to a door and pointed. “Open it,” she suggested, with a smile. Will turned the knob and opened the door. They stepped into a room about four meters by five, with two doors in the left-hand wall.

“How did you do this?” asked Will, impressed.

“Laura helped; it took all my spare time while you were away. We made the metal verticals, crossties, and screws with the carbonyl unit and fabricated the panels with the plastic fabrication unit, then set up the verticals and screwed the plastic panels to them. We had to reinforce the floor, which means we had to reinforce the lower floor. Metal verticals extend all the way to the basement. The wiring was tricky.”

“And we have a walk-in closet?” Will walked into it and looked with admiration.

“Yes, and a bathroom; that was even trickier!”

Will opened the other door and was immediately impressed by a bathroom with a sink, toilet, and compact shower stall. “These came from the *Pavonis*?”

“No, the *Elysium*, since it’s staying. We might as well use them. The water isn’t hitched up yet; we’ll do that tomorrow. You and I will have our own little suite up here.”

“Very nice! I’m surprised Mission Control agreed.”

“Laura twisted arms. There’s room for another married couple, so our privacy may not last forever. We’d have to evacuate immediately if there’s a fire in the habitat;

the plastic emits toxic gasses when it burns. Tomorrow we can look at the remaining wallpaper and see what we want."

"The walls need something. But this is impressive, Ethel. Very impressive. It's a shame we don't have a window, but we can live without that."

"It's a small loss." She smiled. "I'm glad you're pleased."

"Oh, very." He kissed her, mouth to mouth. It grew long and became passionate.

"Five more sols," she said, with a smile.

They descended the stairs and sat at the table. David and Sergei went up to see the room while the others served themselves. Then David and Sergei returned and everyone pronounced the new housing to be a great success. A wine bottle came out—one of Sergei's last—to highlight the specialness of the event.

"There's a bit of news," exclaimed Laura, as they finished their meal of pasta and scanty chicken. "As you know, two weeks ago Lisa Kok had to withdraw from Columbus 2 because of her mother's advanced cancer. Earlier today NASA announced her replacement: Dr. Madhu Gupta-Anderson, the wife of Dr. Roger Anderson."

"You mean, NASA's sending a husband and wife to Mars?" asked Will. He laughed, followed by the others.

Laura nodded. "They're getting the message. She's not even Astronaut Corps! Her Ph.D. is in food technology. One reason she's coming is because the Outpost will have eleven people and that's too many to rotate food preparation duties easily. She'll handle food preparation, cooking, and the greenhouses."

"That's a lot of responsibility," said Ethel.

“I’m sure others will have to help,” replied Laura. “Madhu says she wants our input about plants to add to the inventory. NASA has agreed to add another greenhouse; Ethel’s room construction demonstrated that we could make viable building materials, so NASA plans to remove some items from the cargo at Gateway to make room for the extra greenhouse. I mentioned oranges to her and she said they could indeed fly up a half dozen tiny seedlings.”

“Garlic,” replied Sergei. “And onions.”

“Garlic’s smelly and onions are a root crop; but I think the air filters can handle the former, and the greenhouse now has enough soil for the latter.”

“Jalepeños and hot peppers,” suggested Will. “I miss hot food.”

“I agree,” said Shinji. “Lemons.”

“Chicory,” suggested Ethel. “It’s a coffee substitute.”

“What about more animals?” asked Will. “Rabbit and chicken are monotonous after all this time.”

“They’re flying up more steak, since we now have plenty of vegetables. They want to bring tilapia, but it’s uncertain whether that’s possible. We now have plenty of water for fish. Madhu plans to try rice.”

“Rice on a desert planet!” exclaimed Shinji, smiling.

“What about bees?” asked Will. “They’ve been tried at Shackleton.”

Laura nodded. “There’s a new breed that can handle the lack of ultraviolet inside the greenhouse. They’ll bring them. They’re bringing light-emitting ‘icicle diodes’ that produce light tuned for photosynthesis so that Madhu can use a higher plant density and still get good results. The goal is to make Mars self-sufficient in food for eight people.”

“That would be great; they’d just have to fly up meat and coffee,” said Will.

“How are the wedding plans?” Sergei asked Ethel.

“There’s not much we can do here; the busy people are my sister and Will’s mother! They’re planning family events in Connecticut and Scotland that will be tied in by video. NASA has limited the total mass of wedding presents to 50 kilograms, but coordinating that has proved difficult, so they may have to fly up a bit more.”

“At what? About $50,000 per kilo?” asked Shinji.

Laura nodded. “That’s about right. NASA is spending two or three million bucks flying the wedding presents here. My present to the two of you will arrive then, too; it’s already in Houston.”

“You all don’t have to give us presents,” said Ethel.

“Of course we’re giving you presents!” replied Sergei. “Unfortunately, when we’re here the presents will be on Earth, and when we’re on Earth the presents will be here; but it’s the thought that counts, right?”

“I’m wondering whether we’ll be sending baby presents, some day,” teased Laura.

“Oh, no!” exclaimed Ethel. “This is no place for children. And it’s not clear that a child born here could ever fly home before adolescence because of the radiation; and after adolescence, it’s not clear the child would be able to adjust to terrestrial gravity!”

“I’m not so sure,” said Laura. “A two year old could be flown home in a radiation-shielded room. And this place is already pretty big for a five or six year old to run around. In five or six years it’ll be even bigger. An orchard greenhouse with a swing set would be quite nice.”

"Perhaps, but what you're suggesting is not in our plans," replied Will.

"Then someone else will have the first child on Mars," said David.

The next five sols passed quickly. There was no time to rest; the samples from the field trip had to be unloaded and placed in the basement and preliminary analysis had to be done on samples that might or might not be shipped back to Earth. It was not until Sunsol—which fell on terrestrial Saturday—when they finally rested, and when the wedding was scheduled.

While Shinji and Sergei cooked the wedding banquet, Laura helped Ethel with her hair and nails and David helped Will with the program. The actual wedding ceremony was scheduled for 9 p.m. Sunsol evening, which corresponded to 9 a.m. Saturday morning in Connecticut and 4 p.m. Saturday afternoon in Scotland.

Festivities began on Mars with a banquet at 6:30 p.m. They ate both chicken and rabbit—one of each—with home-made bread and couscous, a generous supply of vegetables in rabbit gravy, wine for those who would drink it, and lots of coffee and tea. When they finished eating, Laura pulled out her keyboard and David his guitar and they sang songs together.

Then everyone headed to their rooms to dress for the ceremony. They gathered in the great room at 9 p.m., Will wearing his only suit, Ethel her nicest dress, with a wedding veil and train of parachute material added to the latter. They actually looked pretty good, especially on video; Laura had helped in the cutting and sewing.

After the couple entered to the tune of the classic wedding march, Laura, as commander, formally rang the Outpost's bell six times and welcomed everyone to the

first wedding on Mars. Then the couple, Sergei, and Shinji all read short scriptural passages about love and marriage, highlighting the nature and eternality of both. David played a piece on his guitar while everyone contemplated the readings. Then Laura invited Will and Ethel to stand before her. “It is my duty and great pleasure, as Commander of this Outpost, to marry the two of you,” she began. “For the last fifteen months, six human beings have made Mars their home. The six of us have had our ups and downs together, but we have steadily grown closer together and the ties of friendship have grown stronger and deeper. Will and Ethel have been a major reason we have been able to build the strong ties we have to each other; they have worked tirelessly to resolve tensions, build trust, and help us understand each other. The joy all of us feel together is one fruit of this marriage. We are delighted that our two friends have grown so close to each other that they have decided to make an eternal commitment to each other, and to create love together. It gives us great confidence that Columbus 2 will be a resounding success, because our friends will build on the foundation of unity already laid and help an even larger team work together here in solidarity. And on that foundation of love, unity, and solidarity, human society on the Red Planet will be founded. Perhaps one eventual result will be a planet that will never be touched by war, poverty, or prejudice.

“From this union, then, great results may result. Will and Ethel, are you ready to exchange your vows?”

“We are,” they replied.

“Good. Will, do you take Ethel for your beloved wife, to have and to hold, in sickness and in health, for richer and for poorer, through all circumstances life brings your way, for all time?”

Will smiled. “I do.”

“And Ethel, do you take Will for your beloved husband, to have and to hold, in sickness and in health, for richer and for poorer, through all circumstances life brings your way, for all time?”

“I do.”

“Then on the authority vested in me as supreme commander of the Columbus 1 expedition, I pronounce you husband and wife. You may now exchange the Bahá'í wedding vows you have chosen to add to this civil ceremony.”

Will and Ethel turned to each other.

“We will . . . . how does it go?” asked Ethel, suddenly embarrassed she had forgotten the vow.

“We will all, verily, abide by the will of God,” said Will, with a chuckle.

“I’m sorry, dear, I’ve said it only a hundred times! We will all, verily, abide by the will of God.”

“We will all, verily, abide by the will of God,” he repeated, and kissed her on the forehead to reassure her.

“You can now kiss the bride,” commented Laura, with a smile.

David stepped forward with the rings. Will and Ethel put rings on each other’s fingers; then they kissed again.

“We’re now married, so you can applaud!” exclaimed Will. The other four cheered and clapped.

“Hey, don’t forget this incredibly beautiful marriage license my friend made!” said Laura.

"Printed on the last huge sheet of paper we had," added David.

"There's room for all four of you to sign as witnesses," said Ethel. "What a marvelous Martian tradition."

They signed the license and turned to the wedding cake. Sergei brought it out. "Martian flour, Martian strawberries, Martian eggs, and Martian soy products!" he announced. "Only the sugar is out of this world."

Ethel and Will cut it up and dished out big pieces to their friends and they all had a grand time eating and chatting together. About the time they finished, video began to arrive from Scotland and Connecticut, where video cameras showed the audiences watching the ceremony and applauding. Lines formed to send video greetings and congratulations. Will and Ethel alternated listening to messages from each continent and taping their thanks and greetings while a breakfast came out in Connecticut and an early supper in Scotland. People came back to the screen to see the couple's responses and to respond yet again, so the exchange of messages went on for two hours. Finally, wedding presents were opened on camera. Will and Ethel watched and briefly thanked each giver. Their four colleagues enjoyed the parade of comments and gifts as well, sometimes adding their own comments or exchanging their own private messages with guests.

Finally, 24:38 closed in, a time that never existed on terrestrial clocks because of the Earth's shorter day, the time considered "midnight" on Mars. The rest of the crew had left the Great Room when the clock had struck 12. Will and Ethel thanked everyone and closed the video lines, ending the wedding and starting the rest of their lives together.

21

Blastoff

June 20, 2037

Laura looked at her closet one more time. “I can’t believe I’m leaving so much behind,” she said to Ethel.

“We’re grateful. Especially the keyboard; even if none of us can play it, someone will come along who can.”

“Easier for me to buy a new one on Earth than for someone to import one to Mars,” exclaimed Laura. “I need a new one, anyway. I hope you can use the clothes.”

“Definitely. We’re pretty much the same size. If I can’t, someone else will.”

“Returning astronauts might as well fly home light; more room for samples.”

“And it sounds like you’ll need all the space you can get!”

“Not really. The two shuttles have almost ten tonnes of samples but they could carry twelve. They’ll flood the university science community with Mars rocks. As far as I’m concerned, NASA might as well start to sell them!”

“Fat chance,” said Ethel. “I’m glad I became your friend, Laura. I’ll miss you. We’ll probably see you in three years.”

“Probably, unless you and Will can work some magic on Langlais.”

“We’ll try. I’m worried, but optimistic.”

“You were able to make a difference on this mission, so I suppose I shouldn’t be pessimistic.” Laura picked up her bag and walked out of her bedroom for one last time. Once Ethel was out, she closed the door with a sigh. Another chapter of her life had ended.

In a nearby room, David was looking at the clothes and the Moroccan rug he was leaving. “I’ll cherish this rug, Daoud,” said Will.

“Hey, I’ve got to leave something with you, Moonman.” David smiled and his voice choked with emotion. “I don’t even know whether we’ll see each other again. I doubt we’ll ever fly together again.”

“Who knows. Ethel and I have committed to only one more tour of duty; we may be back on Earth in early 2040. I bet we’ll come to Paris and have a nice barbeque with you, Malika, and the boys.”

“That would be nice. Or maybe we’ll come see the two of you and your children.”

“God willing, my friend.”

David smiled. He and Will embraced “Let’s keep in touch.”

“Definitely. I’m counting on you to keep my geological theories from getting out of hand.”

“I’ll be glad to,” promised David.

The two of them stepped out of David’s room and headed for the Great Room, where Laura, Ethel, and Sergei were already waiting. Shinji hurried in as well. “It’s time,” he said. “We’re at t-minus two hours and holding the count.”

“I almost feel like I’m going as well,” said Will, a smirk on his face.

David frowned. “What do you mean?”

“Well, Shinji is sending to Earth nearly the equivalent of my entire body mass of fecal, urine, and blood samples!”

David chuckled. Laura slapped Will on the back. “Don’t worry, Moonman, you’re still full of shit.”

Will was startled by that. “I’m sorry; I didn’t mean to offend,” she hastily added.

“Don’t worry, I’ve gotten used to your humor.”

“It took a while!” Laura looked around the room, and a tear appeared in her right eye. “My friends, it’s time to say our goodbyes. This has been the most incredible mission in my life. Nothing can ever top it. I can’t begin to express my thanks to all of you for making it so successful. And. . .” She hesitated a moment. “. . . Thank you for the friendship. We’ve become like a family in the last two years; I never expected that. I hope we get together again at some point in the future.”

The six of them started hugging each other and expressing their tearful goodbyes. Those leaving wished all the best to those staying; and those staying wished the others a safe flight. In either case, they would all be in danger; that was the nature of space exploration.

They all headed to the suit-up area and put on their pressure suits, because those staying were driving the two rangers that would take the departing ones to their shuttles. The shuttles would launch for the interplanetary transit vehicles ten minutes apart to allow the first shuttle to achieve orbit before the second one blasted off.

Suited up, they all clambered into the rangers for the predawn drive to the shuttles and their launch back to Earth. It was a bittersweet moment, culminated by two beautiful and powerful launches and the beginning of the long journey of Columbus 1 back to humanity’s home world.

Dramatis Personae

Columbus 1 Crew: 6 (2 Americans, 2 Europeans, 1 Russian, 1 Japanese)

David (Daoud) Alaoui (Moroccan French, born 1999): Field geologist, Muslim, wife and kids in Fez, politically very liberal, plays guitar, half French by background, writes novellas, was French Air Force pilot.

Wife: Malika

Will Elliott (American): Master field geologist; the "Moonman"; divorced because of excessive work and time from home; turns 35 in 2036 (born May 2001); multiracial; Bahá'í background

Mother: Katherine Elliott (born 1969): Mexican, Scottish, other ancestry
Sister: Molly Nuri (born 1999)
First wife: Jamie
Father: African American, white, Cherokee ancestry

Sergei Alievitch Landsberg (born 1993) (Russian of German Jewish and Kazakh Muslim and Russian orthodox backgrounds): Asst Commander, mechanic/engineer/pilot, plays violin, grown family; wife divorces him on flight out. Brings a supply of wine and vodka.

Ethel McGregor (Scottish, born late 2001): engineer, computer specialist, some physicians training, divorced, poet, agnostic Presbyterian but had a very Presbyterian grandmother, not a good cook. Was a British Air Force pilot.

Sister: Gina; her daughter, Karie
Father: James Ian, born 1965
Mother: Mary, born 1967 (died Oct. 2036)

Shinji Nagatani (Japanese): biologist, paleontologist, horticulturalist, physician (MD), warm personality, hates to lose face, never married. Added to the flight at the last minute; had never been to the moon. Born 1998 (37 in May 2036)

Laura Stillwell (American, born 1995): Commander, Air Force pilot, conservative Protestant (Baptist), a bit inferior on flight, hard to work with, Republican, plays piano and keyboard, divorced.

Vehicles: Elysium (Mars Shuttle), Olympus (Mars Shuttle); Cimmerium (Interplanetary Transit Vehicle/ITV), Ausonia (Interplanetary Transit Vehicle/ITV). The Mars Shuttle Pavonis was already on Mars and flew back to Earth with the Cimmerium.

Summary of *The Valley of Dawns*

1. Gateway 3

Will Elliott and David Alaoui join Columbus 1, the first manned mission to fly to Mars, which is located at L1 Gateway Station between the Earth and the moon. They are reunited with the other crew (Commander Laura Stillwell, Assistant Commander Sergei Alievitch Landsberg, and chief engineer Ethel McGregor), including one new member (flight physician Shinji Nagatani). Heather Kimball, the pilot of their flight from Shackleton (the station at the lunar South Pole), tells her story of being on the first manned flight to return to the moon since Apollo.
Date: July 24, 2035

2. Flight 19

Columbus 1 flies past Earth, fires its engines, and heads to Mars. Will shows Laura his meteorite collection; she notes pictures of his black father and white mother and is surprised by his mixed ancestry. A graywater tank bursts, requiring the three of them on the *Ausonia* interplanetary transit vehicle to move out temporarily. Laura chews Sergei out for not detecting the problem before it happened, even though there was nothing to detect.
Date: July 24-Aug. 2, 2035

3. 2015AS 30

Laura is being tough on all of them and appears to be insecure in her position as Commander. Will and Ethel get to know each other a bit better. Sergei's divorce decree arrives; they all discuss divorces (four out of six are divorced). Laura goes to comfort Sergei and seduces him. They fly by the small near-earth asteroid 2015AS and gather high quality radar and laser data.
Date: Sept. 2035

4. Christmas 44

Laura comes out of Sergei's room naked when David happened to be drifting by. She accuses him of spying on her. Everyone finds out she and Sergei are in a relationship and express concern about the lack of friendships among the crew. Ethel talks to Laura about the problem and Laura proposes a Christmas party. But she quickly discovers that she and Ethel are the only Christians on board and David, as a Muslim, is very hesitant to be involved in a Christmas party. She calls a staff meeting and they agree to a small Christmas party for those who want to participate, a New Year's party, and a series of movie nights.
Date: Late Dec. 2035

5. Arrival 61

Columbus 1 aerobrakes into orbit around Mars. While they wait for the dust storm in the Marineris Valley to clear, Will and David try to free a drill on Phobos, but the drill cable breaks instead. The crew plans a side trip to Phobos to fix it.
Date: Jan. 28-Feb. 2, 2036

ore. Will and Laura have a private talk and she agrees to apologize to David for accusing him of recommending *Gone with the Wind.* He accepts the apology. The next day, three automated cargo landers begin to arrive.
Date: April, 2036

13 Birthday 166
The crew unload the three new automated cargo landers and debate the order that they would set up everything. They decide to start with the chemical synthesis unit, move on to the metal carbonyl unit, and end with the sunwing, an aircraft with solar panels covering its immense wings. Ethel bakes a cake for Will's 35th birthday, surprising him.
Date: May 2036

14 Sunwing 178
Four team members explore ¾ way up Little Colorado Canyon, using a sunwing to relay communications from the deeper sections. Laura and Sergei have a big fight and break up, rupturing social relations in the Outpost. Sergei moves to Habitat 2. To reduce the appearance of rupture, David moves as well.
Date: late June, 2036

15 Breakthrough 188
An article in the *Washington Post* about the social tensions among the Columbus 1 crew forces the crew to discuss their differences in intimate detail. Laura and Sergei patch up some of their differences. David and Laura lessen their tensions somewhat. Ethel confesses she is in love with Will. The next day when work resumes, Will and David are exploring Gangis Chasma via a Prospector telerobotically operated vehicle and spot tiny black spheres in a carbonaceous shale that might be fossils.
Date: early July, 2036

16 Fossil 207
On the eve of the arrival of a sample from Gangis Chasma (by sunwing) a graduate student on Earth, examining images of samples earlier collected, discovers a fossil in a rock found at the Outpost. Will and David confirm the discovery. When the sunwing brings the sample from Gangis, the team devotes several days and nights to its analysis. They speculate that a trip to Gangis will be necessary. Will and Ethel talk about their relationship and agree they cannot marry.
Date: mid July, 2036

17 Conjunction 218
The crew spends conjunction doing relatively little work but planning how they will spend their remaining time on Mars, including their first major expedition across the surface. Ethel's mother has a heart attack and dies; everyone rallies to support her. Will proposes building an overlook on top of Boat Rock in her mother's memory.

Date: late Oct. 2036

18 Gangis 231

Three crew members spend November on a trip to the mouth of Gangis, then December reviewing the samples; January penetrating into Gangis almost to the outcrop of fossiliferous shale; February reviewing their work and analyzing the samples; March driving completely around the lake deposits filling central Gangis and collecting a tonne of fossiliferous samples. Will returns from the third trip thrilled with his work on Mars. He suggests to Ethel that they get married and stay on Mars. She agrees. She asks Shinji whether he'd like to stay and he agrees. They inform the other three crew members.
Date: Nov. 2036-Apr. 1, 2037

19 Decisions 249

They decide not to tell NASA about the wedding plans and just make the request to stay. The request is scrutinized very closely; then NASA listens to audiotapes of conversations in the Great Room, finds out about the wedding, and demands to know what is going on. They explain why they want to get married. Rather than decide, NASA decides to leak the plan, knowing public opinion would force their hand.
Date: early April, 2037

20 Wedding 264

Will returned from the chaotic terrain of southern Aurorae and Ethel shows him the apartment she built for them in Habitat 1's attic. They get married.
Date: early June, 2037

21 Blastoff 274-76

The six exchange goodbyes, then Laura, Sergei, and David blast off for Mars orbit, where they rendezvous with an ITV and head for Earth.
Date: June 20, 2037

Equipment

Project Columbus is named for the explorer of the Americas and is conceived as an international effort to land people on Mars in order to set up an outpost from which the Red Planet can be explored and studied. The plan assumes (1) the use of expendable rockets capable of launching about 24 tonnes to low earth orbit such as the Ariane 5, Delta IV Large, and the Angara (this is the capacity of the Space Shuttle as well); (2) solar powered ion-propulsion vehicles capable of lifting cargo to (3) Gateway, an occasionally staffed space station located at the Lagrange Point (L1) between the Earth and the Moon; (4) chemical propulsion from Gateway to the lunar surface and Mars; and (5) use of hydrogen and oxygen propellant derived from the permanently shaded regolith at the lunar south pole. It assumes that the moon will be visited first, Mars second. The plan derives its ideas from various authors, but especially from Michael Duke's "A Lunar Reference Strategy" (which was once located at http://members.aol.com/dsportree/MM22.htm) and from a recent proposal from NASA's NExT Team proposing a station at L1 called Gateway (see http://www.space.com/news/beyond_iss_020926-1.html). It assumes technology available near term (i.e., extrapolations of existing technology). One feature is the reusability of the principal transportation elements. Another is use of solar power instead of nuclear power.

1. SOLAR-ELECTRIC VEHICLE ("Ion Tug"), mass 8 or 9 tonnes

High-efficiency (30%) solar panels (1,200 square meters, 400 kw), ion engine (Isp, 3,000 seconds), avionics, etc.	3.5 tonnes
Tank	1 tonne
Propellant (xenon)	3.5 to 4.5 tonnes

Note: Deep Space 1 had a 2.1 kilowatt solar array and generated 4.5 km/sec of delta-vee by expelling 81.5 kg of xenon over 20 months. The spacecraft had a total mass of 486 kg and the ion engine a specific impulse of 3,000 seconds. Scaling up the solar array 200 times, 29 tonnes could be pushed to 3.2 km/sec in 5.8 months using a 400 kilowatt array. The ion engine would consume possibly as much as 4 tonnes of propellant. If 4.5 tonnes of propellant were available, 0.5 tonnes would remain to return the ion engine to low earth orbit for reuse.

I have no way to verify the mass of the engines and solar arrays except to note that Michael Duke said an 8-tonne solar-electric vehicle could push 16 tonnes of cargo to the Lagrange point, and one can verify the mass of propellant necessary, assuming a specific impulse of 3,000 seconds (the Isp of Deep Space 1) and assuming 50% gravitational losses. I have scaled up Duke's vehicle about 20% because they described 24-tonne launches that always included a reusable solar electric vehicle, and did not discuss subsequent launches when the vehicle was already in orbit.

The SEV panels, ion engine, and avionics are launched first. Subsequently, the 24-tonne booster launches 4.5 tonnes of propellant and tanks and 0.5 tonnes of solar panels (to replace panels on the SEV that have degraded), and 19 tonnes of payload (half of which can be landed on Mars). If lunar-derived fuel is available at Lagrange 1, the payload could include as much as 14 or 15 tonnes destined for the Martian surface.

2. AUTOMATED CARGO LANDER (ACL), mass 19 tonnes (launched from Earth with 5 tonnes of ion engine propellant to push it to Gateway)

Cargo:	14.5 tonnes
Structure, engine, tanks, legs, avionics	1.0 tonnes
Aeroshield	2.0 tonnes
Chemical stage	1.5 tonnes

Propellant for trans-Mars injection (TMI) and for landing (6 tonnes) comes from the moon or Phobos and is supplied to the ACL at Gateway. ACLs follow a minimum-energy Hohmann trajectory to Mars.

Delta-vee, Lagrange 1 to Hohmann transfer orbit, plus course corrections: 0.8 km/sec (mass ratio, 0.25:1 for methane)
Delta-vee, Mars landing: 0.8 km/sec (mass ratio, 0.25:1 for methane)

Note: NASA is currently developing a standard “platform” for landing scientific packages of up to about 1 tonne on Mars called the “smart lander.” The ACL could be a fifteen-fold expansion of that vehicle.

Once an Outpost is well established on Mars the ACL is phased out in favor of the ACV (next), because the Mars Shuttle can deorbit the cargo.

3. AUTOMATED CARGO VEHICLE (ACV), mass 19 tonnes (launched from Earth with 5 tonnes of ion engine propellant to push it to Gateway), reusable

Cargo:	14.5 tonnes
Structure, avionics	0.5 tonnes
Chemical Stage	1.5 tonnes
Aeroshield	2.5 tonnes (15% of total)

Propellant for Trans-Mars Injection (TMI) (5.0 tonnes) comes from the moon or Phobos. Propellant for Trans-Earth Injection (TEI) (up to 10 tonnes of LOX/methane) comes from Phobos. Since the ACV is reusable, it can fly up to 15 tonnes of cargo back to Earth orbit (if such cargo is available, such as water from Phobos or geological specimens).

4. INTERPLANETARY TRANSIT VEHICLE (ITV), mass 16 tonnes

Cabin structure	4.0 (1 tonne more than ERV cabin)
Life support system	2.0 (1 tonne more than ERV cabin)

Consumables	3.4* (for six months only)
Electrical Power (10 kw)	1.0* (assumes more powerful solar arrays)
Reaction control system	0.5*
Computers	0.1*
Furniture and Interior	0.5*
EVA suits	0.4*
Spares and Margin	2.3 (0.1 tonnes more than the Mars Direct ERV, to make the total 16 tonnes)
Aeroshell	2.4 (0.6 tonnes heavier than Mars Direct)

(* = numbers from ERV in Robert Zubrin, *The Case for Mars*, p. 92)

The ITV is about half way between the Mars Direct's Hab and its ERV cabin in mass and volume. It is a cone with a 6-meter basal diameter and a height of 13 meters. It has five floors with 28, 23, 16, 9, and 3 square meters respectively (total, 79 square meters). Its interior volume is about 183 cubic meters. The base is covered by a heat shield ten meters in diameter. Its long, thin shape is ideal for rotation to produce artificial gravity when docked to a Mars shuttle or to another ITV.

The ITV can be launched into low earth orbit with an 8-tonne ion tug plus fuel that pushes it to Lagrange 1 over six months, or it can be launched with 3 tonnes of extra consumables (for the surface) and 5 tonnes of ion engine propellant if an ion tug is already orbit. A Mars shuttle pushes it to Mars. The Mars shuttle and ITV remained docked and serve as a counterweight to each other for the generation of artificial gravity. The ITV aerobrakes into a high Mars elliptical orbit and remains there untended for eighteen months. The crew returns from Mars and heads back to Earth using fuel manufactured on the Martian surface. The ITV aerobrakes into Earth orbit, is refurbished and resupplied (it needs perhaps 5 tonnes of new stuff for each flight), and is flown back to Mars two years later.

The novel *Valley of the Dawns* assumes use of two ITVs on each flight to Mars. Gateway Station is assumed to be an ITV as well.

Delta vee from high Earth orbit to fast trajectory to Mars: 1.2 km/sec (mass ratio 0.33:1 for LOX/LH2, 0.4:1 for LOX/ methane)
Delta vee from high Mars orbit to fast trajectory back to Earth: 1.5 km/sec (mass ratio 0.5:1 for LOX/methane)

Some ITVs are accompanied by a Docking Cube, a cubical structure two meters in diameter with a docking port on each of its six faces. Its total mass is one tonne and it allows up to six vehicles to dock together. The cube allows large complexes to be flown to Mars including up to four ITVs and two shuttles.

Note: Various stripped down versions of the ITV are possible since the structure is only 4 tonnes, life support 3 tonnes, and other essential features 1 tonne. Thus two stripped down ITVs could be flown to Mars to provide additional housing on the flight out and

could be left on the moons to provide emergency shelter. Later they could be refurbished and flown back to Earth if needed.

5. MARS SHUTTLE (MS), a reusable spacecraft (up to five reuses before refurbishment), initial mass 17 tonnes

Crew Module	4.0
Tanks, engines, landing equip.	7.5
Aeroshell	5.5

The Mars shuttle has a 6-meter basal diameter and is 15 meters high (two meters longer than the ITV).
The Mars Direct Earth Return Vehicle's structure weighs 4.5 tonnes (*The Case for Mars*, p. 92) and contains about 98 cubic meters of fuel storage volume. The Mars shuttle's tanks are scaled up 70%; they occupy 170 cubic meters and weigh 7.5 tonnes. The vehicle also includes a 75 cubic meter cargo compartment (6 meters in diameter; 3 meters high; 28 square meters of floor space) in its base, above the engines and below the fuel tanks. A ramp gives access to the ground.

The crew module can be placed in the cargo compartment if the vehicle is to be flown with crew. For details, see crew module below. The crew module has space for some cargo.

The 5.5-tonne aeroshell is sized for aerobraking up to 40 tonnes into Martian orbit (17-tonne vehicle including crew module, 9 tonnes cargo, 13 tonnes landing fuel without parachute; 17-tonne vehicle, 15 tonnes of cargo, 8 tonnes of landing fuel with parachute; 17 tonne vehicle and 23 tonnes of cargo if fueling is available in Mars orbit). It can also aerobrake 40 tonnes into Earth orbit. Using incremental aerobraking, it can aerobrake heavier loads into Mars orbit.

Landing delta-vee with parachute system: 0.7 km/sec (mass ratio 0.25:1 methane)
Cargo capacity (down): 16 tonnes

Landing delta vee without parachute: 1.5 km/sec (mass ratio 0:5:1 for methane)
Cargo capacity (down): 15 tonnes

Delta-vee to ITV or to Phobos from Martian surface: 5.4 km/sec (mass ratio 3.5:1 for methane)
Cargo capacity up: 20 tonnes (fuel needed by Mars shuttle and ITV for trans-Earth injection)
Fuel consumption, up: 130 tonnes
Delta-vee to low Mars orbit: 4.2 km/sec (mass ratio 2.1:1 for methane)

Note: The Mars Shuttle always lands with a parachute the first time. If the parachute cannot be repacked and reused, subsequent flights require a landing delta-vee of 1.5 km/sec. Subsequent flights are dependent on use of Martian water to make fuel.

To make 150 tonnes of LOX/methane on Mars (130 for the flight to the ITV and 20 to push the shuttle and ITV back to Earth) requires 7.5 tonnes of liquid hydrogen and about 50 kilowatts of power over two years (about 75 kilowatts over 18 months).

Once sufficient water becomes available on the Martian surface (at least 30 tonnes per year) the 8 tonnes of feedstock hydrogen flown up from Earth is replaced by cargo.

The Mars Shuttle carries the crew from the ITV in high Mars orbit to the surface and returns them to the ITV eighteen months later. The Shuttle brings up the 20 tonnes of fuel necessary to push both vehicles back to Earth. Back at Earth, the Mars Shuttle can be refurbished for reuse.

The novel *Valley of the Dawns* assumes that two shuttles and two ITVs are flown to Mars each time and one is left as backup at each planet. This increases the crew flown and makes the mission safer. Subsequent Columbus missions can fly three ITVs and Mars shuttles, or four, etc.

6. MARS SHUTTLE CREW MODULE (CM), mass 4 tonnes

The crew module is an inflatable structure that occupies all of the Mars shuttle's cargo compartment (28 square meters, 84 cubic meters; ¼ the size of the Mars Direct's hab, half the size of Mars Direct's Earth Return Vehicle cabin). It has one side where all its equipment (electronics, stove, toilet, airlock) is located. The rest of the structure can be deflated and pressed against that side, so that it can be removed from the cargo compartment (furniture and possessions must be removed first). Some cargo can be stuffed into the crew module as well.

Note: the CREW MODULE does not have a heat shield and thus has no abort capacity.

The CREW MODULE is normally meant for 2-4 weeks of use, but in an emergency, with the proper supplies, can be used for six months.

7. LIFTER and related vehicles, typical dry mass 4 tonnes

Tanks, avionics	3 tonnes
Propellant (LH2/LOX)	24 tonnes max
Propellant (methane/LOX)	54 tonnes max
Landing package (optional)	0.5 tonnes
Aeroshield (optional)	1 tonne

Dimensions: 5 meters diameter, 4 meters long

The Lifter consists of a stage launched from the Earth on an expendable booster with a total mass of 24 tonnes including fuel. It may be launched with a kit containing landing

legs, or the kit may be launched separately and attached to the stage in orbit. It can also be outfitted with a folding aeroshield (minimum mass, 1 tonne) for incremental aerobraking to low earth orbit or Mars orbital capture. It operates from low earth orbit, Gateway, the moon, Phobos, or Deimos. It can use either hydrogen or methane fuel. The engines can be reused ten times.

Launch capacity to Mars (LH2/LOX, Hohmann): 68 tonnes plus itself; 66 tonnes with return of the Lifter to Gateway.
Launch capacity between Gateway and lunar surface (24 tonnes fuel): 24 tonnes
Launch capacity, lunar surface to Gateway and back with maximum downward cargo: 12 tonnes
Launch capacity from low Earth orbit to Lagrange with 15 tonnes of LOX/LH2: 8 tonnes

8. INFLATABLE MARS HABITATS, diameter 12 meters, height 7 meters. The habitat is shaped like a flying saucer; the central section is a cylinder 12 meters in diameter and 2.2 meters high with hemispherical top and bottom caps up to 2.4 meters high each. Floor area of the main level: 113 square meters. The basement and attic levels have about 55 square meters each with adequate headroom. Their crawl spaces (another 58 square meters each) are used as storage areas.

Structure	10 tonnes
Life support	3 tonnes
Equipment, furniture	1 tonne
TOTAL	14 tonnes

The Mars Direct's hab has a mass of 9.5 tonnes (structure, 5.0 tonnes; life support, 3.0; lab equipment, 0.5; furniture and interior, 1.0) and a floor area of 100 square meters. The Mars Direct's Earth Return Vehicle cabin has a mass of 4.5 tonnes (for the same items) and probably has a floor area of about 50 square meters, but has life support equipment (1 tonne) for only six months. The Habitat is about twice the size of the Mars Direct Hab, so its structure is double, but life support equipment weighs the same.

The Habitat houses at least 6; 8 in an emergency. If the upper and lower levels are used, it can house 10-12.

9. GREENHOUSE, mass 4 tonnes

A greenhouse is an inflatable transparent structure of Kevlar or other tough, transparent plastic, 8 meters wide and 22 meters long, 180 square meters in surface area (because the floor is bowl shaped), with plastic or metal trays covering the floor and filled with treated Martian soil in order to raise crops. It has airlocks at each end. At night a thermal blanket covers the inside of the arched transparent surface to hold in heat. At dawn the thermal blanket on the eastern side is lowered to admit sunlight; the thermal blanket on the western side has a silvered inner surface to reflect horizontal solar rays downward onto the crops. During midday the thermal blankets are removed from both sides. In late

afternoon the thermal blanket on the eastern side is raised and its silvered inner surface reflects the western rays downward onto the crops. By capturing solar energy that the plants would have otherwise missed, total solar insolation is raised to levels similar to those found on the Earth's surface.

Each greenhouse should be able to treat the wastes and feed about two people.

10. SOLAR POWER ARRAY

Each automated cargo lander is accompanied by two rolled up solar power arrays 4 meters wide and 32 meters long, having a mass of 500 kilograms, and capable of generating an average of 6 kilowatts of continuous power. After landing, a remotely controlled rover clears boulders from the path of the array; a ramp is lowered to provide the array a way to the ground; then a pump inflates a hose in the array with Martian air, causing the hose to stiffen and unroll the array. Every lander comes with a 1,000 meter, 200-kilogram power cable that the remotely controlled rover can pull to the nearest lander, thereby plugging them together. The rover can also blow eolian dust off the arrays periodically to keep them clean.

11. SOLAR POWER UNIT

The solar power unit is a transparent plastic cylinder 32 meters long and 30 meters in diameter. Half of the diameter of the cylinder is silvered; the cylinder rolls on the ground to keep the silvered side opposite the sun so that the reflected sunlight falls on high-efficiency (32%) solar arrays on the opposite side of the cylinder. The arrays are 3 meters wide and receive 10 times the usual Martian level of insolation on them, which heats them to as much as 150 centigrade. The solar panels have a network of tubes running across their backs through which compressed Martian air is blown to extract the heat. The 960 square meters of surface area intercept 480 kilowatts of solar energy, producing 150 kilowatts of electricity and 150 kilowatts of thermal energy. Total mass, 1 tonne.

12. MOONLET FUELING PLANT

The Moonlet Fueling Plant (MFP) is designed to extract volatiles from the chondritic bedrock of Phobos and Deimos, process them into hydrogen/oxygen and methane/oxygen fuels, liquefy them, and store them. It is designed to be landed on the moons, ready to deploy. The initial system includes a 1.5-tonne docking pad (in the center of its flat top), two 1-tonne drills (deployed on opposite sides of the pad, and able to swing outward a meter from the pad), a 1-tonne volatile processing plant (built into the base of the pad, including a sabatier reactor, electrolysis unit, cryogenic refrigeration unit, and a fractionation tower), 2.5 tonnes of solar arrays, and two 0.5-tonne rovers. The plants are accompanied to Mars by the lunar-based vehicles that propelled them from Lagrange.

The system lands on the moon near the equator on the side facing away from Mars (the poles do not receive perpetual sunlight; the side toward Mars suffers from regular solar eclipses). The lander sinks harpoons into the regolith using bursts from the reaction control system to keep the lander against the surface. The arrays are like the ones deployed on the Martian surface, but are longer; they unroll and are able to generate 30 kilowatts of power. The two drills deploy and drill up to 100 meters into Phobos. A microwave generator is lowered down each shaft to heat the chondrite bedrock, causing it to break down and release water vapor and possibly carbon gasses. The water vapor rises up the shaft and is captured, electrolyzed, and stored; some of it can be injected back into the shafts later to heat the chondrite further. Excess oxygen injected into the shaft will react with the carbon-rich rock to make carbon dioxide; excess hydrogen will react with it to make methane. The super-cold temperatures inside Phobos (way below the freezing point of water) will cause water to freeze up cracks in the regolith. The fuel production complex should be able to generate as much as 60 tonnes of fuel per year (less, if there are leaks from the shaft or other inefficiencies). The two rovers can explore Phobos as well.

Once the Lifter docked on top is full, it can take off (gently, so as not to damage the unit) and fly to the ITV or anywhere else it is directed to. Full deployment of the fueling system may require astronauts.

13. SUNWING (Solar-Powered Flying Wing), 825 kg

The Sunwing is based on the already-flying Helios, a 700-kg solar-powered airplane which has flown to 100,000 feet on Earth (where the air is as thin as the Martian atmosphere).

Mass: 825 kg without payload
Wings: biwings 270 square meters area, 60 meters long and 2.25 meters wide, 3 meters apart, staggered horizontally by 1 meter
Solar output (40% efficient panels): 1,200 kilowatt-hours per sol
Wing mass: 2.5 kg/m^2 = 675 kg
Propellers and motors: 100 kg
Other: 50 kg
Payload: 450 kg (includes energy storage system)
Two energy storage systems in use:

1. methane/oxygen fuel cells with small VTOL rockets (total mass, 250 kg), OR
2. CO_2 tank, rocket engines, beryllium heater [2000K, Isp 200 seconds], 100 kg; liquid CO_2, up to 200 kg (delta-v, 0.35 km/sec = 1,260 kmph, enough to glide several hundred kms). Vertical takeoff/landing capability with either system.

Typical speed; 30 km/hr (without help from winds). The sunwing has to be assembled by astronauts on the surface because of the immense size of the wings.

14. BUGGY (400 kg)

The buggy is an open rover about the size of a golf cart, able to transport two side by side plus some cargo behind them (a space that could accommodate two others in an emergency). It has four wheels, each powered by its own electric motor. Several fuel cells are built into the chassis; oxygen and methane tanks are mounted under the rear cargo platform. It comes with an optional plastic top.

15. RANGER (2.5-4.0 tonnes)

A ranger is a six-wheeled vehicle rather like a small terrestrial truck. It comes equipped with bulldozer blade (0.25 tonnes), rear-mounted manipulator arm (0.05), rooftop crane (0.4), provisions (150 kg per person per month), internal fuel storage (0.5). Ground clearance: 0.8 meters. The vehicle comes with a frame of solar panels able to be raised 2 meters off the roof and able to generate 20 kilowatt-hours of electricity per sol, enough to run the life support at emergency levels. Dimensions: 2.5 meters long, 2.4 meters wide, 2.0 meters high (interior). Rangers utilize methane/oxygen fuel cells built into the chassis. Each wheel has its own electric motor and regenerative braking system. The system requires 0.25 to 0.5 kg of LOX/methane per kilometer per tonne of vehicle. A ranger normally can support one person, but can keep two alive in an emergency.

16. PORTAHAB (4 tonnes empty mass)

The portahab is a wheeled habitation unit the size of a small recreational vehicle or camper that must be towed by a ranger or (in an emergency) a buggy. It can accommodate two persons. It is 2.4 meters wide, 2.4 meters high, and 4 meters long. From front to back it has:

1. Central cabin, 3 meters long, with dinette (table and chairs on each side) on left side followed by sink and stove; on right side, a couch that became bunk beds for two and storage closets. Under the couch is the life support equipment. The front wall contains a hatch 1 meter wide and 1.5 meters high that can be docked to a ranger or other vehicle via an airtight flexible tunnel that can also serve as an airlock.

2. Water cabin, 1 meter long, with a shower on the left, access corridor in the middle, and toilet/sink on the right side. A sliding door blocks the corridor. From the corridor, one must step up 0.8 meter to enter either the shower or the toilet/sink areas; the underfloor space is graywater storage and purification and life support. The corridor ends at an emergency door 1 meter wide and 1.5 meters high to the outside in the rear wall. Door comes equipped with a 0.8 meter telescoped pressure sleeve for connecting to another vehicle. A portable dustoff facility is attached to the rear of the vehicle as well.