

*The Lunar Frontier*

*Vol. 2*

*Exploring the Moon*

Copyright © 2014 Robert H. Stockman

All rights reserved

[rstockman@usbnc.org](mailto:rstockman@usbnc.org)

## Table of Contents

1. Back to Houston	2
2. Northstar 5	18
3. Making Changes	33
4. Back to the Moon	44
5. September	57
6. Aristarchus	70
7. Tourists	86
8. Northstar 6	102
9. Shackleton	112
10. Gryphon	130
11. Planning	139
12. Rocking the Boat	155
13. Two Steps Forward and One Backward	171
14. Birthday	191
15. Schroedinger	198
16. Canaveral	213

1.

Houston

Friday, 4 January 2030

She was still so incredibly beautiful.

Lurleen waited for Will at the bar, every black hair on her head in place, a tight-fitting, low-cut canary-colored dress highlighting her smooth, olive skin and accentuating her ample bosom, a perfect application of makeup making her brown eyes and lips bright. Will stared a moment and his feelings for her flooded back. Not that they would do any good.

“You made it,” she said, standing up. “Thanks for the text saying you’d be late. When did you arrive?”

“I just drove in this moment; I haven’t been to the house yet. It took several hours longer to drive here from Providence than I thought, because of the snow storm hitting the Carolinas.”

“You drove, rather than flew? Well, I guess you had to, if you wanted a car and a lot of your stuff.”

“It was easier. Let’s get a table.” Will turned to a waiter nearby and he led them to a table nearby.

“A drink?” she asked him, waving her martini at him.

“Lurleen!”

She laughed a little. “You won’t have a drink, even when you’re dealing with a divorce.”

“No, I’ve never developed the need.” He turned to the waiter and ordered a Diet Coke with a twist of lemon. “So, where are you staying? The house?”

“No, I have a room at the Hilton. I’m here on state business anyway, so they’re paying. You can stay at the house. We agreed to continue splitting the bills through December 31. I take it you paid the January mortgage?”

“Yes, I checked the account last week and saw you had indeed stopped your transfer of funds, so I transferred enough to cover the January bills. I’ll pay from now on. My goal is to move into an apartment on February 1 and have the house on the market at that point. The real estate people say it should sell pretty fast.”

“I’ve already moved out everything I want. You can do whatever you want with the furniture. So, are you going to buy a condo?”

“I don’t know yet. Probably; if I’m traveling, there’s no reason to have to worry about lawns and such. I’m surprised I haven’t gotten divorce papers yet.”

“Your lawyer will get them next week, and they’ll be routine, just like we agreed; a clean 50-50 split.”

He sighed. “Alright. When are you marrying Tad?”

“Maybe April; we’ll see. He wants to settle down and help raise kids. He has no plans to travel more than a dozen miles from Austin; certainly nothing like going to the moon. This will be much better for me. I know you never would have given up being an astronaut to be with me.”

“You never asked me to give it up, either. I still don’t understand why all or nothing was necessary. I’ll be making another six-month flight and after that I’m pretty sure four-month flights will be possible. Within a decade, three-month missions will be possible. That’s a long separation, but not impossible. Many families do it, especially with all the nannies available down here.”

“I don’t want a nanny for my children, I want a father! We talked about that, too, Will.”

“I guess you’ll have that, now.”

“I hope so.”

He looked at her. “You hurt me a lot, you know.”

“I suppose that was inevitable. Maybe we never should have gotten married.”

“Maybe not. But it isn’t just that: it’s the infidelity, Lurleen. I trusted you.”

She didn’t reply right away, but thought a moment. “I don’t live in the same world you live in, Will. In fact, most people don’t, even in Texas.”

“I’m not so sure about that.”

“So, when are you going to the moon again?” she said, changing the subject.

“I don’t know; I’ve put in to be on the active list. They announced Northstar 4 several months ago. The soonest would be Northstar 5 or 6. I figure I need a year to digest, organize, and publish the results of Northstar 2.”

“What were you doing in Providence?”

“Digesting, organizing, and writing, when I wasn’t teaching a delightful seminar with some very bright graduate students eager to learn lunar geology. Several worked on aspects of the research and we’ll be coauthoring papers. I wrote 4 or 5 papers myself, and I’ll be coauthor on a dozen more, though some of those have as many as 20 authors.”

“So, you’re still the Moonman.”

“I guess. I don’t like being called that.”

“What? Of course you do!”

“Sometimes it’s used ironically. That’s probably how you just used it. Jerry McCord, the commander of Northstar 2, used it that way constantly.”

“So, you never contacted my parents when you were in Providence?”

“No. I would have enjoyed seeing them, under normal circumstances, but I didn’t want to talk against you, Lurleen.”

“I appreciate that.” She nodded; she really was appreciative. “So; no girlfriends in Providence?”

He shook his head. “No, I’m still a married man.” He held up his left hand, so she could see his wedding ring. He had noticed that she had taken hers off.

“Well, you’ll be free from me soon.”

“I know, and I am very saddened, because I . . . I still love you, Lurleen.” His voice broke when he said it.

“I love you, too, Will, in many ways. You’re a really remarkable man. But we aren’t meant for each other. I’m sorry. It’s as simple as that.”

“I see. And you aren’t sorry for cheating on me?”

“I’m . . . sorry for that, too.”

“Thank you, that’s something.”

She nodded and downed the rest of her martini. “I should get going. Do we have anything else?”

He looked at her and shook his head. “I don’t think so.”

“I don’t think so, either.” She rose. “Goodbye, Will.”

He gave her one last, longing look. “Have a good life, Lurleen.”

“Thanks, you have a long and successful life, too.” She turned and walked out of the bar.

Will watched her go, not sure whether to cry or be angry. He downed the last drops of soft drink and paid the bill. As he walked into the parking lot, he saw a car driving out with Lurleen in the passenger seat. Tad was behind the wheel.

-----

He had the weekend to settle back into his house—alone—and call a few people to tell them he was back. He called Roger and Madhu Sunday afternoon—after church, so they couldn't invite him—and went to see them. Monday morning he headed for the Northstar Command Center. Mission Control and some offices were on the top floor, TROV controls on the first floor, and various support services, such as a cafeteria, were in the basement. After checking upstairs and letting the boss know he was back, he came down to the TROV area.

The operations center for TROVs—teleoperated rovers—had been doubled in size, with stations to run twelve at a time. A few weeks earlier a lander had deployed three of them at Aristarchus and they were being run 24 hours a day by three shifts. Another cluster, at Proclus and Mare Crisium, were shut down because the sun had set, leaving their solar panels impotent. Two others had accompanied an expedition to Lacus Somniorum and were being operated at that moment to support the three-member team on the moon. Will walked over and watched. Soon he was chatting with the lead geologist at Lacus Somniorum—Hillary Crabtree—about the site and recommending some items to examine.

The astronauts were just about ready to take a break when Larisa Tatarinov walked into the TROV control area. “Hey, Will! You're back!”

“Friday night. How are you, Larisa?” He gave her a hug; they had become friends on Northstar 2.

“Really well. At the moment I'm working with the Martian Prospector-400s.”

“Really? Very interesting. Does that mean you aren't going back to the moon?”

“No, I'm still on active duty in the Cosmonaut Corps, but I'm assigned here for nine months to participate in the work and to assist in the transition; Moscow State University has the

operational contract for one TROV starting in September. Zeke Swift likes to keep all the parties involved; they're more likely to give money."

"That makes sense, and he gets free labor as well!"

"He does. How was Providence?"

"Great. I really enjoyed teaching and the peace and quiet I had to organize notes and write."

"I'm sure you got a dozen or two papers written."

"Almost. When did you get here?"

"Early November; I took two months off. I'm here through early May. So, are you and Lurleen divorced?"

"No, but it's a matter of weeks now."

"I see. Well, if you want to go out, let me know; I'm available." She smiled. "I really admire you, Will."

"Thanks, Larisa. I need to grieve a while, if you know what I mean, before getting to know anyone. But we can always have lunch here in the cafeteria."

"Alright, that'll work out." She smiled, but couldn't hide her disappointment.

Just then Jerry McCord walked in. "Will, you're back from Brown University! I see you drove a TROV from up there, too!"

"Yes, every week for a few hours; I wanted to keep in practice, and I needed to check a few things. I think we have some very interesting correlations between the thickness of volatile accumulation, the temperature, and the length of time since impact disruption for the North Polar cold traps."



“Excellent, I know you’ve been working on that problem for a long time. If you want to work on TROVs here, let me know and we can assign you time. But it’ll have to be during third shift, for now; the other guys have seniority.”

That surprised Will. He was tempted to point out he had more hours operating lunar TROVs than most of the personnel there that day. “Okay, Jerry, I’ll let you know. Probably several hours, two or three days a week; I’m still wrapping up the research from Northstar 2.”

“We did a lot, didn’t we? Alright, let me know.” Jerry walked away.

Larisa scowled at Jerry after he was gone. “He wasn’t very cooperative.”

“He still has a grudge against me, I guess. Seniority! I think I have some of that!”

“You sure do! Come see the Mars TROV control area.”

“Okay.” Will followed her out the room and into a control area across the hall. It was pretty small; it had just three control stations. The room next to it for controlling the lunar water harvester-transporters was much larger.

“Looks pretty standard. What was this space before; an office?”

“A Project Redstar office. Swift is leasing a building about half a mile away for Project Redstar, because the spaceflight center is refusing to contract with him.”

“Politics.”

“It’s ridiculous. I may get to Mars because Russia will partner with Swift; he’s working with us to develop a system for extracting volatiles from the chondritic bedrock of Phobos and Deimos. Meanwhile, my American friends will be stuck here!”

“That’s true. So, what’s the difference between a Prospector 400 and a Prospector 350?”

“Fifty kilograms! The chassis and wheels need to be heavier for Martian gravity and the solar power array is much larger; the 400’s have 12 kilowatt-hours of power available to them

per sol. There are improved instruments and they conserve power better. They're good pieces of equipment. They can travel about 250 meters per day all by themselves, stopping to analyze rocks as they go."

"That's impressive." He looked around the room, which was empty of people. "Are you driving all three?"

"No; two of them, at Aurorae and Aram. The third one, in northern Hellas, is in darkness right now. Ideally, there are three of us in here at any one time planning their movements as a team. One person can drive one quite well—one person can actually drive all three—but the team approach maximizes the geology return."

"Of course. I'll be glad to come help, sometimes."

"That'd be great. I'd enjoy the collaboration."

Will nodded, knowing she'd enjoy a lot more than that, but he had no intention to start dating any time soon; he was still hurting too much. Just then they both heard someone at the door and turned to see Zeke Swift himself enter.

"Good morning." He saw the guest and smiled very broadly. "Dr. Will Elliott, it's a pleasure to see you again."

"Thank you, Dr. Swift." The two men shook hands and Will realized how short Swift was; somehow he hadn't noticed before.

"So, do you like our modest TROV control area? It's a small start, but very important."

"Yes, it's great, and very important. I missed the construction of this facility, between my six months on the moon and my four months at Brown."

"Oh, is that where you went? Congratulations for all you did on the moon, Dr. Elliott. The greenery was an extremely important innovation; there's nothing trivial about it. So was

your decision to cook real meals; a very important step. And of course, getting to Mare Frigoris, then all the way to Plato; that's a truly amazing feat of exploration. Moving the original cryo unit prototype was a very clever innovation."

"That wasn't my idea. The expeditions were very much a collective success. The six of us weren't a perfect team, by any means, but we worked together reasonably well. I just hope we can continue to expand from our base at Peary."

"We have to. The next phase will involve landers, carrying rangers and a portahab, to any spot on the lunar surface. They'll explore outward and back for two weeks, then return to Peary. We won't be clearing trails any more, at least not for a while."

"With a two-week nightspan limiting our capacities, that makes sense."

Swift pointed to the TROV controls. "So, will you come drive a TROV some time? We have quite an assault underway on the Red Planet! These three TROVs were made for us in India; 20 million bucks each, and they did a great job. We charged five million dollars a tonne for delivery to Martian orbit and we had U.S., Indian, European, Russian, and Chinese spacecraft on board, in addition to our three TROVs and their landing systems, which total a tonne each as well. The Russians have landers on both Phobos and Deimos with sample return vehicles, so we anticipate getting samples from both moons in three years. The Chinese rover crashed, as I'm sure you heard; a shame, too, because it would have done some great science in Kasei Vallis. The US rover is exploring Holden Crater, operated from Cornell, of course. The Indian rover is also a Prospector-400; they build an extra for themselves. The rest are orbital probes. Mars is better known than the moon, ironically enough."

"I'd love to help sometimes. Mars fascinates me as well; it's sort of the middle case, where the earth and the moon are the end members of the spectrum. It had some amazingly

dynamic geology in its first billion years, and it may be the place to tell us how life originated on earth.”

“Exactly right, because the primordial soup didn’t get fossilized on Earth, but it may be preserved on Mars, along with proto-life forms.”

Will nodded. “It’s amazing to contemplate.”

“Would you be interested in the Redstar Project?”

“Perhaps. Right now, I gather there are political barriers, though.”

“Yes, that’s true; you’d have to resign from the Astronaut Corps and come work for me. But I’m hopeful we can reopen negotiations with NASA soon. I wouldn’t rule out NASA involvement in the project, or even NASA leadership in it.”

“That’s good news. It’ll be a sad day when a U.S. company leads the way to Mars and all the crew members are European, Russian, Indian, Chinese, and Canadian.”

“I agree, actually. At least our partnership with NASA has continued in the Northstar Project. I’m hopeful we’ll sign a contract for NASA to be in charge of Northstars 6 through 10.”

“Oh, that is good news! What about tourists?”

Swift nodded. “They’ll be going to the moon sometime next year, if all goes according to plan. Dr. Elliott, I’m curious; what future do you see for exploration of the moon and Mars?”

“Future? Well, I’m a scientist, not a fortune teller. But I see the Antarctic model as the way to go; establish a program, build a beachhead, and devote money long term for the study of the place, for the benefit of all mankind. That’s what we have at McMurdo and Shackleton in Antarctica.”

“Very true.” Swift smiled. “But that’s phase 1, don’t you think? Because these aren’t cold continents, but entire worlds, and homes of future civilizations. Phase 2 involves export of

resources to Earth or Low Earth Orbit. For the moon, that's water and other volatiles, maybe Helium-3 in the future, maybe metals and silicon someday if orbital manufacturing and solar power production get off the ground. For Mars . . . well, we still don't know, but it may be gold, platinum group metals, deuterium, argon, and possibly volatiles from Phobos and Deimos. Phase 3 will start some time during Phase 2, possibly even before it: the birth of children and the inauguration of families on the moon and Mars."

"If that's possible," said Will. "The gravity and radiation may make it impossible."

"That's true, it might. We don't know. But I am sure we will find out, in the next decade or two. Then there's Phase 4: self determination for the peoples of these places."

"And when will that happen? A century or two?"

"Who knows? The year 1776 came 169 years after the establishment of Jamestown. The key to everything is the cost of transportation. I think in the next decade we can get it down to \$500 per kilogram to low Earth orbit. If manufacturing and tourism there expand it'll be possible. With lunar propellant and fully reusable systems, we can get things and people to Mars for perhaps \$1,500 per kilogram. A person needs to arrive with several tonnes of equipment and consumables, so that means each new person costs five million dollars in terms of transportation alone; perhaps double that with training and purchase of equipment. That would mark the beginning." Swift pointed to the three TROV control stations. "So, where do you think we should set up our beachhead? Aram, Aurorae, or Hellas?"

Will was startled by the question. "They all have scientific advantages, but I don't know the sites geologically, so I can't say what they are. Aurorae can get you into the Mariner Canyons and out to Chryse easily, Aram is on a north-south route to Chryse or Argyre, and Hellas is very low, so the atmosphere is thickest. What about water?"

Swift shrugged. “Depends on whether you want it at the surface or you want to drill. None of them have it lying around; they’re too close to the equator. All of them have water if you drill at least 50 to 100 meters, and that’s not difficult technology with a human crew to supervise. I’ll tell you what I think: they are all about equally useful, so we should go with the most dramatic landscape, and clearly that’s Aurorae. A base doesn’t need to be on a boring plain.” He pointed to the TROV controls. “Anyway, you have permission to be part of the TROV control team any time. But remember, control will be from this room only through June. After that, it has been contracted out to universities in France, Russia, and Qatar. Alas, NASA wouldn’t pay, so no US universities are involved.”

“That’s a shame. Thanks for the access; I’ll give it a try. Right now I can use the lunar Prospector-350s only late at night!”

“That’s ridiculous; a man of your talent?” Swift shrugged and waved. He turned and walked out of control room. Will watched him go, wondering whether Swift was just flattering him. He certainly was being generous; he had a reputation for generosity.

Zeke Swift headed to his office on the third floor. He had half an hour before he met with the Administrator of NASA, Dr. Dorinda Stetson. She always wanted him to come to her office in Washington to finalize deals; he wanted her to come to his headquarters in Colorado instead; they had compromised on the Northstar Administration facility in Houston. Swift checked in with his team of assistants and lawyers, reviewed the contract again, then retired to his office for ten minutes of yoga to relax and clear his mind before heading to the meeting room.

Dorinda Stetson rose to greet the representatives of Swift Space Company as they entered. “Good morning!” she said, shaking hands with Swift and his assistants. “So good to see all of you again. It looks like we’re very close to a memorandum of understanding, too.”

“We certainly hope so,” replied Swift, sitting at the table, so everyone else sat as well. “Have you changes to make? We’re always interested in additional business.”

“Good. The memo specifies our administration over Northstars 6 through 10, but we’d like to add an option for Northstars 11 and 12. The missions are popular with the public; they have accepted Peary Station quite readily, with only a minimal number of people demanding that the money be spent on social programs instead.”

“I was hoping that would happen. No one demands that Antarctic exploration be stopped.”

“It’s also much less dramatic and is not covered by the media. But the price you want to charge us is \$35 million per astronaut per flight; \$70 million for two. According to published figures, that gives you a twenty percent profit. We want the profit to be ten percent and think that’s only fair because we helped guarantee some of the loans you needed to develop the system and gave you access to proprietary technology at a very good price. In return, you’re getting two more flights guaranteed, which helps the bottom line.”

Swift considered a moment. “Let’s have the memo of understanding specify that you are contracting for Northstars 6 through 12. Let’s make the options for Northstars 13 and 14. As you said, the public loves them. They’re doing excellent science and are a basis for considerable technological development. This is a long-term commitment to the moon, and if the US doesn’t commit, I will get commitments from plenty of other nations. Have you any idea how many nations are willing to pay \$35 million to have one of their citizens on the moon? Shouldn’t they be partnering with the United States, rather than with a private company, to go?”

“Yes, we agree, but we also don’t want the Chinese to be buying tickets. We’d offer an unlimited option into the future if we could shut them out.”

“But you already agreed that they could go to the moon as tourists, and we already have a signed contract with them to send two Chinese ‘tourists’ to the Lunotel next year. They won’t be going as taikonauts, but they will be going.”

“We’re asking you not to sign additional contracts to fly taikonaut tourists to the Lunotel.”

“I should add that they won’t be going on Northstar flights,” exclaimed Swift. “After Northstar 6, we plan to start a separate series of flights, titled ‘Polaris,’ for tourists. Demand appears sufficient for at least two flights a year.”

“We know about Polaris, but we don’t want official taikonauts at Peary. If a Shanghai businessman goes, we can’t object to that. No contracts with the Chinese government for Polaris flights either.”

“Polaris flights?” Swift pondered. “Alright, I’m willing to specify that in writing. That’s in return for a commitment through Northstar 12, an unlimited option to conduct at least three Northstar flights a year—that’s six American astronaut slots per year—and a 10% profit.”

“We can agree to that,” said Stetson, nodding. “With one additional option: that we don’t want a requirement to launch into low earth orbit on a Thunderbird after Northstar 12. The Lyra shuttle promises to be highly competitive; it’ll be able to launch twelve to Pax Hotel for \$33 million, the same price as a Polaris, but for twice as many passengers.”

“Fine,” replied Swift. “But I’ll have a new, expanded shuttle to LEO by then as well, and it’ll accommodate up to twenty.”

“Twenty? Impressive. Anything else?”

“That’s everything we have for Northstar.”



“Good. We would like to open another avenue,” said Stetson. “How much would you charge for a NASA mission to a near earth asteroid?”

“Using lunar water, a Polaris, a Thunderbird and a Thunderbird-H stage . . . The Thunderbird-H could be refueled at the L1 point to give you plenty of delta-v . . . we’d have to run an analysis. Do you think Congress would approve?”

“It’s quite likely because we’ve identified a potential threat. It’s only 11 meters in diameter, but even that size can do a lot of damage. We’ll give you a specific flight plan next month.”

“We should be able to give you a number within another month. So, how’s the Liberty launcher coming, in your estimation?”

Stetson looked at Swift, irritated. “How’s it coming, in *your* estimation?”

“I congratulate you for keeping it on time and convincing Congress to approve the huge cost overrun.”

“We’ll still price it at about \$2,000 per kilo, because we’ll write off the development costs. It promises to be quite innovative.”

“Yes, the wings, the new thermal protection system, the air breathing engines to Mach 5; very impressive. I congratulate you for that. You have quite a reputation for management, Dorinda.”

“Thank you; my engineering experience is a big advantage. Your three TROVs are doing well on the Martian surface, Zeke; congratulations on pulling off an historic multinational mission. I gather the Gryphon capsule has done very well in air drop tests.”

“Yes, the engines have worked flawlessly. We’ll be doing an unmanned test flight to the moon in 2031 and to Mars in 2033. It’s an impressive piece of engineering.”

“It is. If you’d just postpone your flight to Mars a few years, the Liberty launcher plus the Gryphon would be a very powerful combination.”

“I agree, they would be. But we’re going to Mars in 2035. And we really want American participation—NASA leadership—in Redstar 1.”

“That may be a discussion for another day,” concluded Stetson.

Will Elliott turned off the interstate highway past a glittering south Texas mall, drove down a busy four-lane road, crossed over railroad tracks, and entered a neighborhood of small, old houses. The faces went from white to brown and black. Several more turns and he arrived at a neatly painted, old house with a huge vegetable garden covering the lot next door. Children outside the house dashed inside shouting “he’s here!”

Will parked in front of the house and stepped out. Linda Newport came out of her house quickly, her long, gray braids bouncing up and down. “Alláh-u-Abhá, Will! Thanks so much for coming!”

“Glad to, but wow, I had no idea you drove so far when you come to Houston!”

“The new interstate helps a lot, but yes it’s a long way.” She pointed south, then north. “Five minutes from Mexico, five hours from Houston. How are you doing?”

“Pretty well. I’m sorry I couldn’t get down here in September, after the landing, but I was in Texas a total of three days.”

“I was sorry to hear about Lurleen. But you’re back now.”

“Yes, until I fly back to the moon, whenever that will be. It’s hard to believe Northstar’s launch was almost exactly a year ago. My house is on the market and I’ve moved into a nice condo, so I’ve got a place of my own now.”

“And a new car?” She looked at his Lexis.

“Yes, I decided for once I should splurge on myself. So, is everything ready?”

“Yes, all the plans are confirmed. Come on inside, there’s a big crowd waiting.”

“Alright.” Will followed his old friend into her modest house and was startled to find sixty people crowded into a tiny living room and dining alcove. Some were even looking in from the kitchen. Two thirds were children; many of the rest were local African American and Hispanic mothers.

“My friends, this is Will Elliott, an astronaut on Northstar 2!” exclaimed Linda. “We became friends about ten years ago when he was a young graduate student at Brown University and I was a member of the Providence Bahá’í community, finishing up my last years as a departmental secretary at Brown and contemplating where I would move for retirement. I didn’t see Will for quite a while until he settled in Clear Lake, by the Johnson Spaceflight Center, and we both went to an event at the Houston Bahá’í Center. When I heard he was going to talk again about space exploration, I went up to hear him and brought him several bags of dried herbs and dried tomatoes from our garden here, to make sure he had some good food on his flight. He took the bags to the moon and planted some of the seeds; that was the beginning of the ‘greenery’ they set up, which you may have heard about. When he took the bags, he promised to come down and speak some time, so here he is! From here, he’ll speak at the high school this afternoon to all the kids there, and at the Bahá’í Center tonight. So, we get him first! Let’s welcome him!”

Everyone applauded, and Will nodded in thanks. He moved to a blank spot where he could stand and everyone could see him. “Thank you, and thank you for your very warm welcome to me. I apologize to those who primarily speak Spanish; Mi español no es bueno. My mother’s mother, my abuela, was from Veracruz, and she spoke to my mother in Spanish often, and sometimes to me when I was very little, but I never learned much! My mother was part European American and my father was African American, so I am very happy to see such a diverse audience today. The Bahá’í Faith says we are the flowers of one garden, and what sort of

garden would it be if the flowers were all one color? The future of this world is a diverse future where people mix and intermarry freely. Today we are divided by borders, but from space you can't see the borders; all you see is land, sea, and clouds. The Earth is fragile; from space we can see that, too.”

Will paused to pick up a cloth bag he had brought in and pull out a small plastic bag. “Linda has already told you the story of our meeting last year at the Houston Bahá'í Center, where she gave me some organic vegetables and herbs, because she didn't want me eating ‘dead food’ on the moon. I brought those bags with me to the moon and a week after landing I was making some pasta. I pulled out some of the dried tomatoes for the sauce and saw the seeds, which I pulled out and put in a little bowl. I suppose the idea of planting them had occurred to me, subconsciously, but I didn't make an effort until after I came back from a trip southward from Peary Station—I should add that every trip is southward because it's located at the moon's North Pole!—and a colleague of mine, noticing the seeds had started to sprout, had watered them. So we planted them in lunar dirt—we call it regolith because it has no organic material in it, it consists only of ground up rock—added uneaten food to provide some organic material in it, converted some ammonia into nitrogen fertilizer, and pretty soon we had the ‘greenery,’ which would more or less fit in your bathtub at home! At that point NASA hired some experts to advise us and it became bigger and better. Right now, on the moon, Northstar 4 is setting up a greenhouse about the size of this room, which will be a beautiful addition to the station, because the moon has no plants on it at all.”

Will raised the bag. “And just before I left, I picked two dozen cherry tomatoes, which I brought home and dried. So I am returning Linda's gift with a gift of lunar dried tomatoes.” He extended his arm to her and she took it, startled. “I hope she can make a big pot of tomato sauce

and add them to it. That's what I did with the tomatoes she gave me. But more interesting for all of you, perhaps, is that some of the atoms in these dried tomatoes are lunar atoms. You know how we are all made of the dust of the Earth? Well, these tomatoes are made from the dust of the moon. I wish I could have brought back moon rocks for all of you, but I couldn't carry that much weight back! But if you eat a little tomato sauce made partly from these dried tomatoes, you'll have a little moon in you!"

Everyone laughed, a little nervously, at that thought. "Tell, you what," said Linda. "I'll make a big pot of spaghetti for the meeting at the Bahá'í Center tonight, and use these there!"

"It's safe to eat, right?" asked a boy seated nearby.

Will smiled. "Oh, yes, no problem! Atoms are atoms! We ate a lot of lunar vegetables, and they were very good!"

"So, what's it like to be on the moon?" asked another kid.

"Good, questions; I'd rather answer your questions. Where do I start? Well, if I were to do this on the moon—" Will jumped straight up about half a meter "—I'd hit the ceiling, because the gravity is only one sixth as strong, so you can jump six times as high. Peary Station has two ladder wells where there is a ladder connecting the top and bottom floors, and we used to stand there and jump up and down. It turns out that it's really good exercise for our bones, too; they need to feel the sort of stresses they feel on Earth or they get weak and thin, and jumping is perfect for them.

"The other big difference is the outside. The moon has no air, no rain, no clouds, no plants, no animals. You could even say it has almost no color; everything is black, white, or gray. There are shades of gray, and after a while you get sensitive to them; and if you pick up some reg—regolith, the crushed rock underfoot—it has crystals of various colors. You have to go

outside in a spacesuit to keep in our air and water, and you have to talk to people over radios because without air, there can't be sound. So the outside is perfectly silent, too."

"If you're at the North Pole, is it cold?" asked a girl.

"Yes and no. Where there's no air, there's no cold air, so you don't feel cold around you. But any place where the sun doesn't shine, the ground gets very, very cold; in some places on the moon at the bottom of deep craters, it's colder than on Pluto! In those places, our boots could freeze and crack, so we have to wear very special boots. Those places are very important, too, because over billions of years, the tiny bit of water and gasses that the moon has—sometimes because icy comets hit the surface—has frozen out in the cold places. There are places where there are a couple feet of ice and fluffy snow up to my knees. This is very important because we can dig up the ice and snow, take it out of the cold traps, and heat it up. That gives us water and other gasses that we need for Peary Station, including rocket fuel. They have even started shipping the rocket fuel to Earth orbit, because believe it or not, it's actually cheaper to ship it from the moon than to launch it from down here!"

That surprised some people. "Does it cost the U.S. a lot of money to send astronauts to the moon?" asked one of the mothers.

"Yes and no. It's much cheaper than the last time astronauts were sent there, sixty years ago, but it's still pretty expensive; Northstar 1 cost 500 million dollars, if you include everything. But they figure Northstar 6, which will launch in about a year, will cost 200 million, and in ten years it may be under 100 million. Is that a lot of money? Sure. But Americans spend many billions of dollars a year on potato chips; tens of billions on pet food; over a hundred billion on coffee; and I could go on and on. So the better question is, do we get our money's worth? The main thing the moon teaches us is about the way the earth formed, and that tells us something

about ourselves.” He paused to reach into his cloth bag and pulled out three rock fragments encased in clear plastic. “These are moon rocks. This afternoon at the high school assembly, I’ll be giving them to the Brownsville Independent School District. It used to be, astronauts were not allowed to bring rocks back from the moon, but tourists will be going to the moon next year and they can’t be restricted, so the rule now is that astronauts can bring them back, but can’t sell them. The big, gray rock is a kind called anorthite. Less than a hundred million years after the Earth formed, we got whacked hard by a small planet. The outer part of the Earth was melted and became a magma ocean—magma is like lava. Debris was thrown into space and became the moon, and it was covered by a magma ocean, too. This rock is made of the first crystals that formed, which floated to the top of the magma ocean. The earth would have had a crust like this once upon a time, too, but the rain and air have destroyed all of it.

“The second big fragment that is blackish is called KREEP basalt. After the magma ocean was mostly cooled, there was a liquid layer left in the middle made of this stuff, and volcanoes spewed it out onto the surface of the moon. We don’t have anything like this on the Earth, either, and may never have had it; that tells us something about the Earth, too.

“And you see the little, tiny reddish flake here? I picked that up a mile or so from Peary Station. It was a chunk the size of big strawberry; this is just a tiny left over piece of it. It turns out, 4.1 billion years ago and a half billion years after the Earth formed, a big meteor hit the Earth and blasted rocks into space, and some fell on the moon. We don’t have any intact bedrock left on the Earth from 4.1 billion years ago; it’s all been destroyed. We have run all sorts of chemical analyses on this rock and there are several ounces of it at Johnson Spaceflight Center where more studies are planned. This chunk tells us that the Earth’s atmosphere already had a little oxygen in it, 4.1 billion years ago. In fact, there are scientists who think they can use that



rock to figure out what the Earth's atmosphere was like back then. So you see, we can learn a lot about our home by going to the moon, and ultimately, that's important."

"Important how?" persisted the woman.

"Sometimes we discover something is important only later. A person playing with x rays discovered they fogged photographic plates; that's how the X-ray machine was invented. A man playing with microwaves discovered that a chocolate bar in his pocket melted; that's how we all got microwave ovens. The history of the Earth's climate tells us about global warming and helps us realize that we'll melt the polar caps and make sea level rise if we keep burning oil and coal and gas at the rate we're burning them. Rocks on the moon may tell us how life originated here, how it evolved and led to us. And the machines that got us to the moon will help engineers make better consumer goods; better phones, computers, cars, and airplanes."

"I'd like to go to the moon," said a little girl. "What should I study?"

"Many things," replied Will. "Right now we need scientists and engineers; people to maintain the machines that fly us to the moon and keep us alive there, and people who study the moon. But as the station there gets bigger and as tourists start to go, the types of skills needed will increase. It'll need doctors, nurses, programmers, agriculturalists, mechanics, and all sorts of technicians. I bet in twenty years they'll even need master chefs and beauticians! So there will be many, many possibilities by the time you grow up. But everyone who goes there will need to know science well, so study your science in elementary and high school, then see what they need when you start college."

"Let's have some refreshments now," suggested Linda. "You can still ask Will questions if you want. Then he has to go to Gladys Porter High School. We'll see everyone tonight at the Bahá'í Center."

Everyone applauded and Will, uncertain what to do, bowed a bit. Linda hurried over. “That was great! Did you see the kids? They were fascinated! I cut this a bit short because now you can talk to them individually, and that’s better, I think.”

“Alright, and it means I can show them the moon rocks better, too. Can I use your bathroom real quick?”

“Oh sure! I never gave you a chance when you arrived!”

“That’s alright.”

She pointed and he headed into the bathroom, partly to read the email that had come in during his presentation. He was expecting a message that day, and when he opened the email from NASA, it was indeed the announcement he expected. He had been chosen for Northstar 5.

He wanted to jump for joy; he did a small jump in the bathroom just to get it out of his system. Because he couldn’t say anything; the public announcement was still two days away. He’d have to stay silent about for the rest of the day.

-----

“I’m sorry I didn’t call you last night,” Will said to his parents the next morning. “But I didn’t get back to my hotel room until after midnight here, which is 1 a.m. for you.”

“So, the talk at the Bahá’í Center was a success?” asked Stephen.

Will laughed. “It was incredible! I spoke to 60 people at Linda Newport’s house—you probably remember her from Providence—mostly African American and Mexican American children and their mothers. The kids had the day off from school; it was a faculty enrichment day. They were fascinated and asked good questions. I gave Linda a bag of dried tomatoes from Peary Station because she gave me dried tomatoes, vegetables, and herbs from her garden, and they started Peary’s ‘greenery.’ She promised to add them to some tomato sauce for the spaghetti

she was making for the pot luck at the Bahá'í Center; that way everyone could have a little bit of the 'lunar tomatoes' and eat some lunar atoms. I explained to the kids about atoms. Anyway, then I spoke to the high school—the kids there were in school—and the television stations were there because I presented three small lunar samples in a clear plastic block to the high school, which has an engineering program. The television stations mentioned the talk at 8 p.m. at the Bahá'í Center following the pot luck with the 'lunar tomatoes.' That intrigued people and several hundred showed up! The Bahá'ís had never had a crowd like that, which exceeded the capacity of the Center. Most people stayed to hear my talk about exploration, which wasn't directly about the Bahá'í Faith, though I wove it in quite a lot, of course.”

“Wow!” said Katherine. “Any people interested?”

“Probably a few. Anyway, a Methodist minister was there and she asked me to speak to the church youth group tonight, and then she asked me whether I'd give a 'sermon' on exploration at the service tomorrow morning! I said yes, so that committed me to stay in Brownsville for the weekend; not what I intended, but that's alright. Then a geology professor at University of Texas-Brownsville asked whether I could speak at the university while I was here and I said sure, so he's organizing a lecture for Sunday at 1 p.m. He wanted to arrange an honorarium, but I said no, I didn't need that. Then someone working at the South Texas Spaceport offered to give me a tour this afternoon and I said yes. So I have a pretty full weekend!”

“That's amazing!” said Katherine. “And how was the tv coverage?”

“Good, and they mentioned I had been invited down by the Spiritual Assembly of the Bahá'ís of Brownsville. Linda says I should do the same thing for Laredo and Corpus Christi. But I didn't call to tell you about all this.” Will smiled. “I've been selected for Northstar 5.”

“Wow!” exclaimed Katherine.

“Congratulations, son!” said Stephen. “That’s pretty soon, isn’t it?”

“It is, but Northstar 5 is supposed to have a lot of science objectives. Two members of Northstar 1 will be part of the team, too. Training starts May 1<sup>st</sup> for a launch on August 26<sup>th</sup>. I’ll be back on Earth on March 4th, according to the current schedule.”

“Which won’t change much,” said Stephen. “It sounds like there won’t be much overlap with Northstar 6.”

“On the contrary; Northstar 6 arrives June 30<sup>th</sup>. NASA is switching to three launches a year, so Peary will have twelve crew until August, then just six until October when Northstar 7 arrives, then twelve again until Northstar 6 leaves in December. They hope to switch to four flights per year in 2033 or 2034, subject to necessary funding, of course. At that point Peary will always have twelve.”

“I know Peary can accommodate twelve,” said Katherine. “But one reason it has room for twelve is so that if one shelter has a problem, there’s a back up. But what will you do when there’s twelve there?”

“The ‘Lunotel’ arrives on a cargo flight in July and one of our tasks will be to set it up. It can accommodate twelve in an emergency. It looks like an amazing design, too; quite beautiful. An ‘adapter kit’ for the landers arrives, in early May, so they can be adapted to fly rangers across the lunar surface. We’ll probably be the first ones to use them.”

“It sounds like you’ll have some pretty amazing and exciting tasks, son,” said Stephen. “And I hear the excitement in your voice. Clearly, you can’t wait to get back.”

“I can’t, dad. I figure, I’m 28; I’ll be 29 when Northstar 5 lands. Let’s say I can fly to the moon 2 or 3 more times for six to nine months each time. By then I’ll be 35 and I’ll have spent 2

or 3 years on the moon. I'll be pushing up against my lifetime radiation limit. So I'll retire, settle down, take a university job, and get married. There will be plenty of time to start a family and I won't have to worry about being away for long intervals."

"That's a good plan."

"But remember, starting a family at 35 is not guaranteed and isn't as easy as when you're in your 20s," cautioned Katherine. "And there's the issue of radiation damage. Keep that in mind. Your plan may need rethinking at some point."

"True. And for all I know, when I'm 35 the moon may be getting even more exciting and the radiation medications they're working on may extend the time I can be in space. Swift is projecting that the cost of flights to the moon could drop to half or a third of what they are now. Peary could double or triple in size."

"And I suppose research on the moon, like research in Antarctica, will never run out," said Stephen. "You are blessed with a great opportunity, Will."

"We're so proud," said Katherine. "But don't forget to do talks for the Bahá'ís. You are in a unique position to proclaim Bahá'í principles to the world."

"I know, mom. I'm not very active in the Clear Lake Bahá'í community; I work too many hours every week, and that won't change. But I could do a weekend like this every month or two, and I have the money to pay my own air fare and hotel. Just remind me! I have two more plastic blocks of moon rocks I can give away. I'll have to collect a lot more on Northstar 5! I had better go; I need some time for peace and quiet, I want to go for a jog, and I have email, of course. Any more news from Molly and Taraz?"

"No. Paul's now a month old and they aren't sleeping much!" replied Katherine. "We're going down to meet our new grandson next month."

“Thanks for calling, son, and we really are very, very proud of you,” said Stephen.

“We are,” added Catherine. “Good luck with your talks.”

“Thanks! Bye.”

-----

In spite of his late-night return from Brownsville, Will was up early Monday morning for his jog and got to the Northstar control facility by 8 a.m. He sat in his office wading through emails he hadn't been able to get to over the weekend. The Northstar 5 crew had been leaked Sunday afternoon and there were many congratulations. One was from David: *Northstar 5! So quick! Congratulations. It looks like I'll be going up on Northstar 6, so we will overlap by 2 months. I look forward to more adventures on the moon.* Will emailed back, *Great, I'm looking forward to see you at Peary. I'm very excited and can't wait to go. Northstar 4's landing last night went well. Are you driving TROVs at all? If so, we may "see" each other sooner!*

He and David exchanged several more emails in between other tasks, then Will emailed Rick Page, a friend of his who was a TROV driver and repairman and a member of Northstar 4. Rick was excited about all the engineering goals of the mission: they were setting up a real greenhouse, upgrading cryo units 1 and 4, finishing the set-up of cryo units 5 and 6 in order to double the propellant and water production compared to Northstar 1, beginning regular excavation of the coldest ices, and beginning systematic production of methane, nitrogen, and ammonia. They were also planning to launch an expedition that would travel a total of at least 3,000 kilometers, which was 3/5 of the way to the equator and back.

As he sent a message to Rick, Dr. Redding Desmarais, director of the Northstar Project, walked by, then he stopped and stepped into Will's office. “So, what were you doing in Brownsville this weekend?”

Will was startled by the question. “I was invited to come down by an old friend, who conducts informal classes out of her house for children in her neighborhood, but the Bahá’ís there—my friend is a Bahá’í—arranged for me to speak at their Bahá’í Center, and then I volunteered to give some moon rocks I had brought back to the high school in town with an engineering program. That got a lot of publicity and then I was asked to speak at a Methodist Church twice and at the local U of T campus. It was quite a busy weekend.”

“So, what’s this about ‘lunar tomatoes’ in the spaghetti? You realize that story was carried by the local tv stations here on Saturday night and was on Fox News as well?”

“Really? No, I didn’t realize that. My friend in Brownsville was the one who gave me the dried tomatoes I took to the moon, so I brought her some dried tomatoes back from the moon as a gift and she said she’d put them in the spaghetti sauce she made for the pot luck that night. Quite a few people heard about that and came for a taste. The sauce didn’t last very long!”

“So, you didn’t do that to get your religion publicity?”

“Was there mention of the Bahá’í Faith here and on Fox News?”

“Yes, there was!”

“Oh, I had no idea; I was pretty busy over the weekend. I suppose they mentioned the Bahá’ís hosted me, and the spaghetti was part of a pot luck at the Bahá’í Center.”

“Yes, they mentioned it. You need to be careful about exploiting your position to teach your religion, Will.”

“And what is different between my talk in Brownsville and Roger Anderson’s weekly Bible study from his room at Peary Station? That reached tens of millions of people weekly for five months.”

“Well; true, but his is a much more mainstream religion.”

“I don’t recall anything in the Constitution or the laws of the United States saying ‘mainstream religions’ can do things that smaller faiths can’t.”

Redding hesitated. “You didn’t leak the fact you were on Northstar 5, did you?”

“No, I didn’t, but just before I left the university yesterday afternoon a student reported he had heard the names and I was among them, so we all shared my joy briefly, you might say.”

“So, a student told you?”

“Yes, and he showed us the web page of the *Houston Chronicle* with the news. I didn’t leak anything.”

“I see. Alright; I was just checking. Headquarters is mad the news leaked.”

“I don’t blame them. But no, I didn’t leak it. And near as I can tell, I didn’t do anything improper this weekend, either.”

“Alright,” replied Redding. He nodded and stepped out of Will’s office. Will watched him go. He was upset about the accusations and the apparent unfairness of Desmarais’s comments. Desmarais, like Roger, was a Southern Baptist. So he turned away from the email and headed down to the TROV area.

All six stations were occupied and busy; three were with an expedition into Whipple, the deep, cold crater near Peary, while three were busy assisting Northstar 4 personnel with work on cryo units 5 and 6. Will looked over the shoulders of someone trying to decide which way to go around a snow patch on the floor of Whipple—he advised a wide route around—and chatted with the others. Then Jerry McCord and Roger Anderson entered.

“Hey, Will!” said Jerry. “Sounds like the ‘moon spaghetti sauce’ was delicious.”

“Or at least popular,” added Roger.



Will laughed. "It was delicious because of the herbs and spices, and popular because of six small dried tomatoes from Peary. I had no idea that would happen. So, it was on the news here?"

"On Fox, which means almost everyone saw it. They repeated the story several times."

"A good way to publicize your faith," said Roger.

"That wasn't the intention. I also gave a talk to the geology students at the university there, which worked out quite well. We should get over to the Clear Lake campus; we could encourage students to consider space careers."

"Go ahead; great idea," said Jerry.

"I think it's important to be careful about mixing our professions and religion, though," said Roger.

Will was surprised. "Why do you say that? Isn't that what you do with your Bible study classes on the internet?"

Jerry laughed. "He's got you there, Roge!"

"I suppose." Roger turned to Will. "Congratulations on being selected for Northstar 5. I may see you up there; I've put in for Northstar 6."

"It'll be good to work with you, Roger," said Will.

"Yes, congratulations," agreed Jerry. "I plan to go up again, too, but not just yet."

"Who knows, we may all be up there at the same time in a few years," said Will. "The place is growing fast."

"If we can keep the politics out, at least," agreed Jerry.

3.

## Making Changes

May, 2030

“I was really surprised you came all the way down here for the closing,” Will said to Lurleen, as they both walked out of the real estate office.

“Call it closure,” Lurleen replied. “I think we both needed some. That was the house we owned together. And . . . I think I owed it to you.” She stopped outside her car, which was parked next to Will’s, and looked at him. “I regret that things ended the way they did, Will. I think it’s better that we’re both free to go our own way, now. It’s better for both of us. But we did have some good times. Please don’t think I’ve forgotten them or that I don’t appreciate them. You’re a good man. I wish we could still be friends.”

“Maybe someday,” Will replied, after a moment to control his voice.

“Maybe. So; you’ve got a condo?”

“No, an apartment. Right now I don’t need an empty condo. I’m going to the moon in late August; a bit over three months from now. Some of us have already started training together; I’ve been teaching lunar geology to a group of new astronauts and have been taking intensive classes in the repair of rangers and cryo units.”

“You, a mechanic?”

“Sure, why not? I’m not too bad at it.”

“I suppose. No girlfriend?”

He shook his head. “No, not yet. Maybe after I return next February. It may depend on when I go back up, too. Northstar Control seems willing to rotate me up quite often, because there’s a shortage of trained lunar geologists.”

“Watch your radiation exposure.”

“Oh, I am. Peary’s pretty well shielded, and we aren’t outside that many hours per week.”

“I guess that’s true. Well, I’ll follow the mission with interest. Good luck, Will. Good  
bye.”

“Good bye, Lurleen.”

She nodded slightly, unlocked her car, and stepped inside. In a moment she turned on the engine and drove away.

He stood leaning against his car, watching her go, feeling like a fool. He might never see her again. Their divorce had gone through just two weeks earlier, so they were indeed free of each other. But watching her drive away brought back all the grief of separation he had been feeling for months. And there was guilt: that his passion for lunar geology and his love of exploration had broken the marriage. She was right; perhaps it was better they were both free of each other. But that didn’t deaden the pain or the sense of rejection he felt.

Will got into his car and drove away as well, but rather than head for work, he decided to drive to a nearby park and walk for a while. It had a pretty quarter mile loop and that early May day had beautiful weather for being outside. He stopped at one point to say some Bahá’í prayers from memory; he hadn’t said any for some time and felt guilty about that, too. He was definitely obsessing about the moon; typically, he was devoting 14 hours a day to it. He had spent less time on it when he was with Lurleen, but even then he had worked about 11 hours a day. No wonder she had divorced him.

Depressed, he headed back to his car. Just as he was about to open the door, his cell phone rang. He pulled it out and activated the video link. David Alaoui’s face appeared on the

screen. “Good day, Will! I thought I’d call right before eating supper here; it’s about noon there, right? Hope I’m not interrupting anything.”

“No, I was just walking in the park; the one we jogged in a few times. How are you doing?”

“Pretty good. The ESA bureaucracy is driving me crazy with busy work; we Europeans know how to build bureaucracies, too! But life is good. How about you? Did you have the closing on the house?”

“Yes; it’s sold now. Another chapter of my life, closed.”

“And Lurleen was there?”

“Yes, she really did come. I thought she’d send an attorney to carry out her half of the paperwork. She said she wanted closure.”

He tried to scrutinize Will’s face over the connection. “You . . . look pained.”

Will sighed. “Yes, I feel pretty sad and guilty right now. I’m devoting way too much of my life to one thing, David. It really isn’t healthy or balanced. I’m thinking of pulling out of Northstar 5, actually.”

“Pulling out? Why?”

“So that I can refocus my life. When I was married to Lurleen, I devoted 11, even 12 hours a day to my work, sometimes even on Sunday. Now it’s 14 hours, sometimes as much as 18. It’s really crazy and unhealthy. How will I ever get married if I continue this way?”

“You won’t, but dropping lunar geology entirely isn’t the solution either. You need to find a balance.”

“Well, that’s true. But David, all my life people have praised me for being able to focus on tasks and get them done. That’s how I got where I am today! And now I see the danger of focusing too much.”

“Any personal strength can become a weakness if it’s misused. This is your chance to pull back and reevaluate. But that doesn’t mean pulling out entirely. To be frank, in my opinion at least, the Northstar Project needs you, Will! We’ve got four or five pretty good lunar field geologists, now, but you are the best, without question. And you’re even training the others. How many papers on lunar geology have you published in the last year?”

“I’m actually not sure, because I’m listed as coauthor in so many. Maybe fifty!”

“Exactly. I think I counted ten where you were primary author. And I can tell you a way to free up two hours a day: get the coauthors to do more. You and I are supposed to finish five or six more papers related to our last trip, and I’m bored with my work for the European Space Agency; furthermore, I have a secretary and you don’t. Let me finish them up.”

“I hate to do that to you!”

“Well, it’s done. I’ll get you the first drafts over the next two months, and I will get them done. Second, you *have* to talk the Northstar Project into paying for a secretary for the lunar geology effort. If they won’t do it, hire one yourself, you’ve got the money!”

“Well, you have a good point there.”

“Please ask tomorrow; I’ll even call and make a plea as well. Or I’ll bug ESA into giving me more part time support. I have access to some graduate students. I bet if you call Tim Foote up at Brown, he can find some graduate students who can help you. You’ve got the money to fly up there for a weekend every month to direct them.”

“Yes, you’re right, David.”

“I hope I’m not lecturing at you!”

Will smiled. “No, you’re being a good friend, and I appreciate that. You’re right, I can’t swing too far the other way. I’ve got a mission to prepare for.”

“But maybe fewer hours a day? Find other things to do with your time, Will! There are Bahá’ís there in Clear Lake; go worship with them!”

“You sound like my mother! But you’re right. I’ll take a few days off and reassess things. Why not?”

“Good. It’s always a good idea. Aisha and I try to get away from the kids every month for at least a supper or a breakfast, just to talk and reassess. And I will get you those drafts.”

“Alright. Thanks, I appreciate your call.”

-----

“So, you have a problem.”

Zeke Swift looked up from the restaurant table and was immediately impressed. Louisa Turner was 41 and dressed to convey both style and professionalism. Her opening sentence conveyed confidence and a desire to plunge into a task. They had never met, but clearly she recognized him.

“Thank you, Ms. Turner, I do.” He rose from the table and they shook hands. “Please, sit down and have some lunch.” Swift raised his hand and the waiter came over; she ordered a soup. He watched her, formulating his next thought. “My Washington lobby has not proved very effective.”

“Yes, that’s very true. NASA has undermined your credibility quite effectively, which is amazing, considering all you’ve accomplished on a budget a tenth what they would spend.”

“They never wanted to use our system to go back to the moon and they never would have developed a system to transport six there at once. I basically gave them control over it; I could have made their astronauts fly with the tourists!” His voice rose in frustration. “Without me, the Chinese would have gotten there first. Instead, I gave the United States of America a dignified, proper leadership position in opening the moon to permanent exploration and study. I reduced the cost of access to space so much that it is now possible to fly to the moon for less than it used to cost to fly to earth orbit!”

“I agree; you haven’t received either proper respect or official recognition. And now the pattern repeats itself with Mars.”

“It does. They want me to postpone my first mission five years. I’m not getting any younger! I want to see men and women on Mars before I die. It has far more potential for settlement than the moon; people will go there, have families, and build communities. It could have started a generation ago, and it can start now, the technology is ready. Investors are unnecessarily cautious.”

“They don’t have the vision. But you don’t expect NASA to back settlement.”

“No. Their role should be to open the planet and establish the hub of exploration, the Martian equivalent of Antarctica’s McMurdo Station. After that, someone will need to coordinate the planet’s development. That could be done by NASA as well, or by an international body, or a public/private body. My goal is to set up a simple, basic, reusable transportation system that is expandable.”

“And I gather, from a perusal of your websites, that in the next year you’ll pass some major milestones.”

“Correct. The first gryphon capsule will go into orbit in a few months and will be repurposed to serve as a larger transportation system to the two orbital hotels. Next year—early 2031—we’ll send one to the moon; it may be repurposed to serve as a larger vehicle for tourist flights there, if demand allows. Then in 2033 we’ll send one to the surface of Mars, which will serve as one of the return vehicles for Redstar 1. In 2035, two will go to Mars with three astronauts each. By then, the capsule will be thoroughly tested; it may even have paid for itself.”

“Very clever. You’re leveraging equipment development very efficiently. What’s the argument you want to make to Congress?”

“The ‘cheaper and more efficient’ argument is backfiring, ironically enough.”

“Yes, Congressmen worry the NASA money spent in their district will be threatened. You need to argue that the amount of money being spent by NASA need not be reduced, just redirected.”

“Yes, I think that’s right. Dorinda Stetson says that all the time: the NASA budget can do a lot more and still support many research operations and private contracts. I’m not against research. But when NASA decides to launch a big mission, all its labs and research facilities want a piece of the pie, and the next thing you know, the mission has become a big, bloated project designed to require a lot of technology it doesn’t need. Let them do their valuable research, but don’t tie it to a single, central mission.”

“Or divert it to some other mission.” Turner leaned back in her seat to think. “The ‘Outer Planets’ initiative is the place to put projects to develop a twenty-tonne, 5-megawatt nuclear reactor and advanced ion propulsion, rather than Mars.”



“Exactly! One thing NASA doesn’t need is insisting it must spend 50 billion to develop a fast system to get astronauts to Mars because the slow systems are unhealthy, then have me send astronauts to Mars via the slow system and come back healthy!”

“I think they can count on the public and most of Congress to have a short-term memory, but I agree. So, what you need is a message that long-term technological development is very important and must be tested on automated missions to the outer planets—big ones, now made possible by the cheaper launch systems—and meanwhile, human missions to the moon and Mars must proceed, and use them later.”

“Ah . . . yes, that sounds reasonable. So, will you take the job?”

Turner smiled. “I may. I don’t come cheap; I have two kids in private schools and a big mortgage. But you know my resume; I was the chief of staff for the Speaker of the House for four years and a Senatorial aide before that. I know Congress pretty well.”

“That’s an understatement, according to my friends.”

“What brought you to Washington? Meetings with Congressmen?”

“Yes, we have a few friends on the hill. One of them recommended you.”

“Very kind. Well, if I’m going to start, we should work on your talking points, if you have more meetings. It might make a good test to see whether we can work together well. I’ll give you a good rate on that.”

“I do indeed have three more meetings scheduled, starting tomorrow morning.”

“I’d reschedule that one to the day after. How long can you stay?”

“How many more meetings can you get for me?”

“Maybe six or eight.”

“I can stay three or four more days, but I’ll need to introduce you to the lobbying team I already have here.”

“That’s fine, but I don’t want them interfering with my strategy. Let’s meet tomorrow morning to go over talking points first and try them out on a sympathetic Congressman. Then we’ll talk to your team.”

Swift smiled. “Alright, I like that plan.”

-----

“Where have you been?” asked Larisa, when Will entered the control area for the Mars TROVs.

“Me? I didn’t know anyone noticed I was gone.”

“Four days in the middle of the week? And you never take vacation.”

“Well, I went to New England; early May is the best time of the year to go there. The apple trees and lilacs were in full bloom. I visited my parents on the weekend, then went to Providence and lined up some graduate student help to write up the rest of the Northstar 2 expeditions. And I went for a very nice hike at Sleeping Giant State Park.”

“What’s that?”

“A mountain in Connecticut. Very pretty and restful.”

“Sounds nice. I wish we had some mountains around here!”

“I know; so hot and flat! Say, do you still need some help, sometimes, nights and weekends? I just told Jerry I was done running moon TROVs. I’ll be on the moon in three and a half months, after all. I’ll get plenty of moon then.”

“Oh, alright. We can squeeze you in. The Hellas TROV is exploring a rock glacier right now. Its ground penetrating radar has detected lots of ice, as predicted, a few meters down. The Aurorae TROV is circling a really interesting mesa right now that we’re calling ‘boat rock’ that

has some very pronounced sedimentary strata. There's ground ice down about seventy meters there."

"Not bad, for the equator."

"Exactly. You sure you'll have time?"

"I'll make some time. It'll be my 'hobby.' I need a hobby; I can't just do the moon all the time. I'm also starting a course on TROV repair and plan to take another course on ranger repair."

"Oh, branching out! But if you're giving geology classes to the engineers, I suppose they should give you engineering classes as well."

"That's right. They want people up there with as many certifications as possible. I'm scheduled to give a big lunar geology class for fifteen astronauts the first week of June. Jerry has the second week. We're going to meet to coordinate the curriculum on Thursday."

"What about the remaining publication of the Northstar 2 results?"

"I can't get them done myself, but David is taking on some of the work, there are graduate students at Brown who have NASA contract money anyway who are helping, and there are all the coauthors who can do more. I can't do it all myself even if I weren't scheduled to be on Northstar 5. There's just too much." He shrugged.

"There's always more to do," she agreed. "Even a few hours a week of your 'hobby' time will be a quality contribution, I'm sure. You'd be welcome. And I can help more with the Northstar 2 science. I have the time; my family's in Russia and I'm here by myself. Some of the fog has lifted, you might say. I understand geology a lot more now that I've been running Mars TROVs for five months."

“Thanks, that’s great. If you’ve got some time, let’s get together for lunch and talk about Northstar 2. You were part of several of the expeditions and really could help.”

“Lunch? My goodness, Will, we’re going to have lunch?!”

Will laughed. “Larisa, you’re a friend, and I don’t have many friends. I’m trying to spend more time with friends. Even Jerry; he and I are having lunch tomorrow. I can’t be working all day, every day; I need more variety and more social time. So I’m trying to make some changes.”

Larisa smiled. “Good, I hope some of that rubs off on me! Alright, let’s go to the cafeteria, or even off campus to a restaurant for lunch.”

“Great. I’m going to my office now to take care of email and my tasks list, but I’ll be back here about 12.”

“Alright, great.”

4.

## Back to the Moon

Late August 2030

“Is that it there?” asked Sergei Landsberg, pointing out of one of the windows of Northstar 5’s Polaris capsule.

Dr. Armando Cruz, the Commander of the mission, looked at the screen in front of Judith Remsberg, their Canadian pilot. She nodded. “Yes, that’s the Chinese ‘cargo flight,’” he confirmed. “Let’s get a camera on it.”

She nodded and pulled up the camera controls, then zoomed in. The six of them floated over to look at the detailed image on the screen.

“It looks more like a spacecraft to me,” said Will. He pointed. “Windows.”

“Maybe it’s an emergency orbital accommodation,” suggested Teresa Dos Santos, their Brazilian geophysicist.

“Not necessarily,” replied Ignacio Iglesias, their Spanish engineer. He pointed at the image on the screen. “The porthole windows are clustered around the docking apparatus, but farther down there’s a cover—a fairing—around the module. It looks like an inflatable to me. And below that, it looks like there’s a storage area for who knows what.”

“And we’ll never know, because when the CIA and Pentagon get these images, they’ll write a classified report and nothing will be released to the public or us,” noted Armando.

“I wish we weren’t doing this,” added Sergei. “I don’t trust the Chinese, but a NASA moon flight shouldn’t be modified for surveillance purposes.”

“I fully agree,” said Judith. “I suspect the Canadian government will lodge a protest.”

“Officially, we’re trying a new two-stage orbit docking method,” said Armando. “I think we can all agree that it’s suspicious. But we all need to be discrete, also. There are strategic issues that are above our pay grade.”

“Have they issued any announcement when their next manned mission to lunar orbit will be?” asked Will.

“Winter; maybe January,” replied Armando.

“And they’re sending another cargo flight, probably in December,” added Sergei. “That’s not secret information, but it’s pretty hard to obtain, shall we say.”

“This masses what; eight tonnes?” asked Will.

Sergei nodded. “Their upgraded launcher can put thirty tonnes in low Earth orbit, which is sufficient to push eight tonnes of cargo to an elliptical lunar orbit, plus a two-tonne empty stage.”

“And if they wanted to land this on the moon?” asked Will.

“They’d need another launch with an eight-tonne lander, including propellant. But then this cargo could only mass about seven tonnes.”

“How would they ever get people to the surface?” asked Ignacio.

“Four launches,” replied Sergei. “Launch 1 with the lander passenger module and second stage; launch 2 with the lander first stage; mate them in low earth orbit and push them to lunar orbit together; launch 3 with the stage to push the passenger capsule back to earth; launch four with the passenger capsule; mate them in low earth orbit and push them to lunar orbit together; then perform rendezvous and crew transfer in lunar orbit. Rather complicated and expensive. There’s no evidence they’ve begun to develop a lander, either.”

“So it must be for lunar orbit,” said Armando. “Unless they lease a Swift lander.” He looked at the image on the screen, which was shrinking in size fast, even at maximum magnification. “Looks like we’ve gotten all we can get from this pass, and in our orbit, there won’t be another pass for over a week. So let’s prepare for the burn to take us to the depot.”

“It’s scheduled for over three hours from now,” added Judith.

They scattered to their various spots in the capsule, which was essentially a circular room 5 meters or 16 feet in diameter. Will returned to his seat—it laid flat to become a bed at night and he could pull a cloth tube around him to provide a modicum of privacy—pulled out his tablet, and began to type an entry into the private section of his Facepage account: *We performed lunar orbit injection half an hour ago and entered a special elliptical polar orbit around the moon, perilune the same as the depot, apolune over a thousand kilometers out, period four hours. By coincidence, the Chinese cargo vehicle was in a similar orbit; the perilune was lower and the apolune higher, and for ten minutes or so it flew passed us at a range of less than a hundred kilometers. It was very interesting to see their technology, which is becoming quite sophisticated. It appears they’re starting work on a lunar orbit facility, perhaps as a first step toward a landing, since they don’t have the technology to go straight to the surface.*

*Our flight continues to be flawless. The Thunderbird-H stage that pushed us here and will take us to the depot had been fueled in low earth orbit with lunar hydrogen and oxygen, which was a first. It’ll be refueled and its water tanks filled before we take off from the lunar surface to fly back to the earth, so it’ll push us back as well, and carry the water to make hydrogen and oxygen for Northstar 7 or 8. There was a news report this morning that the cost of flying to the moon is now 2.4 times as much as a flight to low earth orbit and that it should decline to about double the cost of a flight to orbit in five years. I was impressed that only seven*

*hours after launch, we had docked to our Thunderbird-H translunar injection stage and were ready to go. The technology keeps getting better! But I can't wait to be back at Peary again.*

-----

It was twenty-four hours later when the six Northstar 5 crew transferred to the lander *Nectaris*—they had now been named for lunar “seas”—and headed for the North Ridge of Peary Crater. Right after they landed, a ranger with an attached “portahab” backed up to Aldrin Pad number 3. A member of the Northstar 4 crew stepped outside the ranger and pulled a long, inflatable tunnel over to the *Nectaris*, climbed the ladder, and attached it firmly to the capsule’s door-shaped hatch. The ranger inflated it and within thirty minutes the six of them could step into the tunnel without space suits, one at a time, and walk down the long ramp to the rear airlock of the portahab. The tunnel also made it much easier to unload a tonne of consumables and other supplies and move them straight into the portahab.

“This is such luxury, compared to Northstar 2!” exclaimed Will, as they got underway, two hours after landing.

“And Northstar 1,” added Sergei, who had been on that historic mission.

“You are the first crew to use the tunnel,” replied Ethel MacGregor, the engineer and mechanic who had attached and detached the tunnel. She spoke with a subtle but distinct Scottish accent. Will was surprised by the accent and looked more closely; she was about his age, which was unusual, very pretty, with Brunette hair and, he noted, a wedding ring. “It just arrived last month with the latest cargo flight.”

“You all had to deal with what; three cargo flights?” asked Armando.



Ethel nodded. “Late April, mid June, late July. The lunotel massed thirty-five tonnes all by itself, this portahab was three more, and there were many other items brought to make the lunotel tourist-worthy, shall we say.”

Will looked around the portahab. The main cabin was 2.4 meters wide and high and 3 meters long; the size of a small recreational vehicle. The front end had a hatch on the right connecting to the ranger that was towing it; the left side had a stove, oven, sink, and refrigerator. Couches ran along both sides that could serve as beds; a curtain could be pulled down the middle for privacy, and a table could be set up between them so that up six people could dine together. In the rear, an airlock just one meter square occupied the right corner; a bathroom of the same size occupied the left corner; in between was a closet filled with life support equipment and gray water storage. The ceiling was covered by storage cabinets, the contents of which helped provide radiation shielding.

Ethel followed his eyes. “It’s quite a nice vehicle, isn’t it? We took it out on one overnight expedition to break it in. It was really comfortable. With the ranger sleeping one, and a second ranger sleeping one, it’ll be quite easy to mount four-person expeditions anywhere on the moon.”

“Using three landers, though,” noted Will.

“Yes, three, Dr. Elliott, but we have four available to us. Of course, three landers will consume 81 tonnes of hydrogen and oxygen per expedition, and we can’t produce enough surplus to send out more than three per year. But we will be able to reach the entire moon.” She smiled.

“Yes, you’re right; we’ll operate under some limitations. And call me Will. You’re . . . Ethel?”

“Yes, everyone calls me Ethel.”

“Pleased to meet you.”

“Same to you.”

In a few minutes, the ranger and attached portahab approached Peary Station. Will and the others were glued to the portholes to see the “lunotel” or lunar hotel. “It looks like a flying saucer!” exclaimed Judith.

“Yes, it’s a round two-story pancake,” replied Ethel. “You’ll love it, especially the top floor. We’re having our dinner there.”

Just then, the portahab began to back up toward a docking port. It was new as well. When Will had been on the moon, Peary Station consisted of shelter one and shelter two, each a two story cylinder 24 meters long and 6 meters in diameter, with airlocks and docking ports at each end. Now shelter two had a ten-meter tunnel extending from it to the lunotel, with airlocks and docking ports on one side and a greenhouse on the other.

They heard a series of clanks as the magnetic latches attracted each other and aligned the docking ports, followed by louder clanks as the hard docking occurred. A minute later the rear airlock opened up and they could enter Peary Station, and all without putting on a spacesuit!

“Welcome to Peary!” exclaimed Commander Laura Stillwell. She shook hands with each of them as they entered. She smiled broadly when Will entered; they knew each other slightly.

“Welcome back, Moonman.”

“Thanks, Laura. You guys have been busy!”

“We doubled the size of this place and doubled its propellant production, but made very few expeditions! But with you here, geology becomes a priority again.”

“I hope so.” Will smiled.

He moved down the line, shaking hands with the other three members of Northstar 4; with Ethel and the driver inside the ranger, they totaled six. He was particularly pleased to see his friend Rick Page, who had been the mission's sole geologist. "Hey, Will!" he said, giving his friend a bear hug.

"Hello Rick! How are you?"

"Great. Sad to be leaving and glad to be going home, all at the same time. Good flight?"

"Yes, quite routine, except for our flyby of the Chinese cargo vehicle."

"That maneuver has caused quite a political storm, but it isn't you guys' fault."

"It's not like we can choose our trajectory!"

"Exactly. I'll walk you to your room."

"Thanks." Will waited until Rick shook hands with the last members of the Northstar crew, then they headed to Shelter 2. "I'm in room 4," Will said. "Facing the near side. I finally have enough seniority to have an Earth-facing window!"

"That is nice. We rotated rooms so everyone had a view of Earth for four months out of six. That worked well. So, glad to be back?"

"Yes, I'm thrilled. I never fulfilled all my obligations to help analyze and write up the Northstar 2 data, but that'll take years, anyway, and others can finish the task. I'm coming back with a different perspective about the moon."

"How so?"

"A broader, deeper perspective. Rather than looking at specific rocks for their chemistry or age, I've had to debate the implications of the data for a year. Every field trip will have deeper theoretical implications. It's not that I wasn't thinking theoretically before, of course."

“I understand; you have that much more experience and that gives a deeper perspective. And the divorce with Lurleen is finished?”

“Yes, and she got remarried in June. It still hurts a lot; I feel like I was kicked in the teeth. I’m beginning to realize how much it hurt now, in fact. But it has made me more aware of relationships; not just with women, but with friends as well. And I’m trying to slow down a bit, spend somewhat less time working.”

“That’s good. I wish you had been on this mission. Laura Stillwell is a difficult personality; hard to get to know and very demanding at times. The team had some friction.”

“I heard. It’s very hard to judge the personal chemistry of these teams, and three months of training together isn’t enough to overcome problems.”

“Some problems only crop up after a period of time, and at that point no one is going to withdraw from a team or be pulled from it. Since team selection is a multinational process and is partly political, it isn’t rationalized.”

“I’m not even sure it could be rationalized. People are too complicated.”

They hurried up the spiral staircase to the upper level of shelter 2, passed through the medical lab, and stopped at the first room, which was number 4. “I’ll leave you to settle in, now,” said Rick.

“Okay, thanks. See you later.” Will nodded to his friend and opened the door. It was a typical room, 2 ½ meters deep and 3 meters wide against the curving outer wall of the shelter. He lingered a few seconds to look at the Earth out his porthole window, then began to hang up his pants and shirts and put away socks and underwear. Unpacking was pretty quick.

It was time to explore. He headed back to the tunnel to the Lunotel and turned right into the greenhouse. It was a lush, warm, humid space, packed with plants from floor to ceiling, 10

meters long and 5 meters in diameter, with bright lights scattered about and LED “sticks” providing light along the floor and walls. Overhead was a reflective silvered ceiling, with lunar regolith above it to shield the greenhouse from cosmic radiation. Apparently it was the place in the station with the least radiation; ironic, since plants were far more tolerant of radiation than humans. Shelves allowed several layers of short herbs and vegetables to be stacked on top of each other.

When he came out, Sergei, Judith, and Ignacio were walking by. “Is it pretty?” asked Judith.

“There’s a place to sit, but it’s more functional than anything else. It looks to me that it can grow all the vegetables six people need. There’s a lemon tree with lemons on it, and an orange tree with one orange, and a few maturing watermelons under them.”

“Sounds delicious,” said Ignacio. “Are you cooking for us, like you did on Northstar 2?”

“Once a week with fresh ingredients, unless the tourists come with a chef,” replied Will.

The four of them walked into the Lunotel. Inside the airlock there was a corridor that led them past a grand staircase to a circular room in the center of the circular structure, off of which were six numbered doors. Each opened into a large, comfortable room with a private bath and two private windows to the outside. “These are nice!” said Will, stepping into room number 5.

“Very comfortable,” agreed Sergei, sitting on the bed. He looked out the window. “With at least a meter of regolith around it; pretty good shielding.”

“More than twice as big as the rooms we have,” said Ignacio. He pointed to a track in the floor and ceiling. “And they can be divided into two single rooms if necessary, with their own doors.”

“Clever,” commented Will.

They stepped back into the central space and walked to the spiral staircase. The magnificent atrium occupying top floor was set up the opposite way of the first floor; the central four meters was a circular room that contained the kitchen and food storage, while the rest of the level was an open ring one could walk around and look outside. At the moment the nearside had the sun and was filled with pots of beautiful flowering plants and tropical flora; the hotel's exercise equipment was set up among them. The farside was in shade and had a long, curved table able to seat fourteen. At the top of the stairs was a desk, presumably for the hotel staff.

But most impressive was the ceiling and the curved walls, which consisted of transparent plastics with occasional dark cables running through them for strength. The sun shone in fiercely on the near side and projected all the way across the space, except where plants blocked it. They were immediately attracted to the outer wall and looked out on magnificent, rolling moonscape. Ignacio and Judith had never been to the moon before and were awestruck.

“Incredible!” said Ignacio.

Will followed them to the edge and looked out at the lunar terrain; beloved moonscape, because he could see footprints and vehicle tracks and was pretty sure some of them had been made by him. The view was a bit distorted because the transparent shell was divided into a series of compartments, each filled with a meter of water. “Too bad we have to look through the water,” he commented.

“But we don't have to worry about radiation or micrometeoroids,” said Judith. “Any hole will produce frost on the outside and we can find and plug the leak.”

They walked around the outer ring of the hotel, stopping to look at the quarter-full earth in particular. Because the hotel had been inflated on top of a slight rise in the ground, the top

floor looked over shelters 1 and 2; because it had been built along the axis of the shelters, it didn't block the view out of any of the shelters' windows.

They didn't stop looking out until the Northstar 4 crew came in and light refreshments were brought out of the galley in the center. The microwave ovens were fired up and soon there were twelve hot meals ready. Will was disappointed there was no fresh food; apparently Northstar 4's crew didn't include any amateur cooks. He had every intention of cooking for Northstar 6 when they arrived and couldn't wait to check out the new galley.

"So, do you guys ever eat in shelter 1?" he asked Ethel, while everyone was eating dinner. She was seated across from him and one seat away.

She chuckled. "Not after we got this set up, last week. Shelter 2's common area is scheduled to be converted into three more bedrooms and a bathroom next month, and shelter 1's commons will have one bedroom carved out of it. This is such a beautiful space, who could stay away?"

"The life support is still only partially set up, though," added Laura. "Don't try to use any of the bathrooms! We have to take the dishes to shelter 2 to wash them because the wastewater processing unit isn't fully installed yet."

"The thermal controls are still getting adjusted, too," noted Ignacio, who had been trained in the operation of the lunotel's systems. "It's warm in here. We'll have to get that fixed by November, when the first tourists arrive."

"I'm sure you will," replied Laura. "We still have two bedrooms to set up."

"Can we use any of them when the tourists aren't here?" asked Teresa.

Laura shook her head. "Only if you can put a hundred thousand dollars on your credit card! We can use the upper level in return for providing services to the tourists."

“I’m not looking forward to serving tourists,” growled Sergei.

“I’ve been assured it won’t take that much of our time,” replied Armando. “We’ll only have one flight to deal with; Northstar 6 will have two and Northstar 7 may have three. The Lunotel company’s goal is six flights a year, 5 tourists and 2 crew each.”

“How long before they pay off this investment?” asked Will.

“I’m told that the tourists will pay four million just to stay here,” replied Armando. “It cost 400 million to build and launch, so it’ll take four years to pay it off, excluding interest, insurance, and operating costs. I wonder whether they’ll ever make a profit, but I suppose over the long term, this place will.”

“Very long term,” agreed Laura. She looked around; most people were nearly finished with their meals. “Let’s get started.” She rose from her seat and everyone stopped talking to look at the commander. “This is our opportunity to offer another formal welcome to Northstar 5,” she began. “It’s so nice to see six new faces, after six months of just looking at ourselves, and very nice to have twelve people here all at once! We welcome your additional labor over the next two weeks before Northstar 4 departs and the command is formally shifted over to Dr. Cruz. We’re proud of all we’ve accomplished, this magnificent facility being our most important legacy. I think we can also make the claim that we completed the exploration of the north polar region; we made a lot of short two and three day expeditions as far south as 85 north and have reached all major craters and cold traps. But there are a lot of firsts left for Northstar 5! So I’d like to propose a toast: to Northstar 5: may your accomplishments be great, all your challenges easily overcome, and your supplemental victories numerous. To Northstar 5 and our exploration of the moon!”



Laura raised her wine glass; everyone said “here, here!” or “bravo!” and drank from their glasses, Will downing carbonated water from his. Then Armando rose.

“Thank you, Commander, for your warm welcome. For the next two weeks, we are your willing and obedient servants as we complete the tasks on our mutual schedules. We extend our hearty congratulations to you for this beautiful facility, your very successful exploration, your success in raising propellant production to 250 tonnes per year and water production to as much as 600 tonnes, and your set up of a Sabatier reactor able to produce significant quantities of methane. We look forward to turning to our own long list of tasks: completing the Lunotel, hosting the first tourists, making the first long overland expeditions with the portahab, making the first long-distance expedition with the landers, possibly to Tycho or the South Pole, setting up a sophisticated clinic for lunar medicine, including a surgery robot, and carrying out a series of tests of equipment for the Mars project. We will be as busy as you were, and in turn will lay the foundations for Northstar 6 and many great accomplishments. So we toast you.” Armando raised his glass. “To Northstar 4: in hearty congratulations for your many successes and in gratitude for making our tasks possible.”

“Here, here!” exclaimed the others, and they sipped from their glasses again. Will looked out the transparent walls at the Earth, and up at a few stars visible through the ceiling, wondering whether they would face major obstacles and crises. But it was good to be back at Peary.

5.

## September

September 2030

“We can stand down now,” announced Armando over the public address system.

“We copy,” replied Sergei and Ignacio from ranger 1. Will and Judith watched the launch of the lander *Tranquillitatis* from a screen in the Lunotel’s galley, as they washed pots and placed dishes into the dish washer.

“They’re on their way,” said Will, as the lander shrank into a bright burning dot on the screen. “Just two minutes to lunar orbit and six hours to the depot.”

“Then three days for Northstar 5 to reach earth,” added Judith. “This place will be pretty quiet, with just six of us.”

“Yes, we’ve gotten used to having twelve! It was rather nice.”

“We won’t have a guitar player any more, though Sergei’s violin playing is pretty good.”

“If we had stayed at twelve, we could have even had plays!”

Judith laughed at that. She rinsed the spaghetti pot and put it on the stove where it could dry. “That was absolutely incredible spaghetti, Will.”

“Thanks, though Armando, Teresa, and maybe even Ignacio would like more spicy food, and we don’t have the right spices. Wish we had planned that better. I was raised in New England where we don’t cook so much hot, spicy food.”

“That’ll be a challenge for you. I’m sorry; I can see you really like to cook for people. You can be sure I like your food, which is quite comfortable for a Nova Scotian.”

“Why, you’re practically a New Englander!”

Judith laughed at that. “Actually, I have a few Puritan ancestors that crossed the Gulf of Maine about 1740! My husband is pure Yankee.”

Will laughed at the irony. “Then you may be a more authentic New Englander than I.” He glanced down at her hand and saw the wedding ring. “Judith, if I may ask a personal question, how do you and your husband handle six months of separation?”

“It hasn’t been good for a lot of marriages,” she conceded. “And I was sorry to hear about your divorce, Will. I suppose I’m lucky. He went to Greenland over the summer when I was in training; he’s a glaciologist. And he’ll be going to Antarctica for three months, starting in November. So we’ve scheduled our respective trips quite carefully!”

“That’s pretty good.”

Just then, Armando walked into the atrium with Ignacio and Teresa. The first two were speaking in Spanish; Teresa was contributing to the conversation in Portuguese-laced Spanish. They came into the galley to pour themselves cups of coffee. Armando lingered after Ignacio and Teresa headed to a table. “Well, Peary now belongs to Northstar 5,” he said in English. “Will, I was hoping we could talk about exploration plans. I’d like to postpone some of the trips for a month or so, so we can get the Lunotel set up and the common areas in shelters 1 and 2 divided up. But that means I need your help with construction.”

“Sure,” Will replied. “I don’t have a lot of experience with the kind of construction we’re talking about, but I can pick it up. I suppose you’re not talking about zero hours a week devoted to geology.”

“No; more like twenty or twenty-five, with thirty or thirty-five given over to construction.”

“And we’ll make it up later? Because this expedition has a geologist and a geophysicist and theoretically it should devote a third of its hours to lunar geology.”

“I know, and I am committed to that. But we can’t postpone the arrival of the tourists in November and the Lunotel is proving more complicated to finish than expected. Northstar 4 was proud of their work, but they were behind schedule.”

“That helps explain the paucity of geology they completed.” Will pondered, then nodded. “Alright, I can do that. We need to get the Lunotel finished. But if we can make it up, we really need to. We’re on the moon to do science, not cater to tourists.”

“We’re on the moon for a lot of reasons, I’d say,” replied Armando. “Another one is setting up an advanced medical facility, and I’ll need help for that, too. Teresa will help with that when she’s not doing construction.”

Will nodded, conceding Armando’s point. He looked at Judith after Armando left.

“We have a lot to do up here,” she said. “And engineering will always intrude. The machinery to keep us alive and get us around is pretty complex.”

“I know,” said Will.

-----

“So, should I dial back or not?” Louisa Turner asked Zeke Swift. He studied her face on the screen; she looked nervous.

“A private message to you from a NASA spokesman does not necessarily represent the feeling of the majority in Congress,” Zeke replied. “What does Congress think?”

“Our allies in Congress are getting pretty skeptical of NASA’s claim that the new Liberty two stage reusable shuttle will represent a cost breakthrough. They’re inclined to kill it entirely and cut NASA’s budget, except for the money they’d dedicate to Project Redstar, that is.”

Swift considered. “I’ll make perpetual enemies in NASA if that happens, and that will make life difficult. We must emphasize that the Liberty is valuable because of the technology it is developing. It probably won’t provide cheaper access to orbit, but it will lead to other vehicles that will.”

Turner shook her head. “NASA sold it as a cheaper way to orbit; what you propose will ‘dejustify’ the whole thing. I suggested they cut the large space reactor program because it isn’t needed and won’t make enough power for a VASIMR or advanced ion engine anyway. But the real problem is beyond NASA; social security and other programs are consuming the entire budget, international insecurity is driving the defense budget higher, and infrastructure is crumbling.”

“And deficit spending won’t work forever; less and less, the dollar is functioning as the world currency. But those are problems every year, Louisa, not just this year. What NASA needs is a coherent vision.”

“It hasn’t had that since Project Apollo, and it is simply impossible to achieve now.”

“No Louisa, I disagree. We can offer some coherence because the new private partnerships—not just with us—promise to continue the cost revolution. I sent three rovers to Mars for a third the cost of the one sent by the US just a few years ago. How? Thunderbirds allow a huge increase in throw weight and a big cut in launch costs, so one can build things that are heavier and less foolproof—which saves a lot—and then one can mass produce them and send several, in case one or even two break.”

“The US isn’t going to outsource Mars probes to India the way you did. They can’t cut costs the way private industry can. Zeke, we can push for a vision only so hard. Really, we are one of many people pushing visions for NASA, and that’s one reason it’s incoherent; its vision is

the product of a committee that is trying to please everyone. Should we tone back our campaign or not? This is the time the budget for the next fiscal year is finalized. We can dial the pressure back up later, for the next year's budget."

Swift considered the dilemma. "Alright, dial back," he said. "But we need to develop a much more coherent message for next year, one that emphasizes steady support for the existing manned exploration of the moon, that emphasizes continued technological development for the moon program, and investment in Project Redstar. And we need to build a broader coalition."

"And you need to prove that Project Redstar will work."

"Don't worry, that's coming in the next six months. You'll see."

-----

"Sorry I was gone for so long," Will said to Sergei, as he returned to the former common room of shelter 2, the floor of which was covered by piles of metal panels. "The mass spectrometer didn't take that long to reload with samples, but then Armando texted me and asked whether I could help set up the robotic surgical system. He thought he needed only five minutes of help but it turned into thirty."

"That robotic system is proving almost too complex for anyone to use," complained Sergei.

"Almost impossible to set up," agreed Will. "But Armando is close. He jokingly asked whether I'd be willing to have my appendix taken out so they could be sure it was ready! I declined of course!"

"Of course!" Sergei laughed. "I'm glad the new sick bay is almost finished, though. It's been a tough three weeks."

“It has, but we’re pretty much back on schedule, which means there’s six weeks to test everything before the tourists arrive.” He looked at the metal panels. “So, you have the wall frame finished.”

“Yes, it’s now ready to bolt the wall panels in place.”

Will picked up a panel, which was pretty light in lunar gravity, even though it was made of meteoritic nickel-steel. “So, Ethel MacGregor made these with the metal carbonyl fractionator?”

“She did. The system was very temperamental, but she nursed it. We can now harvest nickel-iron meteorites, bathe them in hot carbon monoxide, convert them into metal carbonyls, pour them into molds, and solidify them.” He held up a bolt. “These were made out of imported metal powder with the three-d printer. They’re pretty good, too.”

“But we still can’t produce large quantities.”

“Correct; Ethel managed to make six panels in a month. Most of these new walls in the shelter are imported from Earth. But the system will get better. Manufacturing on the moon has begun.” Sergei took a metal panel, slid it into place in a frame, then he and Will bolted it down. The frame fit snugly against the outer wall of the shelter, glued in place with a powerful glue they had applied that morning. Will nodded, pleased that it fit so well. He took the next one and bolted it in place himself, with Sergei watching approvingly.

“I’ll get these up; you work on the frame for the front of the room,” Will suggested. The frame was much more complicated, so Sergei had to do that job.

“Okay. We should be able to get this bedroom enclosed by supper. The other one across the old commons will be finished tomorrow and the half bathroom will take a day and a half.”

“I’m still skeptical that we even need so many rooms,” said Will. “The hotel accommodates up to 12 and the two shelters will accommodate sixteen more; that’s 28. We only have six here and I can’t imagine we’ll have more than 18: 12 crew and a tourist flight of 6 more.”

“Yes, I’m surprised as well. But we need redundancy. If we had 18 here and the Lunotel had to be closed in an emergency, we’d need all 16 rooms and then some.” Sergei paused. “And I think transport capacity will soon increase.”

“Really?”

Sergei nodded mysteriously. He was at Peary as an employee of Swift as well as in the pay of Russia, and Will wondered which source of information Sergei was tapping.

Will bolted another panel in place. He hated the idea of filling the old commons with bedrooms, but the Lunotel provided far more open space anyway. Once the metal wall panels were in place, they would be covered with “wallpaper,” a stick-on, decorated, insulating coating.

“Say, can you take two hours tonight to help me get some chondrite?” Sergei asked.

“Chondrite? Do you want to drive over to Borealis GA, where’s thousands of tonnes of the stuff?”

“Sure, I’d like to see it. I only need a few hundred kilos, but it’s good to know there’s a huge supply nearby.”

“It’s thirty kilometers away,” Will confirmed. He knew something about the experimental device to extract volatiles from carbonaceous chondrite, a common material in asteroids and meteoroids from the outer asteroid belt.

He finished bolting the metal panels in place, then helped Sergei set up the framing for the front wall and its doorway. They broke for supper at 6 p.m. when the text arrived from Judith



that it was ready. They headed for the atrium to enjoy the luxury of that space and a relaxing meal, even if it was prepackaged; essentially a “tv dinner,” for Will only cooked on Sundays, and no one else tried to cook at all.

“So, what did you get done today?” Will asked Judith, who was seated across the table from him. She looked up at him and he smiled involuntarily; she looked back at her food. “We’ve got the Lunotel’s waste water management system working pretty well.” She looked at Armando. “I’m afraid we all have to sacrifice terribly next week. We have to move it, breathe the air, use the toilets and showers, and see how it does.”

Armando laughed. “Such a terrible sacrifice! How long must we endure this situation?”

“I’ll try to stretch it to two weeks,” Judith offered, with a smile.

Armando nodded. “Let’s argue for a really big test; three weeks.”

“It’ll be a good time to overhaul shelter 1’s life support system,” noted Ignacio. “The filters are pretty old; we could move up the routine maintenance and do some additional cleaning. Otherwise, some of the work falls during the time the tourists are here.”

“Yes, please do move it up, then,” said Will. “I’d rather that the engineers be available to play tour guide as well. Otherwise, it falls on Teresa and me, as the geologists.”

“I’d rather be able to focus on lunar seismology!” agreed Teresa.

“I can help,” said Judith. “There will be a Canadian tourist on board.”

“If we continue as planned, we’ll be able to resume a more normal schedule after next week,” said Armando. “The Lunotel will be set up and I gather the four new rooms in the shelters will be completed.”

“They’ll be done by the end of this week,” said Sergei. “I’m already making plans to start some of my tasks for Swift.”

“Yes; you guys are going out to get chondrite tonight, right?”

Will nodded. “Right after supper; we’ll be back by 10 p.m.”

“Take an extra hour tomorrow morning to rest, then.”

“When will we be able to make the first long distance expedition? We’ve taken the portahab out on several half day trips and people have been sleeping in it to test its life support systems. It seems ready to go.”

“You want to go to Aristarchus, right?”

Will nodded. “That’s the big, obvious expedition. The sun rises there on October 9<sup>th</sup> or a month later on November 7<sup>th</sup>. It’s at 23 degrees north; two thousand kilometers from here. We’ll need up to a week to get there, a week there, and up to a week to get back.”

“I think we’ll be in pretty good shape for you to leave about October 6 or 8,” agreed Armando.

“The landers won’t be cleared for use by then?” asked Ignacio.

Judith shook her head. “We need to test the system here a few times, including one launch and landing. We probably can’t complete the testing regime until December.”

“I don’t mind,” replied Will. “I lament the day when we’ll stop clearing trails and will fly everywhere. I love to watch the moonscape roll by.”

“Well, we can’t explore the whole moon that way from here,” said Judith.

“Oh, I agree,” said Will, with a smile.

They finished up their dinners, then Will and Sergei grabbed their suits and headed for ranger 1. They grabbed sledge hammers in case they wanted to break up boulders, and put a big metal bin on the trailer attached to the back of the ranger. Will jumped into the driver’s seat and began to undock from the station. “I know exactly where to go.”

Sergei smiled. "You're the Moonman."

Will began to move the vehicle forward and headed for Whipple Trail, which passed all their cryo units and solar power masts. At the time the sun was over the lunar far side, with horizontal rays illuminating hilltops and slight rises; dips and crater floors were in darkness.

About the time they passed Armstrong pad 1, Sergei said, "So, I take it you like Judith."

Will smiled. "She's pretty and has a great personality. But she's married and committed to her husband. I have no intention of breaking that up. That's what happened to me, last time I was here."

"I heard about that, and I'm sorry. But you were flirting a bit, weren't you?"

Will smiled, embarrassed. "I suppose I was. It was involuntary; I'm attracted to her. I suppose at this point, I'd like to think women are still attracted to me!"

Sergei laughed at that. "I know what you mean. My wife and I have a sort of agreement. I think you're right about Judith; she'll remain faithful to her husband. But Teresa is unmarried."

"Divorced."

"Yes, divorced. I'll see what I can do."

Will was startled by the admission and nodded. "Don't worry, I have no intention of 'moving in.'"

"Good." Sergei looked relieved. "I'll tell you, once you adjust to lunar gravity, sex here can be great."

"I'll keep that in mind." Will wasn't sure what else to say. Sergei heard the ambiguous tone in his voice and said, "So were you a 'good boy' growing up, Will?"

"I suppose I was! My older sister was the hellion."

Sergei chuckled at that. "I thought so."

They didn't say anything more for a while. They passed the landing pads and turned off Whipple Trail for a well-worn track in the regolith. In half an hour they reached Armstrong GA, a 600-meter diameter crater that had been blasted by a 60-meter carbonaceous chondrite comet nucleus 2.2 billion years earlier. Sergei drove to the outer rim and parked with the headlights shining up slope, so they could see what they were doing. "Let's go."

The men suited up, then went out through the airlock one at a time. They began picking up chunks and hauling them to the bin and dropping them in; Will was always amused that something that was probably deafeningly loud on Earth would be a silent on the moon.

"Not that one," said Sergei when Will lifted a boulder. "Too big. We'll start with rocks no bigger than a soccer ball."

"Okay." Will pointed to a rock Sergei had just dropped into the bin. "That piece isn't chondrite, by the way."

"Oh, thanks." Sergei picked up the rock, scrutinized it, then tossed it away.

It didn't take long to fill the bin. Serge swung a sledgehammer at a boulder nearby as an experiment and easily broke it into many pieces, then smashed some of the larger pieces. The carbonaceous chondrite was extremely easy to break apart. He brought a piece inside the ranger cabin with him and looked at it with gloved hands—because it was a hundred below zero—while Will drove them back to Peary.

"Very dark, this sample."

"It's carbon rich, but it was heated up upon impact and I suspect it partially devolatilized. It won't have a high water or hydrocarbon content."

"Good; that's what the outer hundred meters of Phobos is like. It's smashed and partially devolatilized chondrite. But this should still a few percent carbon compounds, right?"

Will nodded. “Something like that. I can run an analysis on it, if you want. It may be a percent or two water, too. So what does the device you have do? Heat it up?”

Sergei nodded. “That’s part of it. It’s a small prototype for one type of propellant production unit we hope to land on Phobos or Deimos in 2033. It has a grinder to reduce the regolith to pea-sized pieces, then they go into an oven where they are heated to several hundred degrees Celsius. The gas that is released is captured and separated into components—water, carbon dioxide, carbon monoxide, methane—and the water is electrolyzed. We can inject hydrogen into the oven and break down the carbon-rich material further to produce methane. We can even inject oxygen and burn off the carbon to make carbon dioxide.”

“Methane and oxygen being the primary propellant for Project Redstar.”

“Exactly, for landing on Mars, launching back to Mars orbit, and for trans-Earth injection afterwards. If the moons can supply propellant through automated systems, the entire transportation system becomes cheaper. That’s why Swift has a partnership with Roscosmos for the propellant making system. If NASA isn’t interested in participating, we certainly are.”

“I can imagine. This could be quite a breakthrough.”

“We think so, especially now that we have a rover on Phobos and samples returned from it. But the system with the most promise involves a deep drill, which we’re also working on. Moving regolith in nearly zero gravity is not easy, and we’d have to haul and grind up a hundred tonnes of it to make a few dozen tonnes of propellant. The Phobos lander can anchor itself firmly to the surface and deploy two drills able to penetrate at least fifty meters. There’s a good chance there’s disseminated ice in the regolith down there. But even if there isn’t, if we place a microwave probe into the shaft, we can heat the regolith in place and capture the volatiles that

drift up the shaft to the surface. We can even inject hydrogen or oxygen into the shaft and ‘cook’ the chondritic regolith in place. The oven I’ve brought here can test that process as well.”

“That sounds quite effective,” said Will. “I’m surprised I haven’t heard about that project.”

“It isn’t secret, but we aren’t publicizing it widely, either. Just before Northstar 6 arrives here, I’ll fly to the depot in the lander that goes up to bring them down. I’ll stay at the depot for a week and test the oven with chondrite there, in simulated Phobos gravity; very slight rotation of the depot is sufficient. Then I’ll fly back down here with them.”

“In the lander? It has room for only 6.”

“We can add a seventh seat.”

“Ah. Is that what you were referring to when you said the transportation system could become bigger?”

Sergei smiled and shook his head. “No, I’m afraid not.”

6.

Aristarchus

Early November 2030

“You lucky devil!” said Sergei. Will smiled, thinking Sergei was joking, but then realized he definitely was not.

“Hey, it’s logical,” he defended himself. “Teresa is the other geologist on this mission, so it makes sense we’d both go on this expedition. She has studied Aristarchus extensively; her publications are excellent. And someone has to go along as mechanic and engineer. Judith specialized in rangers and knows the portahab well.”

“So do I!” replied Sergei. “At least, leave one of the women here! I won’t have anyone to look at for two to three weeks!”

Will smiled at that. “And I’ll have two to look at. But Armando’s the one to complain to, not me. I didn’t ask for the crew; he assigned them.”

“I know. But I won’t say anything to him. It’d be an unprofessional objection, damn it.”

Will smiled at that, too.

“So, you like Judith and will at least be able look at her, but of course, she won’t do anything with you—or any other man here—because she’s married, and Teresa if anything likes you, but you don’t seem to like her—”

“No, she doesn’t seem like my type—”

“Fair enough.” Sergei dropped the matter as quickly as he brought it up. He beckoned to Will to hold up a “Mars jacket,” so Will picked one up and unzipped the huge pocket that opened across the shoulders and extended most of the way down to the waist. Sergei dipped a big trowel into a bucket of nickel-iron fragments—they had accumulated almost five hundred kilos of the

stuff over two months of local expeditions—filled the trowel, and poured it into the pocket. Will shook the jacket to settle the fragments into the bottom, then Sergei added more.

“I hope the nickel-iron doesn’t produce a lot of cosmic ray secondaries.”

“They say it won’t raise your radiation count. But admittedly, down by the waist, it’s not a good spot for radiation.”

“At least it’s in back and not in front.”

“I’m wondering how sweaty these jackets will be.”

They stopped and weighed the jacket after three scoops. Eleven kilos. Will massed 79 kilos, so they needed 109 kilos of nickel-iron to raise his apparent “weight” to what his bones would feel on Mars. Sergei added twenty more scoops and they were almost there. They added one more, then Will shook the jacket one more time, zipped up the opening on the shoulders, and put it on.

“Yuck! It feels so heavy!”

“And just think, on Earth you actually weigh 2.6 times more than this. Mars is 2.4 times more than on the moon and Earth is six times more than the moon.”

“There’s a certain symmetry to that.” He walked across the room with the jacket on, turned, and walked back. “My bones will experience Martian ‘gravity’ this way, but of course my muscles are accelerating and decelerating 2.3 times as much mass as before. That may get tiring.”

“I know. We’ll give it a try and see. I suspect we’ll want to cut the mass in half and add some bouncing exercises or something.”



“These things are going to be sweaty.” Will sat in his chair and moved around. “But they started the pocket high enough so that the weight doesn’t rest on the seat, so my shoulders and bones are still experiencing the full load.”

“Good. Walking will be easier, in one way; we’ll have better traction. Smooth floors feel almost slippery in lunar gravity. Let’s get the other ones filled up as well.”

Will nodded and picked Sergei’s jacket. His mass was 82 kilos, so they put about 113 kilos in his jacket. He stood, walked around, complained about it, then sat and they filled the “Mars jackets” for Judith, Teresa, Armando, and Ignacio. When they finished, the bucket of nickel-iron fragments was nearly empty. “We had just enough,” said Sergei.

“I’m glad we won’t have to wear these on the trip to Aristarchus.”

“No, just around the station. But when you go outside, you’re wearing a suit and it masses almost this much anyway.”

“It feels like wearing a suit.”

“It does. They say Martian pressure suits will be much lighter. Just as well, in the greater gravity.”

Will nodded at that. He picked up two suits and Sergei picked up the other two. It was a strain in lunar gravity; they were lifting almost 300 kilograms or 660 pounds of mass. The weight was only a sixth as much in lunar gravity, so it was manageable, but when they started forward or stopped they still had to accelerate and decelerate 300 kilos of mass, and that meant they had to move slowly. “It’s like we’re carrying a copy of ourselves and a copy of two of our colleagues on our shoulders!” laughed Will.

“That’s for sure!” grunted Sergei in reply.

They carried the suits from the geology lab in the basement of shelter 2 through the airlock and tunnel into the Lunotel. The spiral stair to the upper level was a nightmare; they went very slowly and lifted the mass one careful, measured step at a time. At the top, Sergei called. Armando and Teresa hurried over.

“You’ve got them!” said Armando, running. Sergei handed him his jacket and he put it on with a note of triumph.

“Welcome to Mars,” quipped Will.

Armando chuckled. “Thank you. We’ve been studying bone decalcification and other changes in lunar gravity for two years, now, and we know that it can be minimized and slowed pretty well, especially with the right exercises. I hope you all can tolerate these coats for most of your daytime activities for the next month or so. We’ve got your baseline measurements on Earth and after two months of lunar gravity. If the theory is right, bone loss will slow even more or possibly reverse under simulated Martian gravity.”

“Wow!” said Teresa, taking her jacket from Will. She put it on and groaned.

“It’s hard to believe we weigh more than twice as much as this on Earth,” noted Will.

“On Earth, our weight doesn’t press down on our shoulders!” said Teresa.

“It’s a pain in the ass,” added Sergei.

“But for science,” said Armando, raising a finger. “Be careful with your backs, especially bending down to pick something up. You’re accelerating 2.4 times your body mass and you could pull a muscle. I suspect we’ll have to switch to lighter jackets and do jumping exercises.”

“If we jump up and down in the shelter 2 stair well for twenty minutes a day, that may equal Martian gravity,” said Sergei, citing a study they were all familiar with.

“Perhaps, but these jackets are the way to test that theory,” replied Armando. “Where steady vertical force on our skeletal structure is concerned, this is the gold standard, because it is exact. The problem is the need to move about, and we have to do that, too. I’m sure none of you want to carry five times your body mass around to simulate terrestrial gravity!”

“No, definitely not!” replied Teresa.

“I came close to that, coming up the stairs, and can assure everyone we don’t want to do that,” said Will. Armando picked up Ignacio’s jacket and Will picked up Judith’s and they walked to the galley, where the two of them were cooking bread; the crew had gotten used to cooking real food and did it two or three times a week. The other two crew members paused to put on their “Mars jackets” and the usual round of comments and complaints followed. When everyone was satisfied the issues had been aired again, the four of them left the kitchen crew and sat at the dinner table. Teresa turned to Will. “So, did you see the latest gravity measurements for the Schroeder Plateau?”

“Yes; quite interesting. The seismometer network we set up will provide some important data on crustal thickness and density.”

“We just got permission today to set off some explosives, too,” said Teresa, with a smile. “That should be fun!”

“Bombs away on the moon,” agreed Will, chuckling.

She laughed a little, as well. “I’m looking forward to this expedition with you.” She smiled.

“I’m looking forward to it, too.” He smiled back, wondering how much to encourage her. There was something about her that he didn’t like, but he couldn’t put his finger on it. Maybe he’d get over it. Like him, she was divorced.

The kitchen crew came out with lasagna fresh from one oven and a loaf of warm bread from another oven, so everyone sat to eat supper. Armando and Ignacio chatted in Spanish, much to Sergei's irritation; he would become the linguistic minority once the expedition departed and he was not happy with it. Teresa and Judith talked about portahab issues; it had been leaking air through one airlock and it was clear that lunar dust had to be cleared from the doorframe carefully each time to avoid the issue. Ranger 1 would be towing the portahab; ranger 2 had a trailer with 2 TROVs, 2 portable cryo units, and three sets of hydrogen and oxygen tanks, each holding 1.5 tonnes of propellant. With the one tonne of propellant that each vehicle carried in its internal tanks, they had enough propellant—without use of solar energy—for the two rangers and their loads to travel a bit over 2,000 kilometers. That would get them to Aristarchus, but the cryo units had to take the resulting water and convert it back into hydrogen and oxygen using solar panels to get them back.

“So, we have the final permission,” Will said to Armando at one point, so the commander could confirm the latest information from Mission Control.

“Yes, indeed. They apologized again that they had vetoed the October departure, but I think we can all agree that the additional testing of the landers and their deployable ramp system was wise.”

“Yes, we have more workarounds if there are problems,” said Judith.

“Exactly. If you all have a problem, we can't fly a lander down to rescue you and leave the rangers and the portahab out in the middle of nowhere! Now we have a very high level of confidence that the ramps can be deployed and the vehicles can be moved up on top of the landers for the flight back here. Mission control has said that, tentatively, we can schedule our first expedition using them in January.”

“Not December?” asked Will.

“There’s a little more testing to do, but we’ll have tourists here in early December and Northstar 6 arrives in late December, so we’ll be pretty busy. We can’t have a crisis at those times, either.”

“That’s for sure,” agreed Sergei.

Armando turned to Sergei. “So, volatile transporter 3 is now upgraded?”

“I need another day to complete the replacement of the shovel with the new bucket able to handle 20 Kelvin. The americium heaters have been deployed around the motors to keep them within temperature limits and the wheels have been upgraded. Maybe tomorrow night we can drive it over to Armstrong RJ and scoop up some of the really cold stuff, as a test.”

“If you have time, let’s do that. How much methane do we have in storage now?”

“I think it’s now 8.3 tonnes, which is a pretty good supply. We should be able to get production up to 30 tonnes per year by January.”

“That’s good news. Methane production should help reduce our oxygen surplus.”

Sergei nodded. Water was only 1/9 hydrogen by weight, but the hydrogen/oxygen propellant their rockets used was 1/7 hydrogen by weight, because a hydrogen-enriched exhaust protected the engines from oxidation and had a lower overall atomic mass, and therefore a higher exhaust velocity. But that meant their water electrolysis produced a large oxygen surplus. Extracting carbon dioxide from the volatiles didn’t help, but obtaining methane and other longer hydrocarbons did. “The chondrite digester is getting more efficient as well; we’ve now gone through almost a tonne of the stuff, mostly using heated hydrogen, and we’ve extracted nearly ten percent by weight carbon. If we can find some large chondrite masses, that’ll boost our carbon production quite nicely.”

“But what is the need for all this methane?” asked Will. The lunar landers used hydrogen-oxygen propellant.

Sergei smiled. “The Gryphon capsule that lands in January or February or March—we’ll see!—uses methane and oxygen propellant, because that’s what it needs to land on Mars.”

“How many test flights are you preparing for?” asked Will.

“One; for that, it needs seven tonnes of methane and twenty-five tonnes of oxygen, half for landing and half for the launch back to Earth. But the Gryphon is a potential replacement for the Polaris for flights to the moon.”

“Oh?” said Will.

“How many can it accommodate?” asked Judith.

Sergei shrugged. “We’ll see, but the capsule is twice as large as the Polaris.”

Will nodded, startled by that thought.

They finished eating supper silently, considering the implications for the future. Will put his dirty dishes in the sink—Armando was on cleanup duty that evening—and headed to his room to finish packing. It didn’t take long because he was bringing all of his uniforms and underclothing; they’d be gone up to three weeks and would be running the clothes washer/drier on board the portahab quite often. He walked to ranger 1 and put them in the cab, then headed to the galley to see what additional food needed to be brought on board. He was looking around for the fresh bread when Judith came along.

“Is the bread in the portahab already?” he asked her.

“I just took it there. But Will, I see you put your stuff in the cab of ranger 1. Ranger 1 will be the vehicle for Teresa and myself. You’ll be in ranger 2.”

“That’s fine, but I was in a hurry to put things down so I could help finish the loading, and didn’t want to pass through three airlocks to get to ranger 2.”

“Okay, I understand.” She looked at him. “I assume we’ll have a professional relationship on this expedition?”

“You have nothing to worry about, Judith. My marital bond was violated and it caused great pain to me. I have no intention of causing such pain to anyone else. Our relationship is strictly professional.”

She nodded, satisfied. “Thank you.”

“I’d prefer that you and Teresa have the portahab. I sense she’s attracted to me, perhaps a little bit. But I am not someone who believes in casual physical relationships.”

“I wish more people felt that way. I apologize for bringing up the matter.”

“No, that’s fine.” He looked around. “Anything else here that needs to go?”

She shook her head. “No, I got everything before supper and took the bread to my room so I could get my luggage.”

“Good.” He turned and headed for the stairs, with Judith next to him. “So, do you need a primer about the geology of Aristarchus and the Schroeder Valley?”

“Well, I’ve got the basics. Aristarchus is one of the freshest large craters on the moon, age about 400 million years. The Aristarchus plateau next to it appears to be a tilted and uplifted crustal block up to 2 kilometers above the surrounding Oceanus Procellarum. Schroeder’s Valley is an enormous volcanic rille some 160 kilometers long and 1 to 10 kilometers wide, issuing from a large volcanic crater. It is the site of many transient events; probably the release of volcanic gasses.”

“Exactly, including just two years ago. It may be the only place on the moon where there’s any volcanic activity at all, so it’s quite interesting and important. The area is also rich in ilmenite, an important iron-titanium mineral, and may have sulfur deposits.”

“And very diverse volcanic features.”

“Yes. So we have a lot to investigate. The seismometer and sensor network we deploy may provide very important data.”

“It’s an exciting mission and I’m honored to be in command. But I’ll need your help to figure out what we do.”

“It’ll be a three way conversation.”

They reached the docking port where ranger 1 was docked and entered. Will grabbed his bag and followed Judith into the portahab, where Teresa was already unpacking. She smiled and nodded at him. “Let’s have a quick discussion,” Will suggested. “I’ll take ranger 2; the two of you will have ranger 1 and the portahab. Judith and I already had a discussion about that.”

“Oh?” said Teresa. Then she nodded.

“But I suggest that we usually leave ranger 2 on automatic drive, 75 meters behind ranger 1,” Will continued. “That way, only 1 of us needs to drive at any particular time. We’ll want to rotate that. We’ll want to dock together for lunch and supper anyway, so we can rotate drivers at mealtimes.”

“That sounds good,” agreed Judith.

“Alright,” said Teresa. “Have you been down the Sinus Roris Trail?”

Will shook his head. “No, only by TROV. Northstar 3 made it and Northstar 4 lengthened it. I’m looking forward to seeing it as well.”



“Shall we get started, then?” asked Judith, looking at the others. They both nodded.  
“Good. Then let’s go back inside to say good bye to our colleagues and head out!”

-----

Dorinda Stetson hated to be kept waiting, especially when she was mad. But Zeke Swift would not accommodate the Administrator of NASA right away. “Sorry for the delay, Dorinda, but I had a very important meeting,” he finally said.

“I have a few of them today, too, Zeke,” she replied. “But I’m concerned about breach of contract. When are you planning to fly passengers to the moon with a Gryphon capsule?”

Swift was startled by the comment. Dorinda scrutinized the image of his face closely to see what truths might be hiding there. “I don’t know,” he finally said. “But I can tell you that because last month’s flight to Pax Hotel was flawless, we will start tourist flights with the Gryphon in May. It’ll accommodate seven tourists and a pilot initially, but once we’re confident, we’ll raise the capacity to eighteen tourists and a crew of two. Pax plans to add another inflatable.”

“Yes, and that’s why I asked. And the moon?”

“We’ll see how the test flight goes this winter, but there’s no reason to fly Polaris capsules to the moon with six when a Gryphon can accommodate 12.”

“*Twelve?*”

“Twelve. And the price will go down. NASA will be able to fly three astronauts for the price of two, most likely.”

“And the Chinese? I assume the exclusion clause for Polaris will apply to Gryphon!”

“I hadn’t assumed that, Dorinda. Do you want to extend the NASA contract to state that? If so, we’ll need to increase the number of astronauts you’ll fly. I doubt you want Peary to have just two Americans and ten others: Arabs, Indians, Africans, Latin Americans, Russians . . .”

“I don’t know why you keep wanting to push the expansion of the moon when your goal is Mars.”

“It’s very simple economics. When we send the Gryphon to Mars, I want it to have a lot of flight experience. How do we do that? Tourists. If we fly twenty to orbit at a time, we can give them a good experience for maybe three million bucks. If we can fly twelve of them to the moon at a time, it’s cheaper than flying six, so more of them will go. And that means nations will fly more astronauts there. I can develop the Gryphon for Mars and make it pay for itself. I don’t even need to draw off my extensive profits from launching satellites to orbit more cheaply than anyone else in the world.”

“I’ll agree with you there.” Stetson sighed. “Okay, have your lawyers contact our lawyers. Let’s modify the contract.”

-----

The trail to Sinus Roris or the “Bay of Dew” was 1,250 kilometers long and the rangers were programmed to use GPS to follow it automatically, so the three of them set out to the beginning of the trail, activated the software, and set the speed at 35 kilometers per hour; the maximum that was recommended for automated driving on a well-known trail. There was little for them to do, over the next 36 hours; the vehicles moved forward without human monitoring. There was also relatively little to see because the sun had not yet risen, though the 1/3 full earth shed some twenty times more light than a full moon did on Earth. When they weren’t looking out the

windows at the craters and rolling hills, they drove TROVs or assisted with work at Peary Station via satellite link. There was plenty to do and no time to waste.

About the time they finished breakfast on their second day, the trail descended off the highlands and onto the basaltic lava plains of Sinus Roris. In another dozen kilometers they reached Cache #1, a solar-powered refueling station. Will, in ranger 2, approached the station from the north while Judith approached it from the south, and they flooded it with their headlights. Then the three of them suited up and exited.

“It’s good to go outside, finally,” said Will, as he came around to the refueling unit. “We should have brought some of the exercise equipment!”

“Yes, one can’t jog in place for very long,” agreed Judith. She pointed to a hillock about ten meters south of the refueling unit. “You were thinking we’d set up the second unit there?”

“Yes. The two of them won’t shade each other, and the hillock gives a tiny bit more solar exposure.”

“Alright, let’s get the water transfer started and then get the unit deployed.”

“I’ll transfer the water,” said Teresa. She walked back to ranger 1, which now had 1,900 kilograms of water, the product of their long automated drive. It would take the refueling unit and its 25 kilowatts of continuous solar power two weeks to convert it to hydrogen and oxygen for the trip back. Ranger 2 had a similar quantity of water, but it would go to the new unit they were setting up.

Will stepped back inside the ranger and backed it up to the hillock, then he and Judith carefully maneuvered the refueling unit off the trailer. It consisted of a mast on top of which were two closed solar panels; a water tank; a compact electrolysis unit; a cryogenic refrigerator; and tanks for liquid oxygen and hydrogen. The bulk of the 600 kilograms of mass consisted of

the tanks. The unit was on a platform with wide, tall wheels that rolled off the trailer and immediately sank into the regolith, in spite of the design. They struggled for fifteen minutes to orient and position the unit, and it took Teresa's additional assistance to complete its placement. Once it was in place, Will attached ranger 2's waste water hose to the unit and began the transfer of 1,900 kilos of water to the unit while Judith ran through the deployment tests. They couldn't raise the solar power mast or deploy the panels until the unit had "ballast" to keep it from being top heavy. To ensure its balance when the water and propellant tanks were largely empty, Will and Teresa began hauling rocks over and piling them on the platform.

"How much did you do tasks like this on Northstar 2?" she asked him, placing a big rock on the front of the unit's trailer.

"Just about every day. Surface Geology is about one third field work and 2/3 everything else!"

"You have to be patient to do it."

"Of course, like everything else in life."

Teresa laughed at that. "You're right about that. I'm excited to reach the maria, finally! It's quite different in character from the highlands."

"It sure is: flatter, smoother, less pummeled, and noticeably darker, once we have sunlight anyway."

Teresa pointed towards the eastern horizon, where the solar corona and its streamers were prominent. "It won't be long, now. Isn't the sunrise glorious?"

"It is. You don't need an atmosphere to have dawn beauty. We have the beauty visible in a solar eclipse instead."

“That’s one of the spectacles of Peary,” agreed Teresa. When the sun is just below the horizon, the corona is quite a spectacular sight. The tourists should love it.”

“I agree. And we should be able to do some pretty good field geology today; there’s a very fresh crater a dozen kilometers to the south of here.”

“It’ll give us good stratigraphy,” she agreed.

They piled more rocks on the trailer; it was amazing how easy it was to pick up really big ones—boulders—and carry them over. When the trailer was piled high, Judith said, “Can we raise the mast and open the panels now? Because everything checks out.”

“We’re finished, I think,” replied Will.

“Okay, let’s see whether the batteries have enough charge.” Judith pushed some buttons on a tablet computer—she used a stylus because her gloved fingers were too fat—and a moment later, the mast began to rise. They watched with delight as it extended higher and higher until, after five minutes, it reached its full height of five meters above the platform. They she pushed another button to deploy the solar array.

Slowly, the compact bundles on the right and left sides of the mast began to unroll. Air tubes in them pressurized and forced them open, but once exposed to sunlight the plastic would stiffen, so the panels could not roll up again. The panels opened about six meters to the right and left, then a bottom set folded downward into place, and finally a top set folded upward. The final results were two hexagons six meters across facing the eastern dawn, awaiting the sun.

“Hey, look, there’s sun on the very top!” said Teresa, noticing a glint off the tops of the arrays. Will turned east and saw the fierce glow of the solar atmosphere just above the sun itself, almost too bright to look at. The landscape was now more brightly illumined by the dawning sun than by the waning Earth.

And then the topmost bit of the sun peeked above the horizon, and they immediately had to look away because of its dazzling intensity. The moonscape around them was suddenly ablaze with light and the Earthlight seemed to fade into obscurity.

“What a special moment,” said Judith. She looked west across the rolling terrain, now illumined by the day. Looking east, though, there were still many dark shadows to be seen.

“It really is,” agreed Teresa. “The moon has its special moments, doesn’t it?”

7.

## Tourists

Early December 2030

“I couldn’t believe how big that explosion was! Boom!” exclaimed Teresa, with a laugh.

“Yeah, we felt it inside the ranger through the ground!” added Will.

“You did?” said Armando, putting down his fork. “I’m amazed.”

“Who would have believed that lamp black mixed with liquid oxygen would be so incredibly powerful?” said Will. “And with the automated mixing mechanism, so safe. It blew a crater two meters in diameter and almost a meter deep. But it did trigger that gas release from a nearby vent, so we were lucky.”

“And got really excellent seismological measurements,” added Teresa.

“I’m not sure we can say the moon is volcanically active though, if we have to set off an explosion to get some venting!” replied Sergei, with a chuckle.

“Oh I agree; we agree,” said Will, looking at Teresa, his fellow geologist. “But we can say that the moon isn’t completely dead, either. The cooling of the magma ocean, after the moon’s formation, concentrated radioactive elements under Oceanus Procellarum and Mare Imbrium, and they provided the heat for the very last igneous activity: the Aristarchus Plateau and its volcanism. That’s why the KREEP basalt is concentrated there, and the gas releases have radioactive radon in them, which has been detectable from lunar orbit.”

“Aristarchus has been the source of some of the sulfur gases in the polar volatiles, too,” added Teresa. “It’s ironic that we can prove the moon has very limited volcanic activity currently, but we still have no evidence of similar activity on Mars. Not yet, anyway.”

“It’s a matter of time,” agreed Will.

“Aesthetically, it was quite a trip as well,” said Judith. “Schroeder’s Valley is quite impressive; deep and wide, with cliffs heaped over with regolith. Looking into Aristarchus from the rim was stunning. I know the geologists got some excellent measurements and recovered a lot of crucial samples, but visually it was a spectacular trip as well.”

“Bitten by the bug?” asked Will.

Judith smiled. “Yes.”

“Well, it’ll be the turn of others next,” said Armando. “We’re glad you’re back, safe and sound. I guess you have a month of sample analysis to do, right, Will?”

“Oh, yes! We have a lot of samples to run through the mass spectrometer. A lot of dates to determine.”

“Good. Before that’s finished, the tourists arrive; their launch is tomorrow and they’ll be here in four days. Judith, will the rangers be ready by then?”

Judith nodded. “Sure. There’s a lot of maintenance, but nothing unusual. They went 4,500 kilometers quite well.”

“A record; three weeks and 4,500 kilometers,” said Will. “I doubt anyone will drive that far on the moon again, any time soon.”

“The use of the landers will render the need for trails obsolete,” agreed Ignacio.

“It’s a shame,” said Will. “I like these long distance expeditions. But I suppose the landers may be safer, and certainly they’ll be faster.”

“Four thousand kilometers is a long way to drive,” said Teresa. “It wasn’t bad, going down; we stopped every day to explore something and it was all new. But coming back was long and tiring.”



“I agree,” said Will. “But if we establish more refueling caches, and if faster automated speeds are possible—fifty kilometers per hour should be safe on well-known and carefully placed trails—then one could drive from pole to pole in five days and reach the equator in two and a half. That wouldn’t be so bad.”

“And it may be as safe as landers,” conceded Sergei. “We’ll have to see which technology develops more.”

“In the future,” said Armando. “Back to the present. The rangers will be ready. Will and Teresa, you’ve developed the tourist itineraries, so you’ll be taking them out?”

“Yes, with Sergei and Ignacio,” replied Will. “They’ll go to the cairn at the North Pole, to the bottom of Whipple Crater to see the delicate volatile structures there, across the Armstrong Plateau, along North Ridge, down into Peary . . . we have quite a set of tours planned.”

“We have no special instructions regarding the Chinese tourist?” asked Sergei. He seemed to want some.

Armando shook his head. “No, no instructions. Dr. Li is an executive of a company that manufactures rocket engines and is traveling here on his own money. He’s not a taikonaut. China has its own moon program and there may very well be taikonauts on the moon in a few years; they have pledged to develop a lander of their own, as you may have heard, though they’ll probably buy our propellant and fuel up at our orbital depot! NASA’s policy is to welcome them warmly and cooperate once they arrive.”

“That’s good to hear,” said Ignacio, though he sounded skeptical.

Armando shrugged. “I understand the European Space Agency is in a more cooperative mood than NASA, shall we say. But the six of us are up here on the moon. We’ll have to leave the politics to our politicians.”

“That’s true,” agreed Ignacio.

That ended the conversation. People began to take their dishes to the galley and place them in the sink. Will was on clean-up duty, so he began to load the dish washer. Sergei wandered in with his plate and cutlery last. “So, how have the Mars jackets worked out?”

Sergei shrugged. “They’re a pain; you guys were lucky to leave when you did! I suspect we’ll take them off when the tourists arrive. That’ll be just about four weeks of data on the three of us who stayed here and mostly stayed inside, since we didn’t have any big vehicles with us. Armando says the levels of calcium in our blood and urine suggests that decalcification will be slower on Mars than on the moon, and of course here it is slower than in zero gee. So all of that is good news. Vertical exercise—leaping—put a lot of necessary strain on bones and strengthens muscles quite well. Clearly people can stay on the moon for lengthy periods of time; certainly a year, probably two with proper exercise—though who would want to?”

“That’s the bigger question, but as this place grows, it’ll be more enjoyable,” said Will. “On the other hand, I can’t imagine anyone would want to raise kids here; the gravity can’t be good for children.”

“We’ll have to raise some chickens and rabbits and see what happens with them,” replied Sergei. “I guess they’re talking about that experiment in another year or two, especially if this place grows beyond six.”

“We can’t be experimenting with lab rats if there are only six of us up here,” agreed Will. “But with the Gryphon coming into service, that may change. Say: how did social relations work out here, with you, Armando, and Ignacio?”

“Just fine. The first time the two of them began to chat in Spanish at breakfast, I complained bitterly that it wasn’t fair on me and if we ever get two Russian speakers up here,

they'd feel pretty left out if we spoke all the time in Russian. So they switch to English whenever we were eating together. That helped a lot.”

“Good, I’m relieved.”

Sergei nodded. “And what about you, Teresa, and Judith?”

“That worked out fine, too. Once it was established that Teresa and Judith would always be sleeping in the portahab and I’d always be sleeping in ranger 2, we all had our private spaces and had a good rhythm established. The trip was very sociable and pleasant.”

“Good, glad to hear it. The six of us are becoming a team, then.”

Will nodded. “Bit by bit.”

-----

“Welcome to Peary Station!” Will exclaimed, as the first tourist came through the exit tunnel from the lander. It was Abdullah Sistani, a banker from Qatar.

“Thank you, thank you! Lunar gravity is quite something!” He moved to jump upward a bit and Will put his hand out to catch Sistani’s shoulder, before the man banged his head against the ceiling. His garment bag floated upward and bumped into Will.

“Wait until you’re inside; we’ve got a few spots with very high ceilings.” Will pointed to the two benches running along both sides of the portahab, then turned to Jacob Lawrence, a very successful software engineer and entrepreneur. “Welcome to Peary, Dr. Lawrence.”

“Thank you; call me Jake, and I hope I can call you Will.”

“Certainly. I seem to be acting as chief tourist guide for the next ten days!” He pointed to the bench and turned to Patricia Caputo, President of a successful for-profit online university that she had started. “Welcome to Peary Station! I hope you’ll enjoy your time with us.”

“Thank you, Dr. Elliott.” She seemed distinctly cool and a bit unhappy. “I hope this will be an enjoyable stay as well.”

Will turned back to the tunnel; Guiren Li, the rocket engine executive, was next. Will was surprised he was so young; perhaps 25. “Welcome to Peary Station, Mr. Li. I hope you have a good flight.”

“Thank you.” Li extended his hand and they shook. “Yes, it was a good flight. Please call me Guiren; or if you prefer, Gordon.”

“Guir . . . Gordon,” replied Will, with a smile, unable to pronounce the Chinese “r” correctly. “Is that a Chinese spacesuit you’re wearing?”

“It is indeed!” he replied, pleased that Will noticed.

Will pointed to the bench and turned to the next arrival, Jerome Lamoreaux. “Welcome, Chef Lamoreaux. I look forward to learning a few culinary secrets from you.”

“And I from you! You have pioneered lunar cooking!” They shook hands. “I wish I could stay and experiment, but it appears that it won’t be possible.”

“It’s a shame, lunar cooking will take some time to perfect.” Will pointed to the bench and turned back to the tunnel. “Captain Pregill, I presume,” he said with a smile, because he knew George Pregill from Houston.

“Good to see you again, Will!” They shook hands. “So, you’re the tourist guide, I heard you say.”

“I seem to have been nominated as *chief* tourist guide, but all of us will be involved. Sit, please, and let me close the tunnel.” Will turned to the entrance and closed the hatch firmly, tested it, then called to Sergei to detach it. A moment later he did so, then Judith, who was in the driver seat up front, started them forward. Will held onto a railing as they bounced along. “As I

said already, welcome to Peary Station; more specifically, *to the moon*. You are the 40<sup>th</sup> through the 45<sup>th</sup> human beings to land on the Earth's sister world. Twelve Apollo astronauts came here, sixty years ago; as you know, they have all passed away now. Northstars 1 through 5 have brought thirty more, but three of us have been here, or are here, for the second time, so Northstar 5 brought the total up to 39. This precious privilege may become commonplace someday, but it hasn't yet, so we offer you an especially warm and excited welcome and hope our hospitality will be adequate. We don't get a chance to show folks around, and we're excited to have the chance to do so."

"We'll have full run of the station, right?" asked Jake, glancing at Gordon, who probably had wanted to ask the question.

"Absolutely; there is no secret spot, nothing classified. You all have gone through training with suits and such, so as you know, no one goes outside alone. But you are free to go outside, first accompanied by one of us for the first week, after that with any other one of you. With GPS, you can't get lost, and we'll show you around enough so you will know basically where you can go. Later today we'll go out for two hours, maybe longer, to do a walking tour of our cryo units and other equipment; the equipment that produces the propellant and makes this tourist program possible."

"Can you show us your lab? I'd love to see your work," said Patricia.

"Certainly; glad to do it. We'll sit and answer questions for half an hour every day after supper, too. There are a lot of stories we can tell."

"Could you tell us the story of Northstar 2's landing?" asked Patricia. "I was surprised how abrupt it was!"

“Landings don’t take long,” agreed Will. He began to speak about his own experience, almost two years earlier; it seemed impossible that it had been so long ago. Before they finished, they heard the series of clangs that marked magnetic docking, followed by other clangs that indicated a hard dock. Will spoke to Armando, who was operating the docking controls inside, and they verified the hard docking and pressurization. Will opened the hatch and gestured to the others to enter Peary. As soon as they were inside and clustered around Armando, he pushed past them and headed for the atrium, where Teresa and Ignacio were busy with the welcoming dinner.

“I hope I didn’t ruin the dip,” Teresa said. “I never should have let you talk me into this!”

Will glanced at the sour cream and onion dip; the onions were a bit dark, but not too much. He tasted. “No, it’s fine. You guys did great.”

“It’s a waste of our time, though,” said Ignacio.

“Is it? The tourists make moon flight and residence cheaper, and that makes exploration and development easier. Long term, this is an important aspect of what we’re trying to do.”

“Well, I suppose that’s true,” agreed Ignacio reluctantly.

“It’s amazing to think that tourists are coming here just two and a half years after the first astronauts,” said Teresa.

“That’s because private initiative also made our arrival possible,” said Will. “Private initiative cut the cost of access to low Earth orbit tenfold over the last fifteen years and made all sorts of things possible.”

“Including Mars,” agreed Ignacio.

-----

They let the tourists rest a while, then gave them a grand mid-afternoon meal. Jerome Lamoreaux took him aside after the toasts and welcoming speeches were over. “This meal was

fantastic, by the way,” he began. “And now you have set the bar very high for this professional cook with fifteen years of cooking experience in some of the best restaurants in Paris. I’m not sure I even know how to boil water here! And the tasting is very complicated, in the lower atmospheric pressure!”

“It takes some time to adjust. Perhaps I had the advantage of ignorance! I didn’t dare trust my intuition because it wasn’t very good anyway, so I had to rely on charts.”

“And I have those charts, which I understand you have adjusted over time.”

Will nodded. “Yes; I found that things cook a bit faster than the charts suggest, for example, when boiling and baking. I don’t know why. Frying is the safest because oil boils at about the same temperature in one third of an atmosphere of pressure as at sea level. With boiling, you taste it periodically. Things that rise, rise faster and will fall if you cook them the usual length of time. I’ve figured out breads pretty well, but soufflés are still impossible!”

“I will make that a challenge. Can you stay and help me with dinner? I need help to find my way around the galley anyway, and I have a lot of important items to add to storage.”

“I saw the list. The tourists will eat well!”

“They had better; they’re spending thirty-five million dollars for the privilege of going to the moon. The in-flight food was ghastly and there’s not a lot we can do about that—not yet!—but on the moon, at least, culinary science can progress quickly.”

“Yes, we have gravity and a moon-full of oxygen, water, and other resources here. Come see the galley.”

“Thank you.” Jerome followed Will into the circular enclosure in the center of the atrium.

“It isn’t much; lots of storage high up and low down, a lot of counter space, a six-burner stove, two electric ovens and a microwave, and a generous sink. But you should have seen what

we started with in shelter 1! Two hotplates, a microwave oven, and a spare geological oven that didn't set a temperature very well!"

"I'm glad I don't have to deal with that!" Jerome looked around. "I can manage with this. Definitely. And you have how much food? Six month's supply?"

"More like twelve months, and for nine people, not six. But most of it is of the precooked, frozen variety; sophisticated tv dinners. Flour, rice, potatoes, fresh vegetables, fresh fruits; these are in much more limited supply."

"That's what I thought. But even precooked, frozen foods can be jazzed up with the right spices, and I have the right spices." He said that with considerable confidence.

Will chuckled at that. "I will gladly turn this galley over to you, then! And I can assist sometimes, I'd like to learn."

"Good, I'd love the company." Jerome smiled secretly. "Polaris 1 is here for two weeks, and I'm scheduled to leave with them. But I'll tell you what I really want: to stay! I told Zeke Swift that just before I left and he smiled mysteriously at the idea. I think he was intrigued." He shrugged. "Someone needs to stay at the Lunotel and watch over its interests, eh? Who better than the chef? That's the biggest job! The robot cleaner cleans the floors and the tourists have to make their own beds."

"We would *love* to have you here. First of all, six is a rather small contingent; we could use the company. Second, as you know, nothing makes a mission like this better than good food!"

"Yes, food and sex. I suppose there's not much of the latter around here." He leaned in closer. "I'm gay."



“Well, I can’t help you with that; I’m not sure anyone up here can at the moment. Have you talked to Armando about staying?”

“No; do you think I should? I don’t need anyone’s permission except Swift’s. I suppose I’d need permission of the President of Lunotel, Inc., as well, but Swift is a big partner and controls the transportation, so he’s the man.”

“I’d let Armando know. It’s not like you’d strain our resources. This place is designed to accommodate up to twenty and has plenty of food. I don’t even know how many flights per year we’ll be getting, now; five or six with people and three or four with supplies? Flying up consumables for you would be ten times cheaper than flying up a replacement!”

“That’s for sure. I’m glad I asked you! It’s good to have an ally.”

“An ally and a friend, Jerome,” replied Will.

Jerome nodded in thanks. Judith came into the galley. “Will, can you take care of clean-up for me? I think I need to accompany President Caputo on the walking tour outside.” She glanced at Jerome nervously.

“Sure. In fact, can you lead the tour? Jerome has asked me to help him with supper.”

“Oh, sure, I can do that.”

“Patricia has been hit upon by two of the gentlemen,” injected Jerome. “A Polaris capsule is pretty cramped, for a woman to have any privacy. Captain Pregill had to say something.”

“And he may not have said enough,” added Judith. “I plan to speak to Armando about it. She’s the only woman on the flight and is relieved that Teresa and I are here!”

“I can understand that,” said Will. “Tell her to ask me about speaking to some of her online classes. I can’t promise to teach anything, but some of us can do live video sessions for her university. That may improve her experience.”

“Good idea. Thanks. They do classes in Spanish as well; I bet Ignacio would enjoy that.”

Judith hurried away. Will turned to Jerome. “Looks like you’ve got me for the entire afternoon.”

“Great!”

-----

Zeke Swift was not surprised that Dorinda Stetson had called; he was surprised that it took her so long, however. “Good afternoon, Dorinda. I hope you have a copy of our 250-page memorandum of understanding and 26 appendices with you. I can call in my lawyer and our copy, if you want.”

“Zeke, were you out of your mind? You’re an American citizen. Yes, this is your adopted home country, but you are a patriotic American. Wasn’t I clear about our concerns about the ambitions of the Chinese? Isn’t American government policy clear?”

“Which government policy, Madame Administrator? The United States has never come out and said that it opposes Chinese exploration of the moon.”

“Don’t play with me, Mr. Swift! The memorandum of understanding makes our position clear.”

“Madame Administrator, the purpose of contracts is to specify what can and cannot be done, and for what compensation. Our contract is very clear: no taikonauts using the Polaris. An addendum specifies they can’t use a Gryphon capsule either. There’s nothing in the language that says they can’t use a lander.”

“But didn’t you know, when we talked about the Gryphon, that they wanted to lease a lander? Shouldn’t you have disclosed it? Don’t you think you misled me and the United States government?”

“No, I most certainly did not mislead the United States government. The Chinese are planning to develop a lander of their own; they have announced it and have started on it. It shouldn’t take long to build, either; these things don’t take too long nowadays. They’ve already flown taikonauts around the moon. They can launch a mission to the moon any time now, and I have equipment fueled and available on the lunar surface. We negotiated the contract in the last three weeks; that’s after our conversation, Dorinda. You can subpoena my emails if you want, though that wouldn’t be very nice and might complicate other aspects of our relationship.”

“Leasing a lander to the Chinese already complicates other aspects of our relationship!”

“Let them land on the moon. What harm is there in that? They already have two automated rovers at the South Pole; that’s where they want to go. They’ll get there with their own landers in two or three years anyway, and that is good for everyone; if there’s an anomaly with one of our landers and we suspend their use for a few months, there will be a backup system. It’s not just a question of good business and profits; it’s also a safety issue.”

“I hope they paid you well!”

“We negotiated a good deal for everyone. It won’t compromise any proprietary or strategic technology. It will get them started and give all of us a backup system. And the United States was first again; that’s very clear. Astronauts returned to the moon eighteen months before taikonauts first arrived. The competition between the two systems will be good for everyone. It’ll be good for my company because everyone will have to charge less for launches. Mars will be more achievable as a result. The moon will be more like Antarctica.”

“Perhaps, Zeke. But I can’t guarantee there won’t be consequences.”

“Your lawyers can negotiate with my lawyers, Dorinda. And we’ll be sure to want to consider reciprocal use of equipment in emergencies.”

“You always have an answer, Zeke!”

-----

The next day, Will took the tourists to the bottom of Whipple crater. Special covers protected their boots from the extreme cold—as cold as the surface of Pluto—and they were carefully instructed not to touch anything with their gloves. Over the ages, frost had condensed into strange shapes, and they had prepared a kilometer-long walking trail through some of the most interesting terrain. Will kept up a running commentary about the area, then they returned to the portahab and went up to the “Armstrong Plateau,” an area on the combined rim of Whipple and Peary Craters, where they explored a very fresh crater and another very old one of about the same size. It was a chance to explain the gradual, cosmic forces of degradation that operated on the lunar surface.

“The United Nations definitely should declare the ‘Whipple Nature Trail’ a special protected area,” exclaimed Abdullah Sistani to Will, as they re-entered Peary Station. “It’s only a small part of the crater floor and won’t decrease the volatile resources significantly. I’ll have to talk to President Husayni about it.”

“I think that’s a great idea,” replied Will. “There are probably some other areas we should preserve as well; maybe an entire small, deep crater, so we have an intact ‘cryosystem’ to study in the future. I’m glad that this trip might produce such a result.”

“Can you help make recommendations?”

That surprised Will. “Ah . . . sure, I suppose I could.”

“The US government might object,” injected Gordon Li, who was standing there with them.

“That’s what worries me, but I don’t think it’d be a serious issue. I could write it up as a paper for publication; it’d be a legitimate scientific topic.”

“Ah, that’s clever, and that would help quite a lot,” agreed Abdullah. “Please do.”

“It may take a few months, but I’ll plan on it.”

Abdullah tapped Gordon’s shoulder. “You see, he’s a good guy. He’s not watching us.”

“Watching you?” asked Will.

“Yes; I think that’s Captain Pregill’s main task!” replied Gordon, chuckling. “How well do you know him?”

“He’s new to the astronaut corps, so not too well. He was added last spring.”

“Less than a year, and he’s both captain and pilot.” Gordon waved a finger.

“He’s a Swift employee, though, for this mission. I don’t know their criteria for choosing flight crew. In the past, they’ve intentionally added people from India or Brazil or Portugal to diversify the team, get publicity, and arrange government subsidies.”

“All the more reason to suspect him!” said Gordon. “There wouldn’t be a US government subsidy for him!”

“Unless he was also a spy!” added Abdullah.

Will smiled at that and decided to change the subject. “So, how’s your Chinese spacesuit working out? I was worried we wouldn’t be able to get the boot covers on, but they fit fine.”

“The suit is great,” replied Gordon. “I’m glad I had a chance to check it out!”

“I see you photograph it very carefully with your communicator when you come back in.”

“Oh yes; they want to know how much dust is sticking to it, how the anti-dust systems are working, etc. And thank you for permission to record your entire lecture in Whipple and in Armstrong AF and BD. I’ve downloaded it to Earth, and you can be sure others will watch it.”

“I was wondering about that, and thank you for warning me. I may hear about that.”

“Tell them I didn’t ask for permission!” Gordon laughed. “NASA is so paranoid.”

“I’m inclined to agree. But the moon is the ‘common heritage of all mankind’; that’s treaty language. Members of every nation will be living and working here, and sooner than we might think. If we can cooperate here, maybe we’ll learn to cooperate a bit more on Earth.”

“Maybe, but meanwhile, this is just another arena for terrestrial politics,” noted Gordon.

Will sighed. “Yes, it is. But I’m a scientist, and I am a Bahá’í, so politics is not my priority. Bringing people together in the pursuit of knowledge; that’s my goal.”

“Oh, you’re a Bahá’í?” said Gordon. “I have Bahá’í friends in Shanghai. One is even part Iranian.”

“I’ve met a few as well,” noted Abdullah, though as a Muslim he sounded much less comfortable with the subject.

“What it means, in this case, is that I believe in the oneness of humanity,” said Will.

“Racial and national differences don’t matter to me, especially in a place like this where we are all studying the moon. Up here, we are all brothers and sisters.”

“I’m glad to hear that,” said Gordon. “And I hope you will have many opportunities to help others come to the same understanding.”

## Northstar 6

Late December 2030

The docking hatch slowly opened and Roger Anderson stepped into Peary Station. “Welcome, Roger!” exclaimed Will. He was the official door greeter; Armando had been inside the portahab when it docked to the lander.

“Hey, Will!” They shook hands vigorously. “It’s great to be back!”

“And as Commander of Northstar 6; congratulations with the appointment.” Will turned and introduced Roger to Teresa Dos Santos and Ignacio Iglesias. He had already met Judith Remsberg, who had driven the ranger, and Sergei Landsberg, a fellow alumnus of Northstar 1, who had been outside in a spacesuit, making sure the docking tunnel was properly attached to the lander. Then Will turned to another, even closer friend.

“David Alaoui, you’re a sight for sore eyes!”

“Ready for more adventures with you, Moonman!” He and David embraced; they had both been on Northstar 2.

Ethel MacGregor came out next. “It’s good to see you again, Ethel! I’m surprised you came back so soon!”

“I am too, Will!” she replied with a smile. “But there’s more important industrial engineering to do up here with metal carbonyls, so I’m back for that, after a six month hiatus.”

“And with improved equipment, I hear.” They shook hands, then Will turned to the next person. “Seoyun Park, I presume? Welcome to Peary Station.”

“Thank you, Dr. Will Elliott.” She shook his hand. “Delighted to be the first Korean on the moon, and delighted to be continuing your work with the greenhouse.”

“Well, I didn’t do much! I look forward to working with you.” She moved on to Teresa and Will turned to their Pakistani engineer. “Rostam Sharif, welcome to the moon.”

“Thanks, Will. It’s very exciting.”

“And you’re here to check all the engines?”

“That’s right, and believe it or not, I can pull out and replace a few if I want, with Ethel’s help.”

“I had no idea we could do such sophisticated work up here. Looking forward to working with you.”

Rostam moved on and the sixth astronaut came out, flight bag in his left hand. Will extended his hand. “Bruce Cordani, very pleased to meet you. Are you ESA astronaut corps?”

“No, I’m American!” He shook Will’s hand. “And you’re a geologist, I hear? It’s very good to meet you.”

“Thank you.” Will shook Cordani’s hand, wondering how he had never heard of an American astronaut—he knew them all—and why Cordani didn’t know William Stephen “the moonman” Elliott was a geologist. David saw Will puzzlement and smiled. Will walked over to him. “I’ll walk you to your room. This time, you have a nearside view.”

“I have the seniority!” replied David. “You guys have had a busy four months.”

“Yes. The portahab is great, but we haven’t been able to use it very much because the Lunotel took so much time to finish, and then the tourists arrived.”

“How did they work out?”

“Pretty well. Abdullah Sistani’s smart and loves the moon; he wants some areas declared ‘natural parks’ and I plan to write up a proposal he’ll take to the President of Qatar—a cousin—



who will take it to the United Nations. I think I need your help, or at least your coauthorship, to reduce any political heat.”

“Good idea!”

“Gordon Li was bright and helpful as well; his father owns the company that makes the rocket engines China uses and he wants to be an astronaut. He knows all the taikonauts. He even met me when I was in Beijing. The other two were bright, friendly, and not too demanding, considering they paid 35 million to come here. How was the flight out?”

“Routine.” David reached the door to his bedroom in shelter 2 and opened it. They stepped inside and closed the door. “So, who is this Bruce Cordani?”

“I was going to ask you. Never heard of him.”

“Never? On the flight out I went to the web. His bio is on the official Astronaut Corps website, but it’s dated November 2.”

“Really? They couldn’t have added him to the Corps last month and given him an assignment right away. They usually wait at least a year. I thought August Hamner was scheduled to fly.”

“He was, and we were all training together, starting in August. Then he suddenly pulled out about four weeks ago, and Bruce Cordani was added.”

“Why did he pull out?”

“There was no explanation. I asked Roger, privately, and he said it was personal.”

“That could cover a lot of ground. And Cordani is an engineer?”

“That’s what he says, but his bio says he went to the Air Force Academy and doesn’t say anything about engineering training.”

Will shook his head. That's very strange. I wonder if this has something to do with the Chinese."

"That's what I wonder, too." David looked at Will.

"Maybe it'll become clear; meanwhile, I guess we had better not speculate, it'll just cause trouble."

"I agree. Let me unpack, then show me around the Lunotel."

Will nodded. David opened his flight bag and hung up six uniforms and two casual outfits. He placed his Qurán and pictures of Aisha and the boys on his desk and hung up a beautiful, framed "Alláh" on the wall. His toiletry kit went on his desk as well, then the flight bag disappeared onto the floor of the tiny closet.

"It's nice to have twelve people here," said David, as they stepped out of his room.

"Thirteen."

"Thirteen? Oh that's right, Jerome . . ."

"Lamoreaux; he's French, so you'll have someone to talk to. He asked Swift whether he could stay for six to twelve months and it was arranged. He spoke to Armando, who said 'I don't know anything about it.' He knew NASA would be unhappy, so he stayed out of the matter. And they were. But the Lunotel really should have a manager, there's enough room up here for as many as 30, there are plenty of consumables . . . and he cooks for us every day!"

"Really? With what?"

"He can take the frozen dinners, thaw them, add some herbs and spices, and cook them. Jerome's very clever, and he has picked up how to cook here very fast. Now I'm learning from him."

"Great."

They entered the Lunotel and went up the grand spiral staircase to the Atrium, David gawking in wonder. Jerome was busy cooking a turkey dinner for everyone; David went into the galley and talked to him. Will got bored with the French conversation, which he could manage to follow but not contribute to, so he poured himself a coffee and sat down next to the window to look outside. Ethel MacGregor came in.

“So are you settled in?” asked Will.

“Mostly; I wanted to see the Atrium now that it’s all set up.” She looked around. “Wow, so beautiful!”

“The design is spectacular. You guys did the bulk of the work inflating it and installing walls.”

“I remember all too well. I completed only half the research on metal carbonyls that was scheduled. But that was partly because of problems with the equipment that should be fixed, now.”

“This is for manufacturing items on the moon?”

“That’s one use. If you crush nickel-iron meteorite into a fine powder—not an easy task itself, though it is facilitated if you cool it to cryogenic temperatures—then heat it with hot carbon monoxide gas, it interacts to produce various compounds. Iron carbonyl,  $\text{Fe}(\text{CO})_5$ , for example, is a liquid at room temperature. Nickel, cobalt, chromium, etc., all form their own carbonyls, all at different temperatures, and they break down at different temperatures as well; iron carbonyl, for example, breaks down at 200 Celsius into carbon monoxide gas and solid iron crystals. So a three dimensional printer with iron carbonyl gas can expel tiny drops of iron carbonyl and build up an object of any shape and size—theoretically—or we can pour the liquid into molds and heat them up to form solid objects. If we can perfect the technology, there’s

enormous potential. The European Union is putting a couple hundred million euros into it, over the next decade or so.”

“That can revolutionize work up here.”

“Exactly, if it can be automated. Right now, we can’t get the three-dimensional printer to work well; the nozzles clog. The resulting metal is extremely pure and remarkably strong. The research has another very important implication too, though: nickel-iron meteorite typically is several parts per million platinum and related metals, most of which are as valuable or more valuable than gold.”

“And can be exported from the moon?”

“Possibly! The nickel-iron can be picked up from the regolith with a magnet! We have carbon. It’s not likely to be economic for a long time, though; it’d be pretty expensive to convert 100,000 tonnes of nickel-iron into carbonyl gas in order to obtain one tonne of platinum! There are some high-nickel asteroids that are one part in ten thousand or so platinum; if we can find such a body that impacted the moon, it would be much better.”

“That could take a long time, though, and if it were near the equator we’d have to haul carbon to it.”

“Not to mention energy, during the two-week nightspan. It may be easier, long term, to mine asteroids, but then you’d need one with carbon as well as the right kind of high nickel composition. Such an asteroid probably exists and some day it will be found and mined. Meanwhile, we’ll start working with metal carbonyls and learn how to manufacture with them.”

“This sounds like a mission of sorts, for you.”

“It has become one.” She smiled shyly. “My husband is not very pleased. The six-month mission of Northstar 4 almost sunk our marriage. I hope it survives Northstar 6!”

“Northstar 2 sunk mine, I’m afraid.”

“We have a lot of divorces in the corps.” She held up her hands. “I can build or fix just about anything. I love building and fixing things. I hope to be back up here in a year or two. Not only will there be a new generation of carbonyl processing equipment by then, but we want to try plastic manufacturing from lunar methane. Not only can products be exported to low Earth orbit, but the technology is crucial for setting up an outpost on Mars, because it’s too far away to import spare parts.”

“Oh, so this is part of the Mars effort as well.”

She nodded. “Definitely. Swift himself was in Paris lobbying ESA three years ago; this was the project they liked. So . . . it sounds like you’re a man with a mission as well.”

“What; lunar geology? Yes, that’s true, but please don’t call me ‘Moonman.’ Half the time, people are using it ironically or negatively.”

“I noticed that, when I was here four months ago. I like meeting people with missions. They’re interesting.”

“Thank you, most people consider it freakish!”

“I suppose so. Then I guess I’m a freak as well, though I like to think of myself as a person with a purpose.”

“Yes, that’s the better way to think of it. Life needs a purpose, doesn’t it?”

“Absolutely! A useful, positive purpose, too; not just sitting around and surfing the web all day. Something that serves mankind.”

“Exactly,” said Will. “It’s nice to meet someone else who thinks that way.”

-----

Jerome's turkey dinner, with incredible sweet potatoes, a magnificent fresh salad from the greenhouse, fresh French bread, homemade peach ice cream, and wine—optional for Will and David—was an incredible success. As the ice cream was finished and the coffee and tea poured, Armando rose.

“This is our official welcome to Northstar 6,” he began. “We were the supplemental crew for Northstar 4 for two months, and now you're our supplemental crew for two. It's great to have twelve—well, thirteen—personnel up here again. We still have some great tasks to accomplish. Sergei just spent two weeks at the depot, which was spun slowly to simulate Phobosian gravity, and in that gravity he ran experimental regolith moving equipment—I'm not sure our earth return Polaris vehicle will be clean enough to use conveniently!—and ran a chondrite processing system.”

“Which worked adequately, I should add,” Sergei said. “A second generation system can now be built.”

“Great research,” added Ethel, who had assisted for a day, before the lander had brought all seven of them down to Peary.

“So that's our first important engineering success; testing a first generation device to extract carbon compounds from chondrite. Of course, we finished the setup of this magnificent hotel and entertained the moon's first tourists, and we completed the first truly long-distance surface expedition, to Aristarchus. We have some important equipment testing coming up; the redesigned three-dimensional carbonyl printer and the Gryphon capsule. And we have at least one long-distance expedition to launch using the landers, maybe two.”

“To Tycho,” injected Will. “David and I had the chance to talk about the destination this afternoon, and that's our recommendation.”

“No: the south pole,” replied Bruce Cordani.

Will scowled. “What?”

“The South Pole,” replied Roger Anderson. “That’s the first destination of the landers.”

“But the South Pole’s geology is basically the same as the North Pole’s; there’s no new geology to be done there,” replied Will. “We can’t get into new, fresh craters overland; the rims are too steep. We’ve tried to get into Anaxagoras, Timeus, and Aristarchus. Tycho, Copernicus, and Aristarchus need to be reached via lander.”

“Later,” said Armando. “The South Pole is first, Will.”

“The TROVs there are dead,” added Roger. “We still have two portable cryo units available; you deployed only one on the Aristarchus expedition. We can deploy a volatile miner-transporter and two units there and build up a volatile supply, which will allow us to visit the South Pole periodically and even launch expeditions from it.”

“But we have a huge facility here,” said Will. “Why do we need a smaller, less efficient operation there?”

“That’s the plan,” replied Armando.

Will stared at Armando, shocked that he had been overruled without explanation. Rostam Sharif was not so surprised, and his face was turning redder and redder as the conversation continued.

“Look, let’s not beat around the bush,” Rostam said. “You guys want to beat the Chinese to the South Pole, too, and no doubt Mr. CIA, here, wants to photograph everything they have set up there already.”

Cordani glared at Sharif. “That’s a stupid thing to say. I am not CIA, and I don’t need to photograph anything at the South Pole.”

“That’s true; orbital imagery would be sufficient,” said David.

“I thought we were here to do science, Armando,” exclaimed Will.

“We are,” Armando replied. “Among other things.” Armando looked at Roger Anderson, then at Bruce Cordani. No one said anything else.



9.

## Shackleton

Early January 2031

“We go on January 6<sup>th</sup>,” said Bruce Cordani at their New Year’s eve party, five days after Northstar 6’s arrival.

“What?” said Will. “We have no scientific objectives, no proposed routes.”

“Do you have possible routes?” asked Cordani.

“There’s a website full of them.”

“Then grab some and make plans. We’re landing at Shackleton, nearside rim.”

“Why? De Gerlach and Faustini appear to have more volatiles, but they haven’t been explored. Shackleton has, by TROV. The area over by Ibn Bajja crater appears to expose some of the floor of the South Pole-Aitken Basin and might be a good candidate site for finding lunar mantle fragments.”

Cordani waved his hand. “Fine. We’ll visit them.”

“You’ve just committed to a full two-week trip and traveling 300 or 400 kilometers!”

“Whatever.”

“You won’t be watching the Chinese much if you’re 200 kilometers away,” noted David.

“This is not a Chinese surveillance mission, it’s a geological expedition.”

“A well planned one, too,” said Will.

“Never mind.”

“And you’re going as a what? An engineer, to repair the equipment if it breaks down?” asked Ethel. “No offense, Bruce, but you have no idea how to repair fuel cells, electric motors, life support equipment, space suits, and a dozen other essentials.”

“Which means taking both rangers, so we have transport redundancy if one breaks down,” noted Will.

“And the portahab?” said Rostam. “That means flying three landers down.”

“Better send four crew, then,” said Armando. “We have twelve; that’s not difficult. Ethel, will you go?”

“It’ll delay my carbonyl work.”

“Please,” said Bruce. He looked at Rostam. “He’s not going.”

“Suit yourself. I don’t want to go with you,” replied Rostam.

“Judith or Ignacio can go; they have the repair experience,” said Armando.

“I’ll go,” said Sergei.

“Alright, and David; if this is a geological expedition, it needs two geologists,” said Armando.

“If you want three landers, you’ll have to wait a few days,” said Rostam. “Because we only have four and we need a backup.”

“What are you talking about?” demanded Bruce.

“Swift has a contract; a fully loaded lander has to take off on January 3. It rendezvouses with the eight tonne cargo module already in lunar orbit and with the three-man Chinese crew, refuels their Earth-return vehicle, transports them to the lunar surface, then carries the crew back to their vehicle in orbit at the end.”

“Shit, our hydrogen and oxygen propellant makes their landing possible!”

“No!” replied Rostam. “It’s not your propellant, it’s Swift’s!”

“Then fuck Swift.”

Rostam rose from his seat and approached Bruce to strike him. Armando jumped up and grabbed him; Roger stepped between the two of them. “No fighting!” exclaimed Armando.

“Apologize, Bruce,” insisted Roger, who clearly could talk to Bruce effectively.

Bruce glared at Rostam. “I apologize for my language,” he finally said.

“Let’s all sit down,” said Armando.

They sat. Bruce looked at Armando. “I don’t see that launching one lander to orbit on January 3 interferes with sending three to the South Pole on the 6<sup>th</sup>. By then we’ll know whether the lander arrived safely or not.”

“Sometimes there are problems with fuel transfer,” replied Rostam. “That’s still not a highly reliable technology.”

“Then launch the Thunderbird-H we have here as a backup,” said Bruce.

Armando turned to Rostam. “That would be a possible alternative.”

“It would,” agreed Rostam, reluctantly.

“So, when do the Chinese launch?” asked Bruce.

“I can’t disclose that,” replied Rostam, defiantly.

“Fine, suit yourself. They can’t launch the people until they know they have trans-lunar injection fuel in low Earth orbit and trans-Earth injection fuel in lunar orbit. So let’s assume both of those unmanned vehicles launch on January 3. The crew would launch January 4 and would arrive in lunar orbit three days later on the 7<sup>th</sup>. They’d rendezvous, transfer fuel for the earthbound leg of the trip, and land on the moon on January 8. That happens to be full moon, the best time to land at a site on the Earth-facing side of the moon.”

“That sounds right,” agreed Roger. “That means if you fly down on the 6<sup>th</sup>, you’ll beat them by two days.”

“Good,” said Bruce.

-----

“Will, what’s going on up there?”

“What?” Will rubbed the sleep from his eyes. “Mom, what time is it; 6 a.m.?”

“Your time; it’s 7 a.m. here. Sorry to call so early, but it’s hard to reach you or have a private conversation after you leave your room. Have you seen today’s *New York Times*? No, I suppose you haven’t. There’s a front page article that says Bruce Cordani isn’t an astronaut at all, but a National Security Agency operative.”

“What?” he gasped, sitting up in bed. “It says that?”

“They did an investigation. He was added to the flight just 6 weeks ago. He’s not a member of the astronaut corps. Why would they send a spy to the moon? The Chinese?”

“I think so; they just launched to the moon on January 2, a day sooner than we were guessing because we forgot their clocks are 14 hours ahead of ours. Apparently the U.S. found out ahead of time about the impending launch and the lease of Swift’s lander to get them from orbit to the surface.”

“The article says that sources told them one astronaut who was scheduled to fly—August Hamner—was asked to bow out for ‘personal reasons’ so this man could be added to the roster.”

“That sounds right. I know August. He couldn’t wait to come here. He’s now scheduled for Northstar 8.”

“So what’s this guy like?”

“Mysterious. Look, I had better not talk about this. They could have people listening. We’re not in any danger or anything like that. Cordani’s concern seems to be the Chinese; he’s

not spying on us or threatening us. I think we should talk about this more after I get home in another seven weeks.”

“It’s hard to believe you’ll be home in less than two months; your stay up there has flown by. Okay, I’ll drop the subject and will explain it to your father, who’s very concerned, but didn’t want to call. You’re doing well?”

“Yes, I’m fine. I’m rather frustrated that we’ve only made one big expedition so far; I’ve been busy running sample analyses, helping to collect carbonaceous chondrite and nickel-iron meteorites for various experiments, repairing broken equipment, and serving as tour guide for tourists. Northstar 2 was much more successful, in terms of geology. But you take what you get.”

“I understand. We’re fine down here. Your dad is thinking about retirement again; I wish he’d make up his mind! His heart is accumulating plaque again and the doctors are worried about that.”

“Retirement won’t help with that; it could make it worse.”

“I know. I had better let you get up and moving. We can talk again on Sunday.”

“Okay, thanks, mom. Bye.”

“Bye.”

The line closed; his mother’s face disappeared from the screen. Will looked out the window at the Earth, which was three quarters full and waning. The sun was shining into his room from the extreme left and falling on a potted mint plant he kept on a little table that he moved every few days, so the plant would always get light. He contemplated the situation. Cordani’s cover was now totally blown; he would be furious. Breakfast would be interesting. He rose and got dressed.

When he arrived in the atrium, the BBC news was on. Jerome said good morning to him very quietly and poured him a coffee. Will sat with David, Ethel, and Ignacio and noted that everyone was talking very quietly. He looked at David.

“Have you seen—”

“The BBC item; yes.”

“My parents read the *New York Times* article and called me.”

“Ah.”

Jerome brought Will a ham and cheese omelet and toast; he enjoyed serving everyone when he had breakfast ready, which he usually did. He smiled knowingly; no doubt he had been up since 5:30 and had turned on the television. Then Bruce stormed up the stairs and entered.

“Alright, who talked to the press?”

They all looked at each other, intimidated.

“I can have all your emails and calls reviewed. Don’t think the United States government is powerless over people who don’t work for it.”

“So how long have you worked for the National Security Agency?” shot back Will, angry.

“You? How dare you!”

“Not me. My mom called me this morning because she had read the *New York Times*. You can check all my communications if you want, I have nothing to hide. I’m a scientist—a geologist—who is quite angry about the way you are disrupting our work, intimidating us, and generally distracting us with useless issues.”

“Useless?”

“Well, I assume you haven’t brought a shoulder-held Stinger surface to air missile with which you propose to shoot down the Chinese spacecraft, and I can’t see how your presence here is contributing to national security. Can you?”

“The details of my mission here are none of your business, so shut your mouth! Okay, who talked?”

“Since I’ve been told to shut up, I’m eating breakfast.” Will turned away from Bruce and cut a piece of omelet with his fork, which he proceeded to eat.

“More coffee?” exclaimed Jerome, hurrying over to Will with his coffee pot, even though Will’s cup was full.

“Sure; thank you.”

“Me, too,” added David, though his cup was full. Ethel and Ignacio nodded as well, then Jerome had to go to the other table and top off cups there as well.

Bruce stood there, watching the others ignore him. “You bastards,” he finally said. He turned and stormed out.

“I’ll keep your breakfast warm for you,” Jerome called out after him.

They watched him go in silence. “I apologize I did that, but I couldn’t stand him any longer,” Will said, looking at Armando.

Roger looked at him, furious, but Armando was commander and nodded. “Thank you; this is a scientific facility and we should not be subject to verbal intimidation. I’ll talk to Mission Control about this incident.”

“Armando, he’s doing his duty!” exclaimed Roger.

“Inappropriately,” replied Armando.

-----

“We have to go on January 5 instead,” Bruce said to Rostam, at the expedition meeting three hours later.

Rostam looked at him. “I’m afraid you can’t go until at least January 7, maybe January 8.”

“What did you do?” asked Bruce, accusingly.

“Nothing. Lander 2 needs new navigational software in one of its computers; testing revealed an anomaly. We can upload a new system in an hour, but testing will take at least a day. That delays the rest of the launch checklist.”

“You can’t cut some corners?”

“We’re talking about safety. We don’t cut corners. Do you want to end up a crushed corpse on the rim of Shackleton Crater?”

Bruce glared at Rostam, wondering whether to believe him or not.

“One crash can set everything back for months, even years,” added Will. He had acquired an intense dislike for Bruce. The two of them stared at each other for several seconds.

“Let’s turn to the geology,” intervened David. He pulled up on the wall screen a big map of the south polar region with a long, winding, dotted green line on it. “This cobbles together seven proposed one and two-day expeditions that can be found on the NASA exploration website.”

“The public site? So anyone can see what we did?” asked Bruce.

“We’ll add our own embellishments, don’t worry,” replied Will. “I have two side trips in mind, and David has three more. Once we add those, the expedition will look much more original.”



“We can be thankful there are so many proposed expeditions,” said Sergei. “Over the years, many universities have used the existing data as an exercise for their lunar geology graduate students. One of those trips was a proposal I made with the collaboration of two friends.”

“International cooperation; it works wonders,” commented Will.

“Drop it, Elliott,” growled Bruce.

“Alright,” said Will, a note of triumph in his voice.

Armando’s communicator buzzed; he pulled out the device and read the text message that had come in. “You’re going to the South Pole no sooner than January 8.” He turned the phone so others could see the screen. “This is from Mission Control. The diplomatic flack has gotten intense. If we fly to Shackleton before the Chinese land there, we’ll look like spoilers and bullies. They want an expedition to provide ‘collaboration and cooperation.’”

“Sanity reigns,” said Will.

Armando glared at him. “Cool your jets, Moonman. Sounds like you’re going to be cooking Chinese food. Talk to Jerome and get some basic stuff cooked up and refrigerated for the visit. Sergei, you will command the expedition. Bruce is the non-engineer and David and Will are the geologists. If the Chinese plan to visit a certain crater, you will *not* go there first. No trumping our neighbors. I am in charge of Peary Station and I make the assignments. I don’t think the National Security Agency can override that, right?”

Bruce nodded. “Aye, aye, Commander.”

“Thank you. Will, Sergei, Rostam: Figure out how you can squeeze seven into the portahab for dinner.”

-----

The Chinese rendezvoused with the lander in a lunar polar orbit on January 6<sup>th</sup>, transferred to their cargo module—which included a tiny cabin—and descended to Shackleton the next morning. Everyone at Peary took off their time to gather in the Atrium and watch the live television. In a carefully planned and pre-scheduled television event, Armando called them and welcomed them to the moon.

On January 10, the expedition blasted off for a spot on the outer rim of Shackleton about two kilometers from the Chinese lander. The portahab went on the first lander, and once it landed safely an hour later, the second lander took off with Sergei and Will riding in the ranger. It was a quick, 60 minute flight up to 150 kilometers altitude, across the front side of the moon, then back down to Shackleton 5,000 kilometers south of Peary.

“What a funny feeling, to be riding in a flying ranger,” said Will, after they touched down.

“It is. Now let’s see whether we can get this thing off the lander.” Sergei pushed a button to switch to the Chinese communications frequency. “Yueliang 2, this is lander 2. We have arrived safely at Shackleton Summit 36.”

“Acknowledged. Welcome to Shackleton, lander 2.”

“Thank you.” Sergei closed the line and turned to the ramp controls. The ramp was folded up in front of the ranger and protruded over the edge of the lander platform. He pushed on a series of icons to check out the various motors and unlock various restraints. Meanwhile, Will put on his helmet and gloves, put on his life support pack, and entered the airlock in the rear passenger side of the ranger. He stepped outside and descended a ladder to the ground about the time Sergei was ready to deploy the ramp.

“Go ahead,” said Will, standing to the side where he had a good view.

“Here we go,” said Sergei. A moment later, a combination of air pressure, inflating tough plastic tubes, and electric motors began to open the ramp and unfold it. It unrolled upward and outward almost 180 degrees and angled diagonally toward the ground, a pair of legs extending downward until they touched the regolith. Then Sergei activated a second phase and the ramp unrolled twice more until the end touched the ground. In five minutes, the deployment was finished; the resulting ramp was ten meters long and provided a six meter descent to the ground.

Will moved in and began to check every single joint. Sergei ran through the checklist aloud; Will examined and checked every single latch and replied “ready.” Some of the bigger, more important joints required the insertion of pins to ensure their reliability, and he did that as well. It was a long process; almost an hour.

“Releasing the wheel anchors,” announced Sergei. Will climbed the ramp quickly and looked at every single one of the six wheels to verify that they were no longer fixed in place to the cargo platform.

“Activating the deployment system,” reported Sergei. A moment later the wheels began to turn very slowly to inch the ranger toward the ramp. Meanwhile, two cables attached to the rear of the ranger and the rear of the cargo platform began to extend slowly, allowing the ranger to move forward. In ten minutes the automated system had allowed the ranger to descend slowly down the ramp until all six wheels rested on the ground.

“Detaching the cables,” reported Sergei. He pushed another icon and the cables released from the ranger and began to retract back into their spools on the lander’s top.

“Pretty good,” said Will. He climbed into the airlock. “I’m in the airlock and strapped in place, so go.”

“Acknowledged,” replied Sergei. He put the vehicle in gear and headed for the portahab. Will left the outer hatch of the airlock open so he could see the terrain as they rolled across it. Their lander shrank in size.

“Here comes lander 3!” exclaimed Sergei. Will leaned out of the airlock to get a better view and saw lander 3 descending on a fifty meter plume of pale blue hydrogen-oxygen flame. Dust and rocks flew as the plume touched the ground; the engines cut back on their power and the lander settled onto a flat area a half kilometer away.

“Beautiful landing!” said Will. “We’ve all arrived safe and sound.”

“Including Bruce,” said Sergei on the public frequency.

They arrived at lander 1, where the ramp was already deployed. Will and Sergei repeated the checklist with the joints and anchors, then they lowered the portahab down the ramp on its four wheels. By then, ranger 2 was almost ready to descend its ramp as well. Getting the portahab properly attached to ranger 1 took quite a long time; the two attachment points didn’t line up for a long time because some of the wheels were higher than others. By the time they had the portahab properly attached, the power and life support umbilicals hooked up, and the flexible tunnel attached to the airlocks, ranger 2 had driven over to them, rather than the other way around. They docked the rangers together nose to nose so that all four of them could move back and forth.

“It’s fifteen hundred hours,” noted Sergei. “Everything is more or less on time. We rest, eat a late lunch, and do some local exploration, right?”

Will and David nodded; Bruce then nodded as well, as it didn’t matter to him.

“Good. We have permission from everyone to call the Chinese and invite them to a late dinner at 21:00 hours; six hours from now. For them, it’ll be 11 a.m. tomorrow; our late dinner will be their early lunch. Will we be ready?”

“Yes,” said Will. “I’ll need two hours to cook everything, and we have to drive there first because I don’t want a bumpy drive shaking the food off the stove.”

“Okay, I’ll call now, extend the invitation, we’ll rest an hour and go out to explore, then we’ll drive over at 7 p.m.” Sergei looked at the others. “Okay?”

There were no objections, so David retreated to the cab of ranger 1 to rest, Bruce to the cab of ranger 2—where he might have just as easily been talking to his superiors—and Will and Sergei laid down on the couches in the portahab for a half hour siesta. When they finished, three of them suited up and explored the rim of Shackleton for several hours, Bruce remaining inside; David noted that Bruce had not yet gone outside even once. Then they drove over to the Chinese station, a cylindrical inflatable like Peary’s shelters but half as big, where Will started cooking. Jerome had prepared a very simple but nutritious and tasty stir fry and Will was able to heat it up quickly.

At 8:45, Sergei went outside to assist the Chinese commander with the connection of a tunnel between the circular docking hatch in the rear of the portahab and a standard circular docking hatch on the Chinese station. Then each returned inside his own vehicle. At 9 p.m., the Chinese began to open the connection, camera in hand, to record the entire event live.

“Welcome, welcome!” said Sergei, as commander Zhang Bohai crawled through the tunnel and stood up inside. “Allow me to introduce Will Elliott, David Alaoui, and Bruce Cordani.”

“Thank you, thank you. Welcome to Shackleton Station!” Commander Zhang spoke excellent English and shook hands with all four with some enthusiasm. “We never expected to receive visitors so quickly!”

“We want to be good neighbors,” replied Sergei. He turned to the tunnel and welcomed Dr. Xie Fuhua, their geologist, and Liang Jianyu, their flight engineer, next, and the men went around to shake hands as well.

“Very pleased to see you again,” Will said to Dr. Xie Fuhua, whom he had met in Beijing three years earlier. He didn’t recognize the man, but had scanned through notes he had taken of the China trip and had fortunately recorded the name.

“Thank you, it is very good to see you again, Dr. Elliott, and in what a place to see each other!”

“Yes, isn’t this a marvelous occasion!” They shook hands very warmly.

“We are very pleased with this meeting,” exclaimed Commander Zhang. “It is very, very kind of you to invite us into your portahab, which is truly marvelous technology and a very efficient and comfortable way to do lunar exploration. As a token of our appreciation, we would like to present Peary Station with this Chinese flag as a memento of our meeting.” Zhang pulled a silk package out of his pocket and presented it to Sergei, who unfolded the silk wrapping and pulled out a large Chinese flag. He held it up; David took the other end and Will and Bruce (reluctantly) gathered behind it for a smiling photograph taken by the Chinese taikonauts. Then Sergei picked up a box. They had been warned that it was diplomatic protocol to exchange gifts, and Ethel had been busy. He held up the box.

“The Northstar 5 and 6 crew of Peary Station, of which the four of us are representatives, thank you warmly for this treasured flag, which we will display prominently in the Atrium, so

that all our visitors can see it and remember this day. We, in turn, wish to present the crew of Yueliang 2 with this medallion.” He pulled it out the box and held it up. “It is pure nickel, made from nickel-iron meteorites harvested from the regolith of the north polar region, and shows your lander and the date January 6, 2031, the date of the historic first Chinese landing on the moon. May we all come in peace for all mankind.” He handed it to Zhang, who took it with delight.

“It’s beautiful! How did you make it!”

“Three-dimensional printing with nickel carbonyl; it’s a very experimental process and actually worked well, the second time we tried,” replied Sergei. That prompted a laugh from everyone. “Please, come sit and eat with us.” He pointed to the right-hand couch in the portahab and the three Chinese sat on it, with three of the Northstar crew on the left-hand couch. Will, trapped in the narrow space between the end of the couches and the galley, pulled out a folding table and placed it between the two couches; it was designed to fit perfectly. He pulled up a folding chair for himself to the end of the table, then passed out plates, forks, and chopsticks—they had brought some from the Lunotel—and placed the huge bowl of stir-fried rice, fresh vegetables, and chicken chunks in front of the guests, which they admired with delight. He added a bowl of fresh salad and a variety of sauces to the table and encouraged them to help themselves, pulled out a pitcher of lemonade and a bottle of wine, and sat. There was chit-chat as everyone served themselves and passed items across the table, then some seconds of silence when everyone began to eat.

“You know the food is good when people are too busy eating it to speak,” said Sergei, with a smile.

“Yes, exactly,” agreed Zhang, and they laughed.

“It appears you have made excellent progress in setting up your station,” said David.

“Thank you, yes, we feel we have. The station is quite quick to inflate, but we have just been able to move inside last night and the interior still requires weeks of set-up work.” Zhang smiled. “But the toilets now flush.”

They all laughed. “Yes, that’s an important milestone,” agreed Sergei.

“You’ve already spread tracks around the area with your buggy, too,” said Will. “I’m glad to see you’ve already been able to do so much surface exploration.”

“We plan to get down into Shackleton next week,” said Dr. Xie. “Shackleton Summit 12—the one right here next to the station—will be the site of our solar power mast, as it is in sunlight an average of 91% of the time. We’re putting it up in three days, and when we do we’ll also set up our volatile processing unit.”

“That’s an excellent location,” noted Sergei. “Summit 16 is almost as good—it gets sunlight 89% of the time—and is six kilometers away. We plan to set up two portable cryo units there.”

“How will your TROVs get to the floor of Shackleton from there? The slope is quite steep.”

“I suppose we’ll bulldoze a way down,” replied Sergei. “We’ll have to look for a good spot.”

“The slope here is fairly gentle,” noted Zhang, who knew the crater’s topography much better than the Northstar crew.

“Perhaps this is the best spot, then,” suggested Will, even though he felt Bruce’s face tighten.

“Perhaps we can make the trail here,” agreed Sergei. “Our geological exploration is scheduled to take us 150 kilometers from here, to Ibn Bajja, to look for lunar mantle fragments,



among other things. We plan to set out in a day or two, then come back here in about two weeks. By then we'll have more instructions from our respective governments what we can and can't do together."

Zhang nodded. "Yes, that is important, and complicated!"

"It is. We don't want to interfere in any way with your plans. We don't want to trump any of your trips, either. I hope that, over the next two weeks, our governments can negotiate some plans that will allow us to complement each other's efforts without interfering in any way. But if the governments can't do that, we can talk between ourselves to accomplish the same."

"Excellent, we would appreciate that very much. How long will you stay?"

"Two to three weeks; we have some flexibility."

"We're staying four. Yueliang 3 will build on our accomplishments in several months."

"We're hoping to find some lunar mantle fragments as well," Dr. Xie said to Will Elliott. "There's a spot nearby we plan to check."

"Excellent," said Will. "I hope, in the future, that Yueliang and Northstar crews can carry out some joint field trips."

"Yes, that would be excellent."

Just then, Sergei's communicator began to vibrate with an incoming message. He decided to ignore it, but when it vibrated again a minute later, he pulled it out to see who was calling. Much to his surprise, he saw that it was Zeke Swift himself. "Oh!" He pushed activate.

There was a three-second delay before Zeke Swift spoke. "Greetings to the crews of Yueliang 2 and Northstar. I want to thank all of you for this marvelous joint dinner, which of course is being broadcast live to the world and I am watching on my television right now. Normally I wouldn't call you, but since all four of the landers my company has built are all

landed at Shackleton crater, carrying both of your crews to the same location, I felt I had to call and congratulate all of you for your dialogue and the opening it creates for international understanding.”

“Thank you, Mr. Swift! We are all very grateful to you for creating this marvelous transportation system and leasing it out to the nations of the world!”

“It is my pleasure, and this event has proved to me the value of going to the moon first, Mars second. I hope it will become possible for the Mars effort to be truly international and include China as well as the United States. I would like to make a request of the Northstar and Yueliang crews.”

“What is it, Mr. Swift?” asked Sergei.

“When the Northstar crew prepares to depart for Peary, you will no doubt have considerable leftover reserves in food, water, nitrogen, possibly even liquid hydrogen and oxygen. There is no reason to fly them back to Peary where they already exist in abundance. Northstar is setting up cryo production units at Shackleton, which speaks of a continuing presence of Peary Resources, Inc., at the South Pole, and that means there will be a gradual buildup of resources there. I would urge the Northstar crew to leave as much of their spare consumables with the Yueliang crew at Shackleton Station as possible. It will give that crew greater safety and redundancy, if they need any of the resources they can pay for them later, and in turn they can provide and naturally would provide consumables and assistance to any future Northstar crew that is having difficulties in the South Polar region. This strikes me as the behavior of good neighbors toward each other.”

“We fully agree, Mr. Swift,” said Sergei. “And we will plan to do exactly as you suggest.”

“And as good neighbors, we will be wise and careful trustees of these resources,” replied  
Commander Zhang.

10.

## Gryphon

Mid February 2031

“Thanks for going on the EVA with me,” Sergei said to Bruce, as they took off their suits in Peary’s suit changing area.

“That’s alright. I *do* enjoy going outside, though it may not seem to be true. And it was pretty easy to pick up chunks of chondrite from that boulder.”

“That’s really what I needed help with; old fashioned hand labor.”

“I’m glad I’m good for something. So, when does the Gryphon land?”

“February 12<sup>th</sup>; a week from today and two weeks before our departure for Earth.”

“And this is a test of the engines?”

“Not in the sense that the engines will be modified; the design for this model has been complete for some time and the engines have been used quite a few times in the Thunderbird-M second stage, which uses methane instead of hydrogen. There have been three Gryphon test flights in low earth orbit and two carried supplies to Pax Hotel. But this is the first operational test beyond low Earth orbit.”

“And the vehicle leaving for Mars in three weeks; it’s another version of the Gryphon?”

“No; it’s the “Hippogryph” cargo lander. Same engines, but cargo rather than a capsule.”

Bruce nodded. “And we’ll be able to go inside the Gryphon?”

“I don’t know, Bruce; I think I’ll let everyone in but you.” When Sergei saw Bruce’s startled, angry look he laughed. “Don’t worry, N. S. A. spies are welcome, too. There’s nothing inside Swift hasn’t already disclosed to NASA.”

“I suppose that’s true.”

“Then I’ll be glad to satisfy your curiosity.” Sergei pulled on a shirt over his long johns, then pants, while Bruce did the same. Since the return from Shackleton a week earlier, Cordani had become more pleasant, less secretive, and even had tried to contribute to the work at Peary Station. The work schedules were slipping because they had been drawn up for 12, not 11, personnel.

Sergei hung up his suit, placed the life support back pack in a recharge station and made sure it was connected, and left the suit changing area. He entered ranger 1 quickly to grab the “wheelbarrow” full of chondrite chunks and pulled it through the airlock into the lower level of shelter 2, where he and Ethel had their work areas. Armando and Roger were there looking at some metal beams Ethel had made from molds. “So, he helped you?” asked Ethel.

“Yes. I think that was only his third time on an EVA!”

“He’s a spy, not an astronaut,” said Roger, shaking his head. “I don’t know what we’re going to do with him for four and a half more months. It’s an embarrassment.”

“I don’t know what the people in national intelligence were thinking,” said Armando. “Don’t they ever think things through? Asking a professional astronaut to fake a personal excuse to leave the mission and adding an ‘astronaut’ unable to do anything was guaranteed to be a huge public embarrassment. How could they think it wouldn’t leak? The diplomatic fallout was huge.”

“Not to mention the unintended consequence that we helped the Chinese!” exclaimed Roger. “We left them more consumables, allowing them to extend their mission by a week; we set up two cryo units, enabling them to buy dozens of tonnes of hydrogen and oxygen fuel per year and allowing them to drop the production of cryo units from their budget; we bulldozed a route for our TROVs to reach the cold trap at the bottom of Shackleton that their TROVs are now using; and now NASA is forced into having to consider a cooperative arrangement!”

Armando and Ethel both laughed at the thought. “What do they say; ‘national intelligence’ is an oxymoron?” asked Armando.

“That’s right,” said Roger, shaking his head. “I really don’t want him here until June.”

“We can ask someone to stay, so Bruce could fly back in their place,” said Armando.

“But that’s your call, Roger. You’ll be commander starting February 28.”

“I know. I’ll think about it.”

-----

The Peary crew followed the launch of the Gryphon with intense interest. On February 8, it blasted off from the Swift Spaceport in southeastern Colorado. The first stage dropped away and the hippogryph propulsion module, fueled with methane and oxygen, fired, pushing the Gryphon capsule into orbit. It rendezvoused with the Swift LEO fuel depot and the hippogryph refueled with methane and oxygen. Eight hours after launch the engines lit up again and pushed the capsule to translunar injection. Three days later the hippogryph engines fired a third time and put the vehicle into low lunar orbit; the delta-v or change of velocity from low Earth orbit to low lunar orbit was almost exactly the same as a launch from the Martian surface to a low Mars orbit. The hippogryph refueled again, with lunar methane and oxygen stored at the lunar orbit depot, for descent to Peary. There, a partial refueling would be sufficient for a flight directly back to the Earth. The hippogryph methane-oxygen propulsion module, used five times, carried out over two thirds of the total delta-v for the round trip between the earth and moon, and would land safely at the end to be reused.

“It’s an absolute marvel; so elegant,” said Will, watching the Gryphon approach Peary’s Aldrin Pad number 5 on the television screen in the Atrium.

“So elegant, only God or Zeke Swift could come up with it,” quipped Sergei, a comment that made Roger, an evangelical, scowl. “The manufacturing system is set up so they can make the fuel tanks a bit bigger or smaller and tailor them to the specific needs of a particular mission.”

“And they’re making methane from waste in low earth orbit?” asked Ethel.

“Any waste product with carbon; and the tourists are consuming a hundred tonnes of food a year at the various hotels. They’re shipping methane and oxygen up from Earth as well. If we can produce enough carbon dioxide here, we can ship it to LEO and obtain another revenue stream.”

“There it goes,” said Armando, pointing to the cloud of dust whipped up by the landing. “A perfect, pinpoint arrival on the pad.”

“Then let’s go see what they shipped us.” Sergei rose and headed to ranger 2, which was docked to the portahab, which was docked to the station. All thirteen of them couldn’t go at once, so Sergei had accepted the first five volunteers; the others would accompany him later.

Sergei, Will, Bruce, Ethel, Armando, and Laura stepped into the portahab and undocked. While Sergei drove them to Aldrin Pad 5, Ethel stepped into the airlock and suited up quickly. Once they reached the Gryphon, she stepped out to help dock the transfer tunnel to the Gryphon’s side door. While Sergei used the crane mounted on the ranger’s roof to move the tunnel roughly into place, she admired the enormous capsule-shaped spacecraft, 6 meters or 20 feet in diameter at the bottom, tapering to 1.5 meters on top, 11.5 meters or 39 feet above the heat shield. It was twice as tall as any capsule built, with a stylized half-lion, half-eagle on the gryphon capsule and a combination horse, eagle, and lion on the lower hippogryph propulsion module.

Once Sergei maneuvered the tunnel into place, Ethel climbed up the ladder built into the capsule's side and assured a hard dock. She entered the ranger through its front hatch while Sergei retreated into the portahab. By the time she was back inside, the tunnel had pressurized.

One by one, they climbed the angled tunnel, attached to the portahab's rear airlock, and entered into the gryphon. They closed the hatch each time to minimize any danger of air leakage. Will was last. When he entered, he looked around the circular space, which was filled with cargo boxes, in awe.

"It's beautiful! They painted the walls a pleasant range of colors!"

"And that's just the lower deck; come up here!" exclaimed Sergei.

Will turned to the ladder and pulled himself up. The lower deck had been 4.2 meters or 14 feet in diameter; the mid deck was 3.3 meters or 11 feet across; the flight deck on top was 2.4 meters or almost 8 feet across. It tapered to a small ceiling a bit over two meters across, most of which was occupied by a docking port and windows. He joined the others on the flight deck.

"The height is impressive; 2 ¼ meters!" said Will.

"Some of that can be filled with overhead bins," said Sergei. "The Gryphon has 45 cubic meters of volume, about the same as the old space shuttle, compared to the Polaris with 20 and the old Apollo with 6. In an emergency, it can accommodate six on a flight to Mars, but normally it would carry three and be docked to a second Gryphon for another three, with an inflatable between them to provide exercise space, storage, and a large common room. The capsule would be used for sleeping, cooking, washing, and waste disposal."

"How many can this transport to orbit?" asked Will.

"Depends on how tightly you want to pack people. The plan is to fly 20 to low Earth orbit in acceleration couches—they'll have about the same amount of space as on a passenger



aircraft—and 12 to the moon. The empty mass, including tanks and engines, is just nine tonnes. The Gryphon may look like a standard metal structure, but it's mostly composites and plastics; very light. The propulsion module can hold 30 tonnes of methane and oxygen propellant and has a cargo hold at the bottom, right above the heat shield, for ease of loading and unloading.”

“How much does it cost?” asked Ethel.

“I asked that question. It depends on demand. You have to keep the production facility going at a steady pace so the workers acquire experience and become precise, but reuse of vehicles, while it lowers launch costs, could undermine production. The new Thunderbird first stage and the hippogryph propulsion stage and capsule require less maintenance and launch preparation and fewer launch personnel. They think, if demand permits, that prices will fall under \$1,000 per kilogram. That translates into \$13 million per launch, or less than a million dollars per passenger for a twenty-passenger capsule to Pax Hotel. For a flight to the moon, double or triple the price per passenger.”

“Wow!” said Ethel. “That’s an incredible revolution, if it happens!”

“It will happen,” replied Sergei. “It’ll halve the cost of launching cargo to orbit and cut the cost of bringing cargo here to a third of what it is currently.”

“And Mars?” asked Will.

“The Gryphon has to be heavier for a Mars flight,” replied Sergei. “It has to carry consumables for over two years, the furnishings for an inflatable, etc. But it can be launched to L1, the Lagrange Point between the Earth and Mars, and refueled for trans-Mars injection. To return to Earth, it’ll have to refuel in Mars orbit or dock to a kick stage. The work I’m doing to manufacture methane and oxygen propellant from the crustal materials of Phobos and Deimos may be one way to refuel it.”

“Fascinating,” said Will. “So sophisticated, and the entire transportation system is just unfolding before our eyes!”

“And it’ll be reusable,” added Sergei. “Even flights to Mars could become reasonably inexpensive, eventually. Variants of this system can go to Venus, asteroids, maybe even Mercury and Jupiter.”

“That’s ambitious,” commented Bruce, skeptically.

“Let’s go downstairs and start moving cargo,” said Sergei. “This was a free cargo flight for the Lunotel.” He started down, followed by the others.

“What did it get?” asked Will.

“Lots of gourmet food items, plus expensive wine and champagne. But the piece de resistance is a piano.” Sergei pointed to several large boxes spread out along the wall. The others looked at them.

“It’s in pieces?” asked Ethel. “We have to put it together?”

“You can’t get a complete piano through the hatch.” Sergei pointed to their way in.

“That’ll be interesting; we’ve never done anything like that before,” said Ethel, worried.

“I’ll do it,” replied Bruce.

Ethel looked at him. “You? What do you know about assembling a piano?”

“What do *you* know about it?”

“Well, nothing, but I am a trained mechanic.”

“You are excellent with rocket engines, fuel cells, electric motors, carbonyl fractionators, and three-d printers. I have two antique cars in my garage that I’ve completely refurbished and I repair antique furniture.”

Ethel considered a split second. “I bow to your expertise.”

Bruce smiled. "Good. I'll finally be able to make myself useful around here!"

-----

"He hasn't stopped for two days." Ethel leaned her head out from the edge of the table to see around the galley and toward the other side of the Atrium, where Bruce was busy working on the piano.

"It's impressive," said Roger. "And he seems to be making steady progress."

"I can't wait to tickle the ivories; I love to play piano," said Armando, sipping his breakfast coffee. He looked at Will. "So, one last, quick expedition?"

"To western Mare Frigoris; we can go down and back in ten days, tops. This has been a frustrating mission for me. We didn't get in very many expeditions."

"I know; it was all chopped up. I think you can leave tonight."

"Good."

Roger Anderson looked at him. "The rest of our mission should go well and I think we'll get in several long distance expeditions. The problem we have is that we'll really have only five people, because Bruce really can't do anything useful. I almost wish he'd take over the cooking and cleaning from Jerome, and let Jerome go out on expeditions! He'd be more useful."

"But Jerome wants to stay here," said Armando. "It's been great to have a hotel host and gourmet chef among the crew. I wish he could stay a decade!"

"I think he wants to," said Ethel. "Yesterday he asked me whether I could make a special frame to put over his bed to hold a one-meter high water reservoir. That would give him two meters of radiation protection when he sleeps and reduce his cumulative exposure."

"That would reduce his exposure to a level lower than the exposure of high altitude aircraft pilots," said Armando.

“It would. I agreed to make such a frame, too.”

“But back to Bruce,” said Armando. “The only way for him to fly back with me, in two weeks, is someone from Northstar 5 to stay in his place.”

Roger nodded. Everyone thought about that comment a moment, then simultaneously Will turned toward Roger and Roger toward him.

“You’d do that?”

Will nodded. “I would. I have no wife waiting for me in Houston; just more geological work.”

“We’d have three geologists, if you include me. We could do a lot of geology,” said Roger.

“We’d have to check with Mission Control,” said Will.

“Of course, but do you think they’d say no? Flying Bruce here was a huge, embarrassing mistake. It’s the best ending possible. There are no additional Chinese flights or Gryphon flights to observe.”

“It’s fine with me,” said Armando. “I’ll call Mission Control with you, if that’ll help.”

“Sure,” said Roger. “But first we should check with Bruce. Will, are you up to it?”

“Definitely.”

Roger waved at him to stand up, so Will did, and he and Roger walked across the Atrium to Bruce. The piano was mostly put together; a cold cup of coffee demonstrated Bruce’s determination to get the piano finished.

“Good morning,” said Roger. “Northstar 5 flies home in two weeks. Will’s willing to stay and fly home with Northstar 6 in late June and give you his place. Do you want to fly home on February 28?”

Bruce looked up from his work, looked at Roger, then looked at Will. “Ah . . . sure! That’d be great! Is that what you want to do?”

“They don’t call me the ‘Moonman’ for nothing.”

“They sure don’t. Okay. The piano will certainly be done by then. I may be doing you a bigger favor than you’re doing for me!”

Will smiled. “That may be true!”

11.

## Planning

March 2031

*I can't believe I've been on the moon an entire year of my life.*

Will paused to contemplate the opening sentence of his private Facepage entry. He looked out his porthole window at magnificently brilliant Earth, half full and almost too bright to look at, hovering above a nocturnal moonscape. He still couldn't believe he was on the moon, let alone he'd been here a year!

He turned back to his tablet. *Northstar 5 blasted off—without me—this morning. They rendezvoused with their Polaris capsule eight hours later. It was already docked to a refueled Thunderbird-H stage, and two hours later it lit up and pushed them back to the Earth. The Thunderbird also carried a full load of fifty tonnes of lunar water in its water tanks. It separated from the Polaris, which is now controlling its own trajectory and will head straight to Kennedy Space Center. The Thunderbird will dip into the Earth's atmosphere just enough to burn off 1,500 kilometers per hour of speed. After seven such dips, over the next few weeks, it'll circularize its orbit and head for the Swift Depot, a few kilometers from the Pax Hotel, and deliver the water. It took one lander flight to deliver the water to the lunar orbit depot and one lander round trip to bring Northstar 6 to the surface and Northstar 5 back to the depot, complete with enough hydrogen and oxygen propellant to send Northstar 7 and its water load back to Earth. The two lander flights consumed 54 tonnes of hydrogen and oxygen. So for a little over 100 tonnes of lunar water, we can fly from Earth orbit to the lunar surface and back. It's amazing to think we now have such a sophisticated transportation system! One wishes it had been possible to develop it decades ago.*

*I have no regrets staying on the moon for another four months. On the contrary: it is immensely exciting. As of tomorrow, I am the longest staying person up here. Of course, that record won't stand; Jerome has every intention of staying two years, then returning after a six-month vacation in Paris. He has no family and can do that if he wishes. I love the moon, but I can't devote my entire life to it. I'm beginning to realize that there is a limit to this job, and other priorities, like marriage and family, must be accommodated. I won't accommodate them right away; I want to come up here at least one more time, maybe in 2 years!*

*I am excited about the next four months. My first six months here were chopped up by hotel construction, tourists, Chinese, and the Gryphon. The next four months should be much more scientifically focused. We have no construction projects. Jerome promised to handle all day to day tourist matters and be their 24-hour host. The Chinese will be back in May, but if we visit with them it'll be primarily scientific. The landers will provide quick transportation across the moon, so we can now tackle a wide variety of sites. Let's just hope they are as reliable as the engineers say! So this is a good time to focus on the long-term exploration of an area the size of the continent of Africa and set the priorities. In a decade we can have this entire world well characterized and its relationship to the origin of Earth will be much better understood. We can also find a lot more terraclasts; so far we have over 100 fragments from before 3.5 billion years ago, and they are already shedding important light on the evolution of the Earth's crust and the origins of the continents.*

*So the next four months are going to be very exciting for me. In May, I hit my thirtieth birthday; an auspicious time. I wonder what the next decade will bring.*

Will reread his entry, made a few changes, then sent it. In a second and a half it had reached the Earth's deep space network and ran through the worldwide web to his account. In

five seconds, the page refreshed and it had been posted. It was visible only to a small number of close family and friends, but someday the entries might be useful material for a book.

It was almost 6 p.m.; Jerome would have supper ready soon. That was another nice development of the last few months; a full-time professional cook. He headed for the atrium.

The crowd there was a congenial one, he realized; a happier crew than any previous mission he had been on. Roger Anderson, though politically and religiously conservative, was a pragmatic and experienced commander, even though he was just 35 years old. David Alaoui had become Will's best friend; the French-Moroccan was 32, just two years older than Will. Ethel MacGregor was pretty, had a great sense of humor, an attractive personality, possessed an engineering genius, and was a year younger than Will; it was the first time he had actually met someone in space younger than he. Seoyun Park, their Korean hardware and software expert, was unmarried, just a year older than Will, and very friendly; he felt he could come to like her. Jerome Lamoreaux was unfailingly generous and helpful and shared Will's love of cooking; he even had great respect for Will's culinary talents, which made Will feel flattered. Rostam Sharif, their other engineer, was from Pakistan and loved to explain how things worked; Will had great respect for his mechanical abilities. Three geologists, three engineers, and a cook/maintenance person: it was a great balance of skills.

Will sat and traded jokes with the others while they awaited Jerome's latest. They were surprised when heated leftovers came out; he had cooked a big farewell brunch to mark Northstar 5's departure. But even his leftovers were good and they relaxed and joked while they ate. Over coffee and tea, Roger spoke up. "This is a good time for a brief meeting. We've been here two months; we have two months coming up where it is just the seven of us; then we have two months when Northstar 7 arrives but serves as part of this crew. We know what we're



scheduled to accomplish, and we had a lot of input into those objectives; but what do we *want* to accomplish?”

There was silence a moment as everyone considered the question. Roger looked at Jerome, who said, “What I have to accomplish is pretty well defined. We have a tourist flight in two weeks and I will be their host and chef. Otherwise, I am your chef. If you have ideas for things I should cook, let me know. I now have a huge range of spices and condiments as well as a wide range of basic materials. I’ve been expanding the greenhouse as much as I could and have added vegetables and herbs to the atrium that impact the aesthetics positively. That’s been a lot of work because it means picking off dead leaves and constantly moving the plants to follow the sun, but it’s been worth it.”

“We love your food,” said Seoyun.

“It helps to have the absolutely best ingredients. There’s no reason to pay for poor quality goods when the import cost is far greater than the purchase price! And I’m glad you all don’t mind maintaining the air filtration system more intensely. Cooking produces a lot of odors.”

“But we like them, too!” said Ethel, with a smile. She looked at Roger. “My work is fairly well defined and independent, and it is progressing fairly well. The metal carbonyl printer is working slowly, with heavy maintenance; the lab in London has started to fabricate a model 3 that will fix some of the problems and will fly in two years. The fractionation tower has improved and we can now separate out iron, nickel, and cobalt from each other pretty well, at the rate of maybe thirty kilograms a day. The mold making system is working fairly well, also. What I’d like to do is begin a process of upgrading the shelters. If we add supports made from nickel-iron, we can strengthen the structure and add more mass to the radiation shielding. Two meters

of water would reduce our radiation exposure significantly and allow longer terms of residence. If you go on the Peary website, you can see proposals for upgrades.”

“How would they add the water?” asked Will.

“We’d import large water bags that fit over the existing structure. But they’d add 250 tonnes of mass—42 tonnes of weight—to each shelter’s structure, so we’d need to add four metal pillars and related support ribs.”

“And you could prepare the entire support package by the end of June?” asked Roger.

“Maybe; certainly most of it. Someone on Northstar 7 might have to finish the work.”

Roger nodded. “That’s worth writing up and proposing to Mission Control. I’m glad to hear the carbonyl production system has matured enough to make significant items. The next cargo flight will bring us another solar power mast able to produce 50 kilowatts, which will alleviate our power shortages. Seoyun and Rostam: what engineering challenges do you face?”

Rostam shook his head. “As Jerome said, we’ve figured out how to keep the ‘cooked fish’ smell from lingering in Peary for days! But seriously, the landers are doing fine and if the geologists make as many flights as they say they will, we’ll be able to keep up the maintenance schedule. That’s our main task.”

“How many flights are left in each one?” asked Will.

“It doesn’t work that way, but I understand your question. In another dozen flights, they’ll all start to need some pretty extensive maintenance. Each expedition requires a delta-v of over 5,000 meters per second; that’s more than half the velocity needed to achieve orbit from the Earth. They’re pretty simple engines, but they can take only so much wear.”

“A dozen flights?” asked Roger. “Every passenger flight takes two and every cargo flight, one; that’s ten flights per year, and we have only four landers. The expeditions use three landers each.”

“Two new landers are coming next year,” replied Rostam. “Furthermore, by then the passenger flights will be using Gryphons and they don’t need lander support.”

“We could switch the expeditions to two landers,” said Will. “One to carry the ranger and one the portahab, or a second ranger. Two rangers are perfectly safe; if one breaks down, the other one can drive us back to the lander. If we had one ranger and it broke down, the lander could fly to us. We might have to leave the portahab and come back to get it later, but that would be possible.”

“We’ll have to ask about that; it’s in the plans, but for next year. Will and David, what do you propose?”

Will looked at David, who answered. “We’ve looked over the various expedition proposals and exchanged some emails with Jerry McCord and the others in surface geology support. We know you want to go to Mare Moscoviense, Roger, and propose that flight for April. We want to get to Copernicus, Mare Orientale—the most recent of the large impact basins—and to the South Pole-Aitken Basin at its lowest point. We propose the latter in May when the Chinese are at Shackleton, not to compete, but because there may be safety advantages. Orientale and Copernicus would be mid-March and early June.”

“Those sound excellent. We’d sample a wide range of significant terrains. I’ll pass those on to Mission Control.”

“But there’s an additional idea I’d like to propose,” said Will. “It appears that we’ll never use the ‘Procellarum Trail’ again, or at least not any time soon, and we’ve left two portable

propellant manufacturing units on that trail. When we went down the Mare Frigoris Trail several weeks ago, we brought home the propellant manufacturing unit we left there. I'd like to make one quick dash all the way to Aristarchus to retrieve the propellant making units. Then we'd have all three of them here. Then I'd like to propose an additional lander flight with a ranger and crew. It'd go to either Orientale or Moscoviense, then to South Pole-Aitken. It'd stop at each just long enough to drop off a propellant manufacturing unit and two TROVs. The TROVs have small fuel cells already to store energy for peak demands and nighttime activity. If we can add some spare hydrogen and oxygen tanks to them, we could double the electricity available to them and could allow their operation at night, as long as they could get back to the propellant manufacturing unit. We could explore each area by TROV ahead of time and use them to follow up after the expedition departs."

"And then make another flight later to retrieve the equipment," added David.

Roger considered the idea with surprise. "That's *not* on the website."

"It should be," replied Will. "It'd double the science and involve the ground support personnel and university contractors much more actively. We'll need more TROVs because we could easily deploy a dozen or two this way. We'll also need solar power plants designed to charge them up; the propellant making plants can do it, but they have four or five times the necessary mass. We also need something smaller than a portahab, which is well designed for long-distance surface expeditions, but poorly designed for lander deployment. If we had an inflatable cabin that could be attached to the rear of the ranger and that used the ranger's life support system, we'd double our interior volume and have much more comfortable accommodation."

“Swift convinced people to develop the portahab because it is needed for long distance exploration on Mars,” noted Rostam. “But it isn’t so useful here.”

“I think we can provide something like you describe now,” said Ethel. “We have an emergency shelter.”

“That’s right!” exclaimed Roger.

“What?” asked Will, puzzled he didn’t know about a piece of equipment.

“It’s shaped like a Quonset hut; it has a flat floor and a hemispherical top,” said Ethel. “It’s 2.4 meters wide and high and 4 meters long, so it fits on a ranger trailer extended full length or on the top of a lander. It has a standard doorway hatch on one end, so it can be docked to the rear of a ranger, and a standard round spacecraft hatch on the other end. It has a life support system able to support two for 48 hours, but the oxygen bottles, water supply system, and carbon dioxide filters are all standard, so it can be used for longer periods of time. It was designed for two purposes: to provide emergency shelter in case a solitary ranger was disabled; and to provide emergency access to the orbital depot if the passenger module was damaged. It was never used because we never took the ranger any great distance from Peary when we only had one, and now we always send them out in pairs; and because we have always had two passenger modules for reaching orbit.”

Will looked at David, then nodded. “That’d be perfect. The rangers themselves aren’t bad; they provide more volume per person than the Polaris. But if you are staying in them 2 or 3 weeks, they get really cramped.”

“Especially if you bring any equipment for sample analysis along,” said David. “We’ll have to take it on a test trip to try it out.”

“The Procellarum Trail,” suggested Will. “We could take two rangers only and leave the portahab here. If it doesn’t work, no harm is done.”

Good idea,” agreed David.

“Alright,” said Roger. “We’ll inflate it, set it up, try it out on a local trip, then an overnight trip, then you can take it down Procellarum Trail to retrieve the propellant manufacturing units.”

-----

It took most of the next morning to find the emergency shelter, which was stored in a little-used, unpressurized outdoor storage area. The instructions were on a website and the entire Northstar 6 crew spent two hours reading them and discussing them with an expert in California, who apparently used the same website to refresh his own memory. After lunch they all suited up and drove ranger 2 four meters from ranger 1, which remained docked to the station via its circular docking port. Ethel and Seoyun—who had become fascinated by the emergency shelter—entered it and checked out the life support equipment, which had never been used. They had to change the batteries, which were dead, and install an oxygen bottle. Meanwhile, Roger and Will struggled to attach the shelter to ranger 1’s doorway hatch, a task that proved difficult and frustrating, but ultimately possible. Then ranger 2 approached and they docked the emergency shelter’s round spacecraft hatch to the matching hatch beneath the windshield. They entered ranger 2 via its rear doorway hatch and airlock and took off their suits. By then, the emergency shelter had been fully inflated. They inflated the thin space between the ranger’s hatch and the shelter’s hatch, then opened the hatches and crawled into the shelter. About the same time, Rostam and David entered the shelter from ranger 1.

“Everyone has their helmets, right?” asked Roger, looking around. “Because this is still not ‘man-rated’ so we have to be extremely cautious.”

“Yes,” replied David, noting the helmets.

“This is quite spacious!” said Will. “It’s bigger than the portahab!”

“It’s bigger than the portahab’s main cabin,” replied Ethel. “But it’s actually the same size as the portahab overall. And its mass is only 800 kilograms because it’s made out of tough plastics. It has no furniture, cooking facilities, sink, or toilet.”

Will looked at the floor, which had a series of straps crossing it. “But we can bring in furniture and anchor it down; the main thing we need is a table and chairs. A two-ranger expedition needs a common space, more than anything. We can cook and wash in the rangers.”

“And a space for equipment,” added David. “A small alpha scatter analyzer or a mass spectrometer really fills up a ranger.”

“That’s for sure,” agreed Roger. “Will the connection with ranger stay pressurized if it bounces along the moonscape, though?”

“It doesn’t have to,” replied Seoyun. “The hatches are both closed and airtight; the space between them is barely a centimeter wide. It can be repressurized whenever anyone wants to cross.”

“We’ll have to test it,” added Ethel. “But it is clear that we can put the emergency shelter on ranger 1’s trailer and dock it to both rangers at once. Recharging its life support system will take a lot of time; it’s essentially a large spacesuit system and its filters and tanks recharge the same way.”

“But this is more convenient than the portahab for use with the landers,” said David. “It means we can comfortably mount a two-lander expedition.”

“Definitely, if we can get this man rated,” agreed Roger. “And that should just be a matter of testing.”

Seoyun nodded vigorously. “The big question is whether the plastic has been weakened by sitting in a folded position for several years. We’ll need to overinflate it—to terrestrial standard pressure—and see whether it holds up.”

“Which it should,” said Ethel.

Seoyun nodded skeptically. “When can we take it out on a short trip?” asked Will.

“After supper,” suggested Ethel.

“Tomorrow morning,” said Seoyun at the exact same time. They frowned at each other.

“We’ll do it tomorrow morning, then,” said David, and Will nodded at the suggestion. He looked around the shelter. “We’ll need to think about furniture. Let’s go ask Jerome and Rostam what’s available.”

“Good idea,” agreed David and Roger. They headed toward the round tunnel to ranger 2 and crawled through it, so they could undock the ranger and drive it to a dock on Peary Station.

Seoyun and Ethel looked at each other. “Why is this your project,” asked Seoyun. “You already have plenty of work to do with the metal carbonyl lab.”

“I was just trying to diversify my work. You can’t do the same thing all the time; it helps to have some variation. Besides, this allows me to contribute to the current efforts. I don’t like being a station-mate of everyone else and just doing my own thing, all alone.”

“Look, I don’t like spending all my time fixing fuel cells and troubleshooting electric motors. This is something new and exciting. And I want to hang out with these men, too.” She said that with emphasis.

“I see. And we can’t share this task?”



“No.”

Ethel stared at Seoyun, exasperated. “Fine, have your way. Shall I call ‘the men’ before they undock, so I can get through the tunnel to ranger 2?”

“Please.”

“Very well.” Ethel pulled out her communicator, called Roger, then opened the hatch and entered the tunnel. When she entered the ranger, he said, “You were just in time! We were about to depressurize the tunnel! Will is in the airlock and on the way out to disconnect the tunnel.”

“Seoyun and I had a conversation. She wants the assignment to prepare the shelter.”

“Oh? It’s my decision.”

“I’m just letting you know what she wants.”

“I see.” Roger sensed that a difficult conversation had occurred. “Alright, I’ll call her later.”

-----

“Let’s give it two days,” Seoyun said to Will and David that evening, before dinner. “I inflated the shelter to terrestrial pressure—three times our standard pressure—and left it that way all afternoon. There was no leakage. It’s now docked to ranger number 1 and shelter 2, so anyone can open the hatch and enter any time. I propose to let it sit for two days at our standard temperature and pressure. We’ll see if any leaks develop in the plastic tenting material or around the airlocks.”

“That’s a good plan,” said David. “But we also need to test it, bouncing around on a drive and see what that does. We’re going to head down the Procellarum Trail on March 4<sup>th</sup> to pick up the two portable propellant making units. We’ll return about a week later. We could take the shelter along but not use it; if there are three of us on the trip, two rangers will do.”

“Who’s going?”

Will shrugged. “That’s up to Roger. Probably David and myself, and a third person, an engineer.”

“I’ll volunteer, then. I like this plan you and David have proposed and want to get out with you guys as much as possible.”

“Good,” said David, though with a note of hesitation in his voice.

“Let Roger know,” said Will.

Just then David’s phone vibrated. He pulled it out. “It’s a message from the mass spectrometer; a problem with the analysis. I’d better go investigate.”

“It probably needs cleaning again,” said Will. David nodded and walked out of the atrium.

“That’s something I could do,” said Seoyun. “It’d diversify the tasks I do and I’d be able to provide better support for the surface geology.”

“True, but it only takes us five minutes to clean the key part of the machine. It needs to be cleaned every day anyway. We’ve gotten pretty good at it, too!”

“You’ve now been on the moon 12 months, altogether.”

Will nodded. “By the time we leave, my cumulative total will be sixteen months. David and Roger will have had twelve months. It’s a long time, and it gives us crucial experience.”

“But it’s bad for family relations.”

“That’s for sure. I’ve pretty much committed myself to a two-phase life; phase one involves space travel and phase two involves staying home, maybe with a little space travel. We’ll see.”

“It’s hard on everyone. I’m Korea’s only female astronaut, currently, so I’m in the spotlight. Everyone wants me to get married and have a family, eventually. But so far, no Korean men want to get to know me; I’d overshadow them!”

“I know what you mean. My wife wanted to become prominent and well known in her field. She didn’t want to be known as Mrs. Will Elliott.”

“That would be difficult. You’re one of the better known American astronauts.”

Will nodded. “Astronauts don’t get the coverage they used to get, which is just as well. But we’re still interviewed on television occasionally. I gather you’re interviewed in Korean just about weekly?”

“More like twice a week, and my blog is followed by several million people. You should start a video blog! You’d be good at it.”

Will shook his head. “I’d rather spend my time writing up the science. Besides, NASA has had a few bad experiences and now they’re discouraging extensive use of the social media.”

“Yes, I remember that incident, but stopping the use of social media is probably worse. Sounds like it’s not your thing, though.”

“No, it isn’t,” agreed Will. “Are you enjoying your time and work up here?”

Seoyun nodded. “Yes, it’s a fascinating place and the work is great, but it’s rather lonely up here.”

“Yes, that’s true. We need to spend more time as a team, watching movies maybe, or playing games.”

“That would help, but what I need is more than socializing.”

“Yes, everyone has to deal with that, too, and people cope in different ways.” He shrugged.

“That’s true; but keep an open mind.”

Will smiled. “I will, Seoyun. Perhaps we can talk some more.”

“I’d like that.”

“Good.” Will felt his phone vibrate in his pocket. He frowned and pulled it out. “Ah; good news. Mission Control has approved our plan for four expeditions in four months. I had better talk to David.”

“I’ll talk to Roger about serving as your expedition engineer.”

“Great.” Will stood up, waved, and headed out of the atrium. As he walked down the spiral staircase and through the airlock to shelter 2, he contemplated Seoyun Park. She was pretty, young—perhaps two years older than he—and interesting. He wasn’t sure what an international marriage to a Korean astronaut would be like, though.

David looked up when he entered the geo lab. “You got the email?” asked David.

“Yes. Good news.”

“It just said that the plans were approved. That was pretty quick.”

“I’m surprised Jerry McCord didn’t call us to discuss the plans. He’s taking a pretty passive approach to his job as Director of Lunar Surface Exploration. I’d want to be talking to the team at Peary at least once a week, if not almost daily!”

“He does send emails asking us to complete tasks.”

“Yes, but we have no context; we don’t know what the universities want to study, what the ground team wants to explore . . . they do what we want, more or less, and we do what they want, more or less.”

“I see what you mean. If people were coordinated better, everything would go better. And your idea about deploying the TROVS first and picking them up later so that there’s follow-up; that’s brilliant.”

“We’d essentially be making three visits to every area. We’d need a lot more TROVs, but they can be mass produced in India; that’s what Swift did with his three Prospector-450 TROVs on Mars. They’ll be brought back here periodically for repair, after all.”

“You’re right. If this place expands, there’s a lot more that could be done.”

“Exactly.” Will paused to consider his next comment. “In August, Jerry will have been running surface exploration for two years, and I hear he plans to resign and go back into active duty in order to return to the moon. I think I’ll apply for the position again.”

“You were on the short list last time, and you have even more experience.”

“And I’m older; I turn 30 in two months. I think you were right when you said I was too young, last time.”

“You definitely have more geological experience and more people experience.” David nodded. “I think you’d be the top candidate this time.”

12.

## Rocking the Boat

March 2031

*Do you want to talk now.*

Dorinda Stetson started at the text on her phone and thought: *Why the hell would I ever want to talk to you?* Zeke Swift was the source of too many good ideas; ideas NASA had considered, sometimes for half a century, and had never been able to afford. But she had been following the news and knew there were things they had to discuss.

She pushed the connect link and a second later, Swift's face popped onto the screen of her phone. "Rather late to call, isn't it Zeke?"

"Well, you answered. At the moment I'm in Bangalore and it's morning here. I wanted to make sure you had seen the detailed press release about Gateway Station. We'll be sending your lawyers a copy of the full contract with the Indian government, so you can see how the issue of strategic technology is handled. There will be no transfer."

"You've always been incredibly careful about that, Zeke, and I'm confident we won't find anything to sue you over, no matter how hard we look. I'm amazed that they agreed to launch their astronauts from the United States on Thunderbirds and Polarises."

"They want me to launch Thunderbirds from Sriharikota, Dorinda, and I'd like to do it; but that's a negotiation we'll have another time. I think it's worth pursuing. For the Gateway mission, they'll launch three men into orbit with their own capsule. They'll rendezvous with a Polaris at the Pax Hotel and use it complete their travel to the Lagrange 2 point on the gravitational watershed between the Earth and moon. The Polaris will return them to the hotel and they're return to Earth in their own capsule. If they want to fly 6 or more at once, they'll

launch three and the rest will go up from our Colorado spaceport, or possibly from Kourou. That depends on the lowest bidder.”

“So: India wants to keep up with China, China has landed men on the moon and has a low Earth orbit station, so India is going to set up Gateway Station between the Earth and moon? Clever, Zeke; that’s a spot with huge potential and no one has anything there yet.”

“Exactly. Twenty years ago, even ten years ago, a station there would have been exorbitantly expensive. But India is purchasing a used BA-330 inflatable from Pax Hotel for fifty million because the hotel has to expand. A Thunderbird-H filled with lunar hydrogen and oxygen can push it to L2 for ten million, along with a leased Polaris capsule. So India gets an instant station at L2. Peary Resources will place a large solar array there for converting water into propellant because depots in low Earth orbit are in the Earth’s shadow half the time. A solar array will produce twice as much power at L2 and will be much simpler to maintain because there won’t be the array steering issues we have in LEO.”

“And everyone will want to rent the station, I’m sure,” added Dorinda. “It’s a perfect spot to assemble large structures for deployment at L2, like a radio telescope array.”

“Exactly, with a tiny delta-v to get it there. We’ll have a fuel depot there. Spacecraft bound for Mars can refuel there as well. They probably will, in fact.”

“Ah, so this is part of your Mars project as well.”

“Exactly. India will run it, get the prestige of having such a strategic asset, and make some of their investment back. It’s perfect for them, expands the use of the Swift transportation system, and costs me almost nothing.”

“Well, you’ve reassured me, but I wasn’t particularly worried. India is a close ally right now and we’re working closely with them. They had an astronaut at Peary before the Chinese landed taikonauts on the moon.”

“Good, because I have some other news. As you no doubt have already heard, our Gryphon shuttle has now made two runs to Pax Hotel. It starts monthly runs with tourists in March, but with six tourists at a time. In June it will expand its capacity to eighteen tourists at a time and will be running twice a month. We anticipate the lower ticket price will increase demand and it will be flying weekly by the end of the year. Each Gryphon shuttle can be reused a hundred times or more. The price of access to low Earth orbit may fall to half a million per person.”

Dorinda sucked in her breath in surprise. “That’s incredible, Zeke.”

“It’s a revolution. This is what I want to talk to you about: when Northstar 8 is launched to the moon in August, it’ll fly in a Gryphon capsule, not a Polaris. It will be set up to accommodate twelve, not just six. That doesn’t mean I plan to launch twelve. I think we can get contracts to launch eight, if NASA will to allow the increase. Remember that shelters 1 and 2 were sent up to accommodate six each, but now are set up to accommodate nine. The common room was converted into three additional bedrooms when the atrium in the Lunotel was set up. I see no reason why we can’t fly nine on Northstar 8. If we were to fly twelve on each Gryphon every four months, the Lunotel would have to be used to accommodate four astronauts when crews were being changed. At those times, Peary would have twenty-four personnel. Tourists would not fly up during those periods.”

Dorinda assumed the most patient tone she could. “Zeke, humanity does not need twelve personnel on the moon, peaking to twenty-four for 2/3 of the time. What would they do?”



“You’re kidding, right?”

There was a long silence. “Look, we can’t afford it.”

“Twelve can get to the moon for a bit less than the cost of six currently. They don’t need more accommodation; there’s already plenty of space for them. They’ll need one or two more rangers and maybe a portahab. They’ll need a bigger greenhouse. The cost of producing lunar fuel drops every year as the equipment improves. The potential for making items from lunar nickel-iron and plastic is just beginning to be explored; in a few years Peary may be able to manufacture half the stuff it needs, rather than hauling it in from Earth. If Peary is permanently inhabited by at least twelve, believe me, they will keep busy.”

“We’ll need to double ground support! That’ll cost tens of millions.”

“No, leave ground support as is and let the crew make more decisions. Mars will have to be a lot more autonomous; let the moon experiment with it. Right now you have committees in Houston spinning out dozens, hundreds of possibilities, putting them all up on the Peary website, then Mission Control selects the ones the crew will do on the moon, and sometimes they override Mission Control and make other plans. With the same ground support, a crew twice as big will still accomplish twice as much. The website has enough proposed expeditions, clever reuses of equipment, and other innovations to last a permanent crew of twelve a decade at least.”

“Zeke, it’s not in the budget, and can’t be.”

“That’s fine. Shall I fill the extra seats on the Gryphon with astronauts from Bangla Desh, Philippines, Ghana, Taiwan, Israel, Malaysia, Indonesia, South Africa, Mexico, and Chile? We can lease them rooms in the Lunotel. I can get another four-tonne ranger to Peary for fifteen million bucks; if I charge an additional half million per ticket, I can cover it in less than a year. Is that what you want?”

Stetson sighed; this was becoming tedious. “Look, Zeke, if I say yes, I have to battle Congress to get the funds reallocated. If I say no, your new, very smart lobby in Washington will make us look backward and incompetent and Congress will demand that we reallocate; or possibly, if there’s another government shutdown or a near default, they’ll just slash our moon budget in half again. What do you want me to do? We can’t keep up with you!”

“Fair enough. Maybe, for once, my lobbyists and yours could *cooperate*? I’m not going to replace the Gryphon with something else for at least ten years. It’s going to be the main form of transportation to the moon for a long time. Its cost will gradually decline, but we don’t know how much or how quickly until we know what demand will be. We do know it’ll be about 40% the cost of a Polaris per passenger, starting in August; that’s about 15 million dollars per seat, as opposed to 35 million. I want the United States to coordinate the exploration of the moon and I’m handing that possibility to NASA. If the number of astronauts up there doubles and the American contingent doesn’t expand, American dominance will be hard to maintain. Can we make that case to Congress together?”

“We can try, Zeke. But that also means you have to pull back on your lobbying to get us to support Project Redstar.”

Swift considered. “Alright, we’ll pull back somewhat.”

“*Somewhat?*”

“That’s what I said.”

“That’s not good enough.”

“It’s the best you’re going to get. Because I really wouldn’t mind if the Europeans and Indians split dominance of the moon. They’d do a fine job.”

Stetson thought a moment. That was the best she'd get. "Alright, let's ask them to meet together and plan a joint strategy."

-----

"Twenty-four hours before you leave on a so-called 'quick trip' to Aristarchus, you want to convert it into a major expedition?" Jerry McCord's face was turning red, even over the video link, and the exasperation in his voice was rising to anger.

"Jerry, think about it," replied Will. "From here to Aristarchus is 2,000 kilometers. We're going to drive down, pick up two propellant manufacturing units, then drive 2,000 kilometers back to Peary, then fly to Copernicus. But Aristarchus is just 1,000 kilometers from Copernicus. Why not drive?"

"And on the way, make a big detour to the Apollo 12 landing site, past a Soviet crash site, then a small detour to Apollo 14, then past a U.S. and another Soviet crash site, then to Copernicus. Why not throw in Apollo 15 while you're at it!"

"No, Jerry, I know you want to walk in Hadley Rille; I'll leave that one for you," replied Will. It was true; Jerry had expressed the desire to finish the exploration of that classic landing site. But the sarcasm was not appreciated. "I apologize for that one," Will immediately added, before Jerry could express his rising anger.

"It really does make sense," added David. "There's no reason to drive all the way back to Peary. We'll have plenty of hydrogen and oxygen to get to the outer rim of Copernicus, where the landers can land, pick us up, and take us inside. If we have trouble, the landers would have to rescue us either way."

"If anything, it should be less engineering work for me," added Seoyun.

“And you get the grand tour of the moon; 3,400 kilometers or more,” replied Jerry. Will opened his mouth to point out that that appeared to be the issue; that Jerry or anyone else would probably not break that exploration record for a long time. The Apollo 12 landing site was even south of the equator.

“It’ll be great television,” added Seoyun. “The public will be fascinated to see the two landing sites, and we’ll be able to recover some pieces to see what 62 years of exposure to lunar conditions does to various materials.”

“But we don’t have any routes plotted across the lunar surface,” Jerry pointed out.

“Not terribly important,” replied Will. “You know how it works, Jerry; we often head off to a crater or another site of geological interest, then return to the proposed route. There aren’t that many boulder nests to avoid, and we can see the crater rims on the map and go around them. A team would only have to stay a couple dozen kilometers ahead of us. Otherwise, we can get to the various sites via GPS.”

“The potential geology is immense,” added David. “We’ll explore along Imbrium’s flooded western rim and the scattered hills marking its southwestern edge. We can explore Procellarum further and flesh out our understanding of 12 and 14’s landing sites with modern techniques. The landers will have plenty of fuel to land, pick us up, and take us inside Copernicus, then back to Peary.”

“It is an impressive potential route,” agreed Jerry. He picked up his tablet and scrutinized the route. “You won’t have much daylight when you get to Copernicus.”

“But the earth will be 70% full and 50 times brighter than the full moon on Earth,” replied Will. “We’ve traveled and done geology in Earthshine before.”

“We can’t leave earlier,” added David. “Parts of the Procellarum Trail are in darkness until March 6<sup>th</sup>, but sunrise at Copernicus was yesterday, March 3d. It’ll take two days to get to Aristarchus; we haven’t planned any field trips on the way down, parts of which will be in darkness, because the trail has been traveled several times already. Sunrise will occur when we reach Aristarchus on March 6<sup>th</sup>. It’ll take us about six or seven days to get to Copernicus, leaving five or six to explore the crater before sunset.”

“Which may be plenty, but if we need a few more days, we’ll have a waxing Earth,” added Will. “Yes, this is a big request, Jerry, but after almost three years, we know the equipment pretty well, and we know how to traverse lunar terrain pretty well.”

“And the emergency shelter is an optional item for this trip,” added Roger, who had been sitting silently with the expedition members through the discussion. “This is a good test for it, but if it isn’t safe enough, they can operate from the rangers.”

“So, you’re supporting this plan?” asked Jerry.

Roger nodded. “Definitely. Because if this works, the Mare Moscoviense expedition will drive. We can carry enough fuel to get two thirds of the way, but the landers can land and refuel us, then fly on to our destination.”

“That application hadn’t occurred to me,” said Will. “But come to think of it, one could drive around the moon at the equator—10,000 kilometers—in a month if one drives 300 kilometers per day. One would always stay in sunlight, too. You’d need ten refills, but the landers could provide that.”

“Please, no one suggest that any time soon!” exclaimed Jerry. “Alright, I’ll take this to Mission Control. Since this involves a visit to two Apollo landing sites, they’ll be excited about

it, and will have to make a decision quickly. But you're right, it really isn't difficult; just innovative."

"We like to be innovative up here," exclaimed Roger.

"Good. I'll get back to you tomorrow. Bye."

"Bye," they all replied, and Roger closed the connection.

"Well done," he said. "You may have an approval by tomorrow night, but if you don't, load the rangers with two weeks of consumables and go to Aristarchus. I suspect they'll approve the trip before you have to drive back."

-----  
"Why did we stop at 5:30 in the morning?" asked Seoyun, crawling through the hatch connecting the noses of rangers 1 and 2. She stood up in ranger 1's cabin and watched David cooking instant eggs on the one-burner stove while Will ate a bowl of cereal.

"Sorry, we didn't want to bother you," replied Will. "We thought if you were asleep, you wouldn't notice the rangers stopping."

"We were going to cook you breakfast at a civilized hour of the morning," added David. He pointed to Will. "He's fasting."

"He's *what*?"

"Today is March 5<sup>th</sup>; it's the fourth day of the Bahá'í fast. I am a member of the Bahá'í Faith. We fast from sunrise to sunset every day from March 2 through March 20 every year."

"You do?" She looked outside. "How do you fast on the moon where the sun rises every 14 days?"

"We fast by the clock; 6 a.m. to 6 p.m. That's the rule in high latitudes on the Earth," replied Will. "We didn't want to bother you, that's why we didn't tell you."

“Oh, well thank you.” Seoyun looked at Will in a new way, like she had learned something surprising, even disturbing, about him. “What is the point of such a practice, anyway? In Korea the Buddhist monks used to have all sorts of fasts. They still do, but now we have millions of fundamentalist Christians instead, who are crazy in other ways.”

“Fasting isn’t crazy,” replied David. “Remember, I was fasting back in Ramadan? This year it was the last few days of December and most of January, a month before launch. It didn’t interfere with training, really.”

“Well, thank you for making it inconspicuous,” replied Seoyun. She looked at Will. “I’m sorry if I said anything to hurt your feelings. But I’ve always thought scientists should be rational and beyond religion.”

“I know a lot of scientists who are quite religious. The astronaut corps is full of them. Roger’s an evangelical Protestant, for example.”

“I know, but he’s also a military man, a pilot, an engineer by training; not a scientist.”

“He’s a pretty good geologist, you know,” replied David. “Mostly self-taught, too.”

“Maybe he should have had more scientific training.”

“The statistics don’t bear you out,” replied Will. “Psychiatrists, on the average, are agnostics or atheists, but not people in the ‘hard’ scientists. I’ve met physicists who were conservative Protestants. I’m not quite sure how that’s possible, I admit, but statistically, there are plenty of them.”

“Now, *why* would you fast?” asked Seoyun. “Is it good for you?”

“In some ways. Denying yourself food and drink for twelve hours helps build patience and endurance in a fairly gentle and harmless way. It makes you think about your priorities and

the role of the material world in your life. But Bahá'u'lláh says to obey His laws ‘for love of my beauty.’ It’s really a small example of love and obedience.”

Seoyun looked at him, baffled. “Bahá'u'lláh was a man, and he was beautiful?”

“He’s not referring to His physical appearance, but His spiritual presence.”

She was even more baffled, but David nodded. “The prophet Joseph was supposed to be extremely handsome and attractive to women, but this was a metaphor for spiritual attraction.”

“Exactly. I fast to express my love and devotion to him. But don’t worry, it won’t interfere with my work in any way. If we have an emergency and have to do a lot of very hard physical labor, I won’t fast, because that’s a legitimate exception.”

Seoyun nodded and looked at the coffee pot. “Can you pour me a cup?” she asked David. “I guess we’ll all have breakfast now, then get going again. How far did we go?”

“Two-hundred eighty-seven kilometers,” replied Will. “We’re approaching a big, flat stretch where the rangers will speed up to thirty-eight kilometers per hour. If we’re on our way again at 6 a.m., we’ll reach the Sinus Roris propellant manufacturing unit about 3 or 4 a.m. tomorrow morning.”

“And Aristarchus the morning after,” added David. “We’ll show you Schroeder’s valley; it’s spectacular. We’ll check the seismometer network and pack up the other propellant manufacturing plant, then head south, making two to four geology stops per day.”

“Yes, I know the plans. I’ll spend today running thorough diagnostics on the plant we’re picking up and should be able to affect some repairs, if they’re needed. We can even get the main unit, shorn of solar panels and storage tanks, through the hatch and into the shelter, if I need to work on it in a shirt-sleeve environment. Let’s go into the shelter; it’s really crowded here.”

“Too crowded to eat easily,” agreed Will.



David had finished cooking the eggs, so they grabbed all the food and beverages and walked through the airlock to the shelter. There had been no problems with pressurization; it had proved totally reliable so far. But they kept the door to the ranger's airlock open so if there was a problem, they could quickly evacuate. They went in and sat around the table. "Any word from Mission Control?" asked Seoyun.

"No," replied Will. "I think Roger was right. They'll approve the trip to Copernicus after we get to Aristarchus. It'll be two or three days to get to Apollo 12 from there."

"Plenty of time for the media to get ready, and not so long that they'll get bored," said David.

"I wish we could see the terrain outside better," said Seoyun. "Earthlight isn't very helpful! Everything looks ghostly."

"It has its own beauty," said Will. "Once the sun comes up, it'll be much easier to see everything, but then there will be glare, too."

"I suppose. I'm used to polar terrain where the sun is always glancing across the landscape. It'll be interesting to see the moonscape when the sun's overhead!"

"Within twelve hours of sunrise, you'll notice a difference," said David. "So, do you want to come back to the moon?"

Seoyun nodded. "Yes, I would like to. South Korea is now training two more astronauts, so we'll have a total of five, and they want to have someone on the moon at least once every year. A lot of nations are making commitments, now that twelve can fly here at once. Swift Space has even suggested that the training period on Earth be shortened to two months and the training period up here be extended."

"To save money," agreed Will. "They have to be careful about that, though."

“Do you think NASA will go from two astronauts to four?” asked Seoyun.

“Probably,” replied Will. “They’ll go to at least three; they’ll have to. Every day, the internet has news of another country wanting to send an astronaut here. They need to stay in the lead.”

“They need to give in and join Redstar,” said David. “The Mars plans are moving along very impressively.”

“I agree. Swift’s going to pull it off.” Will looked at David. “What do you think of going to Mars?”

David’s eyes sparkled when he nodded. “Definitely. Aisha has already said she could handle it.”

Two and a half years; she’s very patient,” said Seoyun. “I wouldn’t be!”

David smiled and looked at Will. “What about you?”

Will thought a moment, then nodded. “In a few years, I’ll be ready for another challenge. I enjoy the moon immensely, but I’ll understand it even better if I study Mars.”

“You might even enjoy studying Mars.”

“Oh, definitely, I would.”

-----

They reached the first propellant manufacturing plant the next morning, as expected. They loaded its hydrogen and oxygen into the two ranger’s largely depleted tanks, moved the little plant onto range 2’s trailer, and headed on south. A day later, as the sun rose, they reached the second propellant manufacturing plant on a hillock overlooking Schroeder’s Valley, moved the fuel in its tanks to the two vehicles, and picked up that plant as well. At that point, they received the official permission to proceed to the Apollo landing sites and Copernicus. After a busy day

visiting a few geological sites they had been unable to visit previously and a lengthy drive in Schroeder's Valley, they headed south.

The thousand-kilometer drive to Apollo 12 took them across the equator in four long days. Rather than trusting the rangers to drive themselves, they alternated driving the lead vehicle; the trailing vehicle followed autonomously. Each day involved three 90-minute stops for surface exploration and nearly 12 hours of driving, with someone sleeping in a hammock part of the time. On the way, they paused at the site of a Soviet crash to examine the debris.

After a three-hour stop at the descent stage of the Apollo 12 lunar module to give the world a live tour and collect samples of materials to see how well they had held up, the crew went back inside for supper. Will called his parents.

"Is that the LM right behind you?" asked Stephen, moving his head back and forth in a futile attempt to see past his son.

"Yes; hold on." Will grabbed his tablet and pushed a button to switch to the back camera. He held it up to the windshield. "We are parked just 10 meters away. The burn marks from the ascent stage's launch are still fresh."

"The footprints will endure a million years," said Catherine. "That was quite a television show you all put on."

"And in four languages! The three of us were speaking in English, but David was doing a separate, parallel show in French and Arabic, and Seoyun was doing the same in Korean. Sometimes all three telecasts used the same camera images, but sometimes we used our own cameras."

"That's why we sometimes heard other languages," said Catherine. "I was wondering about that. But I didn't realize there were parallel programs going on."

“NASA wasn’t completely happy about it, but after we came back inside, Administrator Stetson called us and thanked us for a good job. She said there were over a hundred million people watching live, worldwide.”

“It was fun to watch you stand on top of the old lunar module!” exclaimed Stephen. “You know, Apollo 11 landed just before I turned three. I don’t remember the landing, but my parents watched them all, and they once told me that I watched them all, too. So I had seen that vehicle on television, live, some 62 years ago. And now my son is standing on top of it!”

Will laughed. “I wish I had known that. It was quite an emotional experience, but that would have made it even more emotional! Our lander looks a lot like the bottom stage of the LM. As you saw, we grabbed the science package they left behind. It’s going to the Smithsonian! They plan to take it apart and study every piece, first. We also photographed every piece of equipment in detail and as many of their footsteps as possible. NASA plans to scan everything for examples of micrometeoroid impacts. That’ll improve our knowledge of their frequency.”

“You guys are in a sort of firing range, up there,” said Stephen.

“How’s everyone getting along on the trip?” asked Catherine. “Are you alone?”

“I am alone; Seoyun is in ranger 2 and David is washing in the airlock. We’re doing fine. It’s interesting; David’s very supportive of the fast. I think he was upset when I broke the fast early before our telecast, because I didn’t want to be fatigued or inarticulate during the program. Seoyun associates the fast with all the old fashioned religious superstition she’s seen in her life and thinks it’s weird and backwards.”

“As a Muslim, he understands fasting,” said Catherine. “But he doesn’t mind you’re a Bahá’í?”

“No, he’s a liberal Muslim, if you want to put it that way. Seoyun feels she’s a modern person in an expedition populated by religious medievals. She has a blind spot, where religion is concerned. Normally, a little praying in private could be done without bothering her, but the fast is a very public thing and interferes with social life. David and I are eating breakfast at 5:30 a.m. and supper at 6:15 p.m., and she joins us at those times. But she’s not very happy that we’ve shifted the time to get up, even if there is no movement of the sun to determine when we should rise!”

“Well, don’t worry about it,” said Stephen.

“Be kind to her,” added Catherine.

“Oh, I am. It’s rather interesting, trying to face Bahá'u'lláh’s tomb when saying my obligatory prayer because the Earth is pretty high in the sky. David says his prayers facing whichever horizon the earth is closest to.”

“That works,” said Catherine. “I’m glad you have a good friend up there. But I wish you’d find a wife, dear!”

“There aren’t many choices up here, but I’ll be back to Earth in three and a half months. If I get the job as Director of Lunar Surface Exploration, I won’t be going to the moon for at least two years, because their policy is that the Director can’t be an active astronaut. I think that’s silly; who better to go to the moon occasionally than the Director of Surface Exploration? But that’s the policy. We’ll see, at that point.”

“Good. We’d better let you get to sleep, Will. Thanks for calling.”

“Talk to you tomorrow; or after Apollo 14!” added Stephen.

“It’s good to talk to both of you. Give my love to Molly and Taraz. Bye.”

“Bye.”

13.

## Two Steps Forward and One Backward

April 2031

“So, are you ready to go to Mare Moscoviense?” Will asked Ethel.

She looked up from the newspaper she was reading on her tablet. He sat at the breakfast table opposite her. “Yes, I think so; and good morning, by the way.”

“Good morning to you as well!”

She smiled. “I’m still thinking about the impressive video of your lander flying up and over the rim of Copernicus, then landing by the central peaks!”

“It was spectacular; the spectacular culmination to a pretty amazing expedition. I gather that video has been watched on the web ten times more than the visit to the Apollo 12 landing.”

“Well, it’s much more dynamic! I think your expedition may have unwittingly saved America’s contribution to moon exploration!”

“Yes, that’s possible.” Will shook his head sadly. “Who could have imagined that Congressman Low would stab Congressman Haight on the floor of the House of Representatives. Nearly killed him, and half the country is celebrating it!”

“While the other half is demanding his impeachment. I thought the two parties would pull back from their fierce partisanship after that incident, but they dug in even more fiercely.”

“And now we have a government shutdown and a debt default.” Will shook his head. “It’s terribly sad; tragic. The fight itself was a culmination of the accumulated hate between the parties; and it has become a hate. They’ve become addicted to their fund raising, and it has become dependent on drumming up fear and hate toward the other side, so a large percentage of the two parties’ bases have been convinced to hate each other.”

“So, we’ll have a world-wide depression, and we’ll be sending at least fifty percent more astronauts up here anyway!”

“And probably fewer tourists. But that may be just as well.”

“Yes. This group that just left ran me ragged. But it was worth it.”

“Hans Muller was interesting. Muller Mining might invest in carbonyl extraction and manufacturing if the economy improves.”

“I’m sure Swift will talk to him. Swift will be scrambling to fund his projects. The economic situation’s a mess. At least Mission Control has been declared ‘essential’ so it doesn’t affect us significantly.”

“So far. I’m not sure what it’ll do to European space plans. My lab is dependent on grants from the British and European parliaments. Work on the carbonyl three-d printer is finished, but we’ve already started on an improved prototype and on an improved fractionation tower to separate larger quantities of metal carbonyls from each other. Both will be ready for testing in another 18 months if the funds are forthcoming. The lab is also collaborating with Colorado School of Mines on a regolith sifter. It scoops up regolith, runs it through a magnetic separator to obtain the nickel-iron fragments, then the rest rolls down a short conveyor belt where automated hands pick off any pieces of carbonaceous chondrite. That’ll improve our supply of carbon, though it’ll take a lot of electricity.”

“A 50-kilowatt power mast arrives next month anyway. But it is such a tragedy that as soon as a new possibility opens up, it is threatened by a failure of political leadership.”

Ethel raised her hands in a sign of helplessness. “That’s the modern world! We really don’t have leadership anymore; we have jockeying for power, with ideological issues and

benefits to interest groups as the leverage. It's a sort of long twilight. I got into space flight partly as a way to escape the meaninglessness of modern society."

"Space exploration does give one a sense that one is contributing to something important."

"Exactly. I suppose I'll be back up here some time; our lab's work won't be dropped. Meanwhile, I'll be able to work on my marriage." She paused, wondering what else to say.

"Reginald's a commercial pilot; he flies for British Airways. Lots of time away from home."

"At least he's not sitting at home while you're away; that was the problem Lurleen had."

"Perhaps, but having us both travel all the time doesn't work any better. He hasn't been faithful to me. He hasn't ever said anything, but I can tell. You can't have a marriage when people are never in the same place."

"No, you can't. That's the lesson of the astronaut corps, isn't it?"

She chuckled. "Often it is. Anyway, our communication has dropped way off, over the last few months. He barely emails me every three or four days and we don't video even weekly. I have been trying, but it seems useless."

"The last two months I was up here, Lurleen and I barely communicated, also. Where did you meet him?"

"Royal Air Force. We were both in pilot training school. I resigned after a year of flying; I decided, ultimately, that I didn't want to be dropping bombs on people. He finished his tour of duty and became a commercial pilot. Being a pilot and an engineer made it much easier for me to be accepted into the astronaut corps."

"I can imagine. Half the American astronauts still come from the Air Force or the Navy, and those of us who aren't military often feel left out."



“It gives you a sense of camaraderie.” Ethel rose and carried her plate to the galley, where Jerome was bustling about, planning his day’s cooking. She came back with a second cup of coffee. “So, what brings you here so early? Are you still fasting?”

“No, the fast is over, but David and I are making a trip to the floor of Whipple crater this morning to retrieve some plastic samples that were put there back in October.”

“Ah yes, six months of exposure to cryogenic cold. I remember Northstar 5 put them there.”

“We have to do it early because both rangers are needed later today. I’m surprised he’s not here already.”

“How did your fast go? It must have been tricky, on the expedition!”

“Seoyun was not helpful; she wouldn’t eat breakfast before 6 a.m. and often asked for supper before 6 p.m.”

“No, she strikes me as a fine person, but how shall I put it . . . secular and materialistic.”

“Yes, I think that’s true. She wasn’t very accommodating. But David was marvelous, and a twelve-hour fast really isn’t that physically difficult. We did only one EVA in late afternoon, which is the hardest time for me. Mission Control decided not to say anything.”

“That was good of them. I’ve never fasted, but I’ve gone long stretches without food and water, and it isn’t as bad as staying up all night.”

“That’s true,” agreed Will.

Just then, David and Roger walked into the atrium. “Good morning!” said Roger. “Good timing; the entire Mare Moscoviense expedition is here, plus Will. You can stay though, Will.” Roger sat at the table. David was looking grave; Roger had already told him the news. “Mission Control asked us to postpone the expedition a few days because of the government shutdown. I

laughed and explained that the sun doesn't wait for us and Mare Moscoviense doesn't get any Earthshine at night. We go on April 17, as planned, or wait until May 16. They said, wait until May. I said, no."

There was a long silence. Will puzzled at Roger's response; he was a military man, an evangelical, a Republican, and not one to disobey orders. "You said 'no'?" asked Will.

"I did. This is nonsense. We're not up here to twiddle our thumbs. Northstar Control is private, so it is unaffected. Mission Control oversees the rangers and shelters and is essential, so it's unaffected. But the Lunar Surface Exploration team is 'nonessential' so they've been furloughed. Mission Control also said that the cafeteria and other services were shut down. I said, 'order pizza.' They weren't happy. I'm pretty sure we'll be going. Departure's still almost two weeks away."

-----

"This is all informal," Dorinda said to Zeke, as they sat at a corner table in the Starbucks.

"That's fine." He looked around the café. "Of course, half the people in here seem to recognize us, which makes sense, since we're a few blocks from NASA headquarters."

"I figured with the shutdown, this place would be deserted." Dorinda turned back to Swift. "They want to close half our facilities and lay off tens of thousands of engineers and technicians. It would permanently cripple some major sectors of America's technological capacity."

"I know, but if they hadn't defaulted on the debt—even for only a week—they wouldn't have made it impossible for the United States to sell bonds at a reasonable interest rate. You can count on Swift Space—and all the space related lobbies—to do everything they can to keep NASA facilities open. But long term, NASA will not be able to retain the budget it has now. The

United States has dug itself into too deep of a hole. Europe and China have done the same, though for different reasons; the Europeans created social safety networks that can't continue with a growing elderly population, and the Chinese one child policy is now hurting them severely. India's economy is in the best shape right now, of all places."

"Their economy will be number two in a generation, though they're still dealing with a lot of poverty. I can see why you're so keen to collaborate with them, Zeke, even though United States policy currently won't allow it."

"I think you know what the best strategy for NASA is, Dorinda. I'm sorry to say it. Shut down the Liberty shuttle project and divert the money to the moon and Mars, relying almost exclusively on private enterprise to develop the equipment for those two places. Encourage the widespread use of the resulting technology for private space missions and missions by allies, like the Europeans and India, maybe Russia as well. To use a rather old analogy, you need a license-able IBM compatible system, not a government-made Mac. The latter may be better, but it's too expensive and won't garner the private investment to be continually improved."

Stetson contemplated his comment calmly and sipped her latté. "You are probably right, from an objective point of view; but don't tell anyone I said so. Politically, that's an immensely difficult move. We have thirty or forty die-hard Congressional supporters who have major Liberty contracts in their districts, and if we betray Liberty now, we'll lose their support. You know how it is, Zeke. Liberty is a major pork barrel project for a district. Votes are essentially bought and sold via government contracts."

"And that's a major reason NASA is taking us almost nowhere while spending tens of billions. I build Thunderbirds in one place, in one building; 90% of the parts are made there. If you gave me ten billion a year, that place would expand tenfold. But money would be spent

elsewhere because a space program needs a lot more than Thunderbirds and capsules. It needs dozens of other major items: inflatables, rangers, cryo units, space suits, communications satellites, etc. They'd be made in many other Congressional districts. The same amount of money would be spent and maybe in as many districts, but much more efficiently."

"That's the advantage of being a private business, and one that is not publically traded, I should add. We can't support the defunding of Liberty, Zeke, and in public we will condemn any lobbying campaign that advocates that route. But at the moment . . . I can't think of any reasonable consequences we could or would level against anyone who advocates that route."

"I see," said Zeke, nodding. "Alas, it won't be the first—or even the twentieth—NASA project on which billions have been spent, with no result."

"As you say, alas." Dorinda sighed sadly, then sipped her latte again. "What have you heard about space tourism?"

"It's in the tank. The Gryphon will still start to take tourists to low Earth orbit in June, but now we're looking at one flight a month for the rest of the year. If we were still using the Polaris we'd have to cut back to three flights a year, but with the Gryphon, the ticket price is half. As for the moon . . . I have a proposal for you."

"What's that?"

"The first Gryphon flight to the moon is still August. We just confirmed a Singaporean astronaut yesterday, so we'll have ten total; three Americans. After that, all flights to the moon will have a full twelve on board; three to six tourists, depending on demand, and the rest astronauts. If the US has two, that's fine, but I recommend three. You can fly three for the price of the two currently, for the next year. It'll cost less after that."

"No separate tourist flights?"

“Correct, not until demand recovers. Right now, Peary can accommodate twenty-four; nine in each shelter and six in the Lunotel. We’ll want to carve out one or two more rooms from the existing space to make sure we can accommodate extras. Jerome, for example now has a one-year contract to stay, renewable annually, and he has said he wants to stay two years. If each flight brings 12 and there are 12 present, Peary will be large enough when both groups are present. I’ve started talking to the Lunotel investors about investing in a shelter 3, which will cost about \$100 million dollars to build and transport. With it, we’ll be in better shape if there are three groups there at once.”

“I think we can support this modification of the agreement.”

“But shelter 3 will belong to Lunotel and will be managed by Lunotel’s control facility in Houston. By the way, with the NASA cafeteria shut down in the Northstar Control Facility, my people are also working under limitations, so I plan to open a temporary cafeteria in the old Mars TROV facility in the basement. It’ll be small, but we should be able to feed everyone in the building, and it’ll cover its expenses. There may be some other things I can do to help out; we can work the compensation in later. This situation is absolutely childish and ridiculous and makes the United States of America look like an ungovernable third world country.”

“I agree, but politics . . . what can you do?”

“We’ll make do as well as we can. I should add that we are in the process of signing a third annual contract for running our three Martian TROVs, this time with universities in Malaysia, Argentina, and South Africa. The governments are so thrilled, they are investing generously in the equipment needed and paying us a good lease fee; the three TROVs may actually make us a profit, if they last another two years!”

“That’s amazing, Zeke. I suppose they all want to send astronauts to Mars, too. But back to the moon. If the crew there is expanding from six to more like nine, they’ll need a third ranger and a few other things.”

“The cargo shipment they get in early May has a solar power mast, which is one thing a larger crew would need, since I am sure industrial applications is a key area of expansion. I have ideas about a third ranger, too, but it will require some flexibility. The Chinese want one, rather than develop their own. Their plan is to keep three astronauts at Shackleton for two months, no more than three times a year. I want to fly a third ranger to Peary and lease it to them for six months a year. The lease will pay the entire price of manufacture and transportation over five years.”

“That’s a good deal. And the ranger has no strategic equipment?”

“We don’t think so, but it could take three years to get one cleared.”

“Send me a formal proposal and I’ll talk to the White House. Our space relations with the Chinese have developed pretty well, with an agreement for the ten-kilometer exclusive use zone around each station and a reciprocal support and rescue agreement. We’re working on an equipment agreement already. The President sees lunar cooperation as one area we can strengthen relations with them.”

“Good. A Chinese lease of equipment will be good for Lunotel’s budget, Peary’s budget, your budget, and my budget.”

“This is a time of belt tightening.”

“And belt tightening is always an opportunity, Dorinda.”

“I agree, Zeke. Two steps forward and one step backward. You do what you can, and I’ll do what I can.”

-----  
“There must be something we can do,” Will said over the dinner table. “You guys are supposed to leave for Mare Moscoviense in four days!”

“The government shutdown shows no signs of ending,” replied Roger with a helpless shrug. “I talked to Mission Control just two hours ago. They said Northstar 7’s launch has to be postponed because some essential training can’t be conducted now. If all goes well, they’ll launch in May.”

“So, we get a 12-person team for one month less,” said Rostam. “That means we won’t be able to complete all the engineering tasks assigned to us.”

“That’s correct,” said Roger, glumly. As Commander, they were his career accomplishments.

“I’m now finished with the carbonyl fractionator and three-d printer,” said Ethel. “Once I’m back from the expedition, I’ll be available. I know how to work on TROVs in particular.”

“But I need help on a major overhaul of the engines on landers 1 and 4,” replied Rostam.

“I’m a quick study,” replied Ethel.

“Okay,” said Rostam, nodding, because it was true.

“Speaking of changes,” said Roger. “The schedule for the robotic ice miner-transporters can be streamlined. They can go up to 10 kilometers per hour, right? But right now they are making one 24-kilometer trip from the cryo units to the bottom of Whipple crater and back every day.”

“The software hasn’t been updated for two years,” replied Seoyun. “Back then, the plans were very conservative and the demand for water was reasonably low. We have more experience

now, and when the new power mast is set up we'll have the spare power to raise the output of the volatile processing units at least 25%; when we get some new parts, anyway."

"Has Peary Resources started to work on an upgraded version of the unit?" asked Will.

Rostam shook his head. "No. A new design with twice the mass could produce four or five times as much hydrogen, oxygen, and other gasses. We've learned quite a lot. But they are still paying off the investment on this system, and now with the economic contraction, demand for propellant will probably drop."

"This is the wrong time," agreed Will.

There was silence as everyone sipped their coffee and considered the situation. Then Will said, "Roge, what does the regulation say about needing the lunar ground support team? We don't need them from the point of view of safety."

"No, we don't. The ranger, pressure suit, and life support people are all on duty as usual. We haven't needed them either, except once or twice. The surface geology support team is there not just to support us, they're part of the team. They assist us and share in the discoveries. There's no regulation per se."

"Got it," said Will. "But they've been furloughed and we haven't been."

"We do get much more done when we have a ground support team, though," noted David. "They plan the routes for us, plan each stop, and drive the TROVs that collect support data. They're extremely important."

"They are; we would have gotten a quarter as much done on the trip to Copernicus without them," agreed Will. He considered. "But it occurs to me that we do have another source of ground support: the university teams that have received NASA grants to run TROVs. They are



all guaranteed a certain number of hours per month to run TROVs. Sometimes they run TROVs during our excursions, too.”

“That’s true,” said Roger. “And they provide pretty good support.”

“Of course, all the universities are about to go into their final exam periods,” said David.

“But we’re talking about graduate students,” said Will. “They have less to do then than the undergraduates. And graduate students love to stay up all night running TROVs and scouting routes.”

“So do the undergraduates,” observed Roger.

There was silence for a while, as everyone considered the idea. “Contact the universities,” Roger finally said to Will. “You know them better than I do. David, can you contact Université de Strasbourg? They have a TROV contract from ESA, right?”

“They do,” he confirmed.

“So, you’ll do it?” asked Will, trying not to sound surprised.

“I’ll present it to Mission Control,” replied Roger. “We have a general 2,600 kilometer route to Mare Moscoviense and around it. The 14-day expedition needs 42 field stops, assuming we do the standard three stops per day. We have 31 proposed stops, so we need at least 11 more, and probably 20 or 25 more, so that we have choices. Of the 31 proposed stops, about 15 of them have completed or nearly completed plans; the rest need a lot more work. There are long stretches of the trip down that have only one or two stops, so there are legs of the trip to fill in. Finally, we need the standard GPS trip markers, and only half the route has them. There is an immense amount of work to do.”

“Some of that work can be done as you go,” said Will. “Someone needs to serve as surface geology support coordinator. If Jerry’s unavailable because he’s furloughed, it’ll have to be one of us.”

“David and I will be on the trip, so it’ll have to be you,” replied Roger. “That’ll keep you busy for the next few weeks!”

“I can fill in the GPS trip markers, but we’ll still need a lot of teams to plan stops,” said Will. “NASA and ESA have six university support contracts. If each one can provide detailed plans for three new stops, that’s eighteen. If each one can flesh out three stops that are already proposed, that’s 18 more. We already have 15 more or less ready; that raises the total to 51. Maybe you and David can check those 15 and see which ones need more work.”

Roger nodded. “That’ll work. If each of the six support centers can provide TROV support for either two or three days, that’ll cover the 14 days.”

Will nodded. “It’s too late to call anyone now, but I can start early tomorrow morning. I think they’ll jump at the chance.”

“Good. Try to get as much to me by noon tomorrow as possible. I want to approach Mission Control tomorrow afternoon.”

-----

“Think of this as a one-credit geology field trip course,” Will explained via video to a group of graduate and undergraduate students at Brown University the next morning.

“And I will arrange that extra one credit,” interrupted Dr. Tim Foote, Will’s former graduate advisor. “You’ll deserve it! What better opportunity to do a lunar geology field trip than live with three astronauts on the moon!”

“And we have the necessary academic credentials,” added Will. “David Alaoui and I have doctorates in lunar geology and Roger Anderson has a Masters, plus he has authored or coauthored a dozen papers on the subject.”

“And I’ll help!” added Ethel MacGregor, who was seated next to Will. “I have a doctorate in engineering from MIT. At every field stop, my job will be to assist the students to assist the geologists.”

“And I’ll be a sort of coordinator back at Peary Station,” said Will. “There will be a daily video briefing every morning and every evening, run by the four of us, to recapitulate what has been done and what is about to be done. We want you to participate in one of the two happening right before the stop you are helping to plan and execute. Before every stop, Ethel will be driving so that Roger and David are free to discuss the upcoming stop by live video with the people participating in it. So you will literally be part of the exploration team for that stop, and any papers published about the geology of that stop will have a long footnote listing all the coauthors, and your names will appear in the footnote. Each stop needs a team coordinator from among your number who will make sure the stop is fully planned; where the rangers stop to deploy the people and machines, where each TROV goes, where each astronaut goes, how many possible stations everyone has for examining and sampling, what the geological units are and what might be found at each, what the overall and individual research questions are, etc. We’ll bunch your three stops together in the same day, if possible. Brown University gets a total of three days, or nine field stops.”

“I’ll be the overall coordinator,” exclaimed Foote. “But I will appoint stop coordinators to do the bulk of the work for each stop. Will, are we sure yet this plan will be approved?”

“No. This is phase 1: approach the schools, make the proposal, find out who will participate. We need to wrap up phase 1 today if possible, tomorrow at the latest. Phase 2: Roger approaches NASA with a plan for an all-university student-centered expedition to Mare Moscoviense. That starts this afternoon, once we have four or five schools committed. The expedition needs to leave in three days, so NASA has to make a decision fast, but we suspect they will like it because it gets them a lot of potential publicity, and because the schools already have a lot of experience with lunar field geology. Many of you know the drill; you’ve participated. Phase 3 starts in three days when the expedition starts. Fortunately, we have five stops already planned for the first two days because the surface geology team had already planned them before the government shutdown. So we don’t need any stops until five days from now, and we could always stretch it to six or seven if we wanted because we’ve explored the farside highlands down to 80 degrees north already, and the geology is fairly uniform all the way down to Mare Moscoviense. We could make some spontaneous stops, too.”

“And you’ll come up this summer for wrap up?” asked Foote.

Will nodded. “I’m scheduled to land at Kennedy Space Center on July 2. I can come to Brown for several days during the summer or early fall to help with the wrap up of the one-credit course. I’ll do the same at all the schools that participate. I’ll even bring you all samples, because we now have permission to do that.”

“Wow!” said several students in the classroom.

Will smiled. “I see you like that idea!”

“It’s about time,” quipped Foote. “Moon rocks are beginning to appear in some stores. The tourists are allowed to bring up to twenty kilos back, and some are selling them!”

“They are. I wish NASA would ship several tonnes back to Earth for sale; it sounds like the budget will need the infusion, soon!”

The students laughed at that. “You should do this every year,” someone said.

“I agree,” said Will. “We have some great geological talent come along. And it’s a great chance for you to shine and show the professionals what you can do. It’s a great start for a job at Northstar Control.”

“What if the government shut down ends during the expedition?” asked Foote.

“The Lunar Surface Geology support team will have to sit in the second row, because the job has been given to you all instead. Some of them can take vacation, or they can help advise you, as you drive the TROVs, what to look for. That’s the plan.”

“I think it’s great,” said Foote. He looked at his class. “What do you say, is this a great opportunity or what?”

“Yes!” they roared back.

“Excellent, sounds like we can count on you,” said Will. “Thanks, Dr. Foote, for hooking us into your class, even if it is two weeks before exams! We appreciate the chance to present our case.”

“Good luck with your conversations with the other schools,” said Foote. “And Will, remember you’re free to come as a visiting scholar any time!”

“I know! I miss Providence, too. But I’ll see all of you this summer or early fall once classes have resumed.”

“Thanks Will. Bye.”

“Bye.” Will turned to his tablet and pushed a button; the video of the classroom disappeared from the screen.

“Fantastic!” said Ethel. “One school down, five to go.”

“I wish we could do this faster, but we can’t. This is going to be a pretty chaotic experience!”

“It is, but you were right to emphasize that this is an opportunity for them. We have to think of the expedition as a student-led expedition, like you said, not as students filling in because of an emergency.”

“You’re right.”

“Well, you said it!”

“I guess I did, but I didn’t think it through. That’s the only way to make this work.”

“And a lot of high quality geology will get done. They’re smart kids, at Brown.”

“And you know about the place because you were at MIT. I didn’t know you had a doctorate from MIT!”

Ethel smiled, pleased. “I sure do.” She looked at the chronometer. “So, we’re calling Washington University in an hour?”

“Yes, and Arizona State at 2 p.m., then CalTech at 4 p.m. We’ll have to call Cornell tomorrow at 11:30 a.m.”

“I’ll be glad to help for all of them. I want to see this expedition happen, too.”

“Great. I expected more student questions.”

“Foote asked them instead. Say, as a result of our conversation the other day, I emailed my husband and suggested we video chat Sunday. I hope he’ll do it.”

Will was surprised. “That was two days ago; he hasn’t replied yet?”

Ethel shook her head. “No, sadly, not yet.”

-----

“Jerry has consented to come out of occultation for this meeting,” said Dr. Redding Desmarais, NASA’s overall director of the Northstar moon program.

“I assume that once Congress comes to its senses and approves some government spending, I’ll get paid,” added Jerry McCord. “So, you guys want to go to Mare Moscoviense without us?”

“We don’t want to,” replied Roger, diplomatically. “We just want to go. I think this student project idea is a great solution. They get invaluable experience and we get some support.”

“This was Will’s idea, wasn’t it?” asked Jerry, irritated.

“I confess,” replied Will.

“The quality of the support won’t be nearly as good,” said Jerry. “Consequently, some important questions that could have been answered won’t be.”

“That’s true,” replied Roger. “But someone can fill in the gaps later. The big questions usually don’t hang on a single geology field stop; the necessary data is probably available in many places.”

“It is good student experience, but what if they all want to become lunar geologists?” asked Redding. “There won’t be enough jobs.”

“The experience will be applicable in many other subfields,” replied Will. “And there’s always Mars.”

“We can’t consider Mars, though,” replied Redding.

“We don’t need to,” said Roger. “And if you’re worried about quality, see whether you can get a skeleton staff in the surface geology support department declared ‘essential.’ A few more professional eyeballs are all we need. The students are enthusiastic and full of good ideas.

If they have a bit more guidance, they'll do a fine job. Will can coordinate from Peary. We have faculty like Tim Foote, who knows how our field geology is conducted and has participated from Houston. We have several doctoral candidates who have been driving Prospector TROVs for as many as four years and have been involved in some of our field trips.”

“I'm pretty sure we'll have at least one professor and one experienced graduate student involved in every stop,” added Will. “So these are not a bunch of complete amateurs.”

“Everyone will learn a lot,” added Roger. “We're thinking about two-hour stops instead of 90-minute stops, so that no one is rushed. We've talked to professors and student groups at all six schools already.”

“You're dejustifying the lunar surface geology support team, though,” noted Redding. “If we publicize this effort—which we should, it's a great human interest story—people will be saying ‘why don't you do all your expeditions this way?’”

“I'm confident NASA can handle that potential issue,” replied Roger, calmly.

“So, you've already talked to all these schools and raised their hopes,” said Jerry, shaking his head.

“We've told them this is a possibility only,” replied Will. “We can't make a commitment. But we also can't bring the idea to you without know what resources these NASA grant recipients are willing to bring to the project.”

“We do get this support work, essentially, for free,” conceded Redding.

“But it's so amateurish and unprofessional,” replied Jerry.

“Then perhaps we need a bit more assistance from your team,” said Roger.

There was silence for a moment. “I think I can get Jerry and one or two others declared ‘essential,’” said Redding. “There's no safety issue. But to be on the safe side, I'll call ESA. I



think we can get some European astronauts at Darmstadt to provide support as well, especially members of the Northstar 7 crew.”

“Good idea,” said Roger.

“If a kid driving a TROV runs it into an astronaut, there is a safety issue,” persisted Jerry.

“The software should prevent that,” noted Will.

“Safety shouldn’t be a problem,” concluded Redding. “Will, this had better work; they had better not be a bunch of bumbling fools who ask silly questions or can’t drive TROVs in a straight line.”

“The quality will be better than that,” replied Will.

“Okay, we’ll give it a try,” said Redding.

14.

## Birthday

Early May 2031

“Glad you finally made it!” Will said to Pete Theodoulos, shaking his hand. He had been the fourth Northstar 7 member to exit from the portahab and had worked his way down the reception line to Will, who was standing at the end.

“Thanks,” said Pete. “Damn stupid delay, if you ask me.”

“Hey, it’s the political process,” admonished Anton Parker, an American pilot and, at age 60, the oldest member of Northstar 7. He reached out to Will. “Good to see you again.” It seemed rather formal, almost cold.

“Thanks,” said Will with a warm smile, shaking his hand. Whenever Will had seen Anton around Houston, Anton had treated him like a kid.

Commander Angela Braun came down the receiving line next. “Good to meet you, Will Elliott,” she said with a smile and a warm handshake. She seemed to be compensating for Anton’s condescension. “I’ve been fascinated by your research.”

“Thank you. Your study of the lunar interior has been influential on my thinking,” Will replied. “I hope your research finally pins down the key parameters of the core!”

“Thanks, that’s my goal over the next six months. We seem to have enough seismometers up here now! North Pole, South Pole, Plato, Aristarchus, Moscoviense, Copernicus . . .”

“It’s impressive,” agreed Will.

“And you’ve got a birthday coming up,” said Pete, who was still standing nearby.

Will blushed a bit. “That’s true. Tomorrow I’ll be 30.”

“Congratulations,” said Angela.

“Thirty? I’m twice that,” commented Anton.

“Your birthday? We’ve got to celebrate it!” exclaimed Ethel, joyfully. She turned to Anton. “He’ll have to tell me what it’s like from the other side. I’ve still got a year to go.”

“Lovely,” replied Anton, with a smile.

“I was impressed by how the Mare Moscoviense expedition went,” Angela said to Roger. “The students did pretty well.”

“They did, but the European geologists provided crucial support,” replied Roger. It’s a shame NASA could authorize only Jerry and one other geologist to support us. The four of you in Darmstadt really helped.”

“It was good practice for us,” she said.

Koyo Takenaka nodded as well; the Japanese TROV operator and repairman had flown to the European Space Agency’s mission control facility in Darmstadt to help. “We have a lot of capable geologists coming along,” he said.

“Definitely,” said Will. He turned to Pete. “Do you know where your room is?”

“Shelter 1, Room 5. But you can come along.”

“Okay, I want to catch up.” Pete had been born in 1999, like David, and was just 2 years older than Will. The Canadian had spent a lot of time in Houston. Pete picked up his flight bag and they walked toward shelter 1.

“How was the flight?”

“Routine. There are now 4 Thunderbird-Hs at the lunar orbit depot. Crowded!”

“I understand they’re old and nearly obsolete, so they’re being ‘stored’ there.”

“Yes, we’re supposed to fill them if we can, then they’ll limp back to low earth orbit eventually. We spent an extra day at the depot purging the hydrogen tank of one of them, so it

can be repurposed to store methane. We're supposed to fly as much methane up there as possible using a methane tank added to the top of lander 3."

"One of several new tasks added to Northstar 7 in the last month, I hear."

"Yes, Swift is pivoting fast in response to the global recession that Congress so kindly gave to all of us. We're getting shelter 3 in July and ranger 3 in November! And production is shifting to methane because the Gryphons need it and it should be cheaper to get it from the moon."

"But he's lifting 50 tonnes to orbit at a time, too."

Pete nodded. "He is. He's gambling that the recession will just slow growth in low Earth orbit, not reverse it. Right now people are panicking, But I bet he's right."

"And you guys had to pack up the shelter in the basement of the Northstar Control facility?"

"It's the best way to learn how to set it up here! He's outfitting it with the latest life support system. Houston will get a new shelter in January. Meanwhile, if something goes wrong with a shelter up here, the engineers up here will have to look at the systems in the other shelters to figure out solutions. The engineers in Houston will remember the system well enough, or that's the gamble, anyway. As for ranger 3, it's being built from scratch in Elkhart, Indiana, and it'll spend six months of the year at the Chinese station! We'll have a joint leasing agreement with equipment going back and forth."

"NASA agreed to that?"

"I guess so. Chinese-American relations in space seem to be thawing."

"Yes, I think so." Pete reached his room and opened the door. They walked in and he dropped his flight bag on the bed. "Another interesting tidbit: NASA is paying for only one berth

on this flight. Anton's the sole official American team member. Sally Budd is on assignment to Swift Space. She, Toyo Takenaka, and Adam Julkunen are all paid by Swift; that's why there are so many engineering objectives on this flight. Anton is the life support officer and Angela and I are the geologists."

"I was wondering why there were four engineers on the flight. Northstars 5 and 6 both had three geologists."

"If we complete our tasks, this place will be able to accommodate a minimum of 12 personnel and it'll have a lot more geologists. The Gryphon that arrives in August will have three US astronauts, too."

"So one of the Northstar 7 slots has been shifted."

"Exactly. A clever move by NASA; it maintains U.S. centrality to lunar exploration. For a while anyway."

"For a while," Will agreed. "We'll see whether Congress has enough vitality to plan ahead beyond August."

-----

That evening they had a grand welcoming dinner for the Northstar 7 crew. Jerome had been getting bolder and bolder with his lunar cooking and had been importing more and more expensive ingredients, the cost of purchase generally being much less than the cost of transport. Will was pretty sure he had never eaten such a fancy meal in his life.

During the pause between the main meal and the dessert, Roger Anderson rose to welcome the arrivals. "You have many vital projects to tackle," he noted. "First, the overhaul of several lander engines; we have helped speed that task along by pulling the old engines out and bringing them into the basement of shelter 2. Second, excavation of the site for shelter 3. Third,

expansion of the production of methane, to meet the flight schedule of the Gryphons, and of nitrogen, to cover our own use here and some of the use in low Earth orbit. Fourth, setting up shelter 3 and, most likely, breaking in ranger 3. Fifth, continued expansion of the lunar seismic network through a series of one-week expeditions to six locations for surface geology and installation of seismometers. I wish I was going to be here for them!” That elicited laughs. Roger raised his wine glass. “To Northstar 7!”

“Here, here!” Everyone drank the toast.

Then Angela Braun rose. “I don’t know how it has become a tradition that each commander talk about the other one’s accomplishments, complete or planned. But I can say that I am extremely impressed by the three long-distance expeditions, first to Aristarchus by Northstar 5, then your expeditions to Copernicus and Mare Moscoviense. It would seem that the entire moon is now open to us for exploration. We have no long-distance travels planned, though we will probably combine some of the six planned visits into single expeditions with, possibly, surface travel from one to the other. You have broadened our vision of lunar exploration and deepened our knowledge of this fascinating world, and we are very grateful.”

She raised her glass and they drank to that toast as well. Roger rose again. “I have two announcements. The first is a surprising one. I received a call from Mission Control this afternoon, an hour after landing. There has been a change in our plans for the South Pole-Aitken expedition in two weeks. We were scheduled to land in Von Karmen crater, head south to Schrodinger, explore it thoroughly, then possibly head to Shackleton and visit the Chinese station there, thereby crossing most of the moon’s largest, oldest impact basin. But as of today, we will do a most unusual thing, and something we’ve never done before; we’ll approach Schrodinger from two different directions. David Alaoui and I will take lander 1 and ranger 1 to

Von Karman and head north to Schrodinger along the proposed route while Will Elliott will take lander 2 and ranger 2 to Shackleton, pick up Dr. Yang Jiayi, and head north to Schrodinger. Two thirds of that route was already followed the last time we went to the South Pole and the rest has been designed for this expedition. At the end of the trip, we will all drive back the Shackleton and fly home in lander 1 from there. Lander 2 and ranger 2 will remain at Shackleton for Chinese use through the end of July, then will fly back here after they depart.”

There was stunned silence in the room for a moment. “Wow!” Anton finally said. “How did that happen?”

“I can only speculate that it has to do with the global recession,” replied Roger. “As you know, the US has been negotiating with the Chinese over the payment of Treasury bonds. The two countries have already been negotiating about exploration of the moon; we can’t build anything within 10 kilometers of their station without their permission and vice versa. This arrangement is probably part of that bigger package.”

“The rangers belong to Peary Resources,” noted Pete. “So they are the ones arranging for the lease.”

“So, you’ll have an interesting traveling companion!” David said to Will.

“I will. But I know Dr. Yang Jiayi from when I visited Beijing, a year before joining the astronaut corps. He’s the taikonaut who texted me from lunar orbit two years ago, then made a videocall; a call that cost me \$100 in long distance charges, I should add!”

“I think Mission Control decided to send you to Shackleton, not me, because they knew you knew him,” said Roger. “It also lowers the level of the contact.”

“Yet another first for Northstar 6,” commented Angela.

“It is, and should start an important ongoing collaboration,” said Roger. “I have one more announcement, and it also involves another first. Human beings have been on the moon now for almost three years, and there is one thing they have never dared to do.” He paused for dramatic effect. “They have never dared to light candles on a birthday cake! This is an enclosed space, after all, and a fire is potentially fatal. But I think we can count on Will Elliott to blow them out before they catch anything else on fire, and he is just thirty years old; a mere babe! We can be sure he has the lung power to do it as well. So, Jerome, can you bring out the dessert?”

“Certainly!” exclaimed Jerome. Ethel had arisen during the Shackleton announcement and walked to the galley, and Will had vaguely wondered why, but now he saw the dessert birthday cake appear with five candles on it and knew she had arranged the whole thing. Everyone began to sing happy birthday to him, much to his surprise.

“Make a wish!” exclaimed Ethel, as he blew out the candles. He got them all in one breath.

“Sorry I didn’t have thirty,” apologized Jerome.

“That’s alright,” said Will. “Thank you everyone, I am flattered and very surprised. I think I’m not supposed to mention my wish, because then it won’t come true. But I will say that I also wish that Northstar 6 gets home safely and Northstar 7 has great, great success. We’re really privileged to be among the people chosen to start a lunar community. Who knows what will result, but it can only grow bigger and more important to the Earth over the years. Let us hope it also helps bring humanity closer together.”

“Here, here,” said David.



15.

Schrödinger

Late May 2031

“Lander 1 has touched down in Van Karman Crater,” Roger announced. Will, Pete, and several others in the atrium applauded.

“Roge and David have arrived,” said Will.

“You’re next,” said Pete.

“Yeah, I had better get down to the lander.” Will stood up. “See you all in about sixteen days.”

“See you then,” said Pete, shaking his friend’s hand. Will went around to the two tables shaking hands—he was a bit nervous—then he headed out of the atrium, down the stairs, and to the locker room, where he donned his space suit. When he walked out of the locker room to the airlock, flight bag in hand, Ethel was there in her suit.

“Are you ready?” she asked.

He nodded, then realize she might not see the gesture. “Yes. Thank you for the ride.”

“Delighted.” She pointed to the airlock, so they both stepped in and closed the hatch tightly.

“It was a good landing,” Will said.

“I saw a bit of it,” she replied. She looked at him and he could see sadness on her face through the helmet. “I finally heard from Reggie.”

“Oh? When was the last time?”

“Three and a half weeks ago. I’ve been emailing him weekly.” She sighed. “He thinks we should get a divorce.”

“Oh, Ethel, I’m so sorry.” He reached out and put his hand on her shoulder.

“Thanks.” She looked down a moment. “Perhaps it’s just as well. The separation really makes it impossible. And I just heard two days ago that the lab will get enough funding for the next generation carbonyl three-d printer, so I’m coming back here in 16 months with Northstar 12.”

“That’s good news, at least.”

“Yes, but it is tinged with deep sadness. I love him, after all.”

“I know, I could see it. It hurts terribly, Ethel, for a while. Or it hurt me terribly, at least.”

“Maybe we can still save the marriage; I don’t know. I hope he’s willing to try.”

The outer airlock door’s light turned green. “Here we go,” she said, turning a wheel to open the outer door. It pushed open and they both stepped out. A golf cart-like buggy was parked just two meters away; they climbed in and Will put his flight bag in the back. Then they were off, down Aldrin Trail to lander 2, 4 kilometers away.

“I wish you all the best in preserving your marriage,” Will finally said. “Marriage isn’t easy, but divorce can be very painful and leaves one with a sense of personal failure.”

“I’m already feeling that!”

“I’ve decided that if necessary, I’ll postpone marriage ten years while I do my lunar research, then settle down and start a family.”

“I can’t wait ten years; I’ll be 38, and it may get difficult to start a family by then. Men have an advantage, that way!”

“Maybe not, with all the radiation I’m being exposed to.”

“Maybe not,” conceded Ethel.

They rode the rest of the way to the lander in silence. Ethel parked the buggy and they stepped off. Will looked at it. “It’s rather frightening to get in the ranger and fly all the way to Shackleton by myself, and have no control over the vehicle!”

Ethel chuckled. “Yes, I know what you mean. But no one can fly a lander better than the lander itself. There’s no wind to deflect its course, no birds to avoid; it just takes off and lands based on its engines, its gyroscopes, and the GPS data. It’s the same technology that lands Thunderbirds and capsules on Earth.”

“That’s true, and has been used hundreds of times. Good point.”

“Bon voyage, Will.”

He turned to her and smiled. “Thanks.” They shook hands, then he tossed his flight bag up and climbed the ladder. The emergency shelter was with Roger and David, not him; they knew how to set it up and inflate it, but Yang Jiayi did not, and thus could not help Will very easily if there was a problem. Will grabbed his flight bag and entered the ranger’s airlock. A minute later he was inside. He thanked Ethel again, then called Mission Control so they could start the countdown.

An hour later, the lander’s five engines lit up and it immediately took off. Will was startled by the one gee of force; it was easy to forget what terrestrial gravity felt like. Less than a minute later the engines throttled down, then went out; Will was in weightlessness. Mission Control confirmed that the burn was perfect. Will sat in his seat, seatbelts attached, and looked at the moonscape roll by underneath. The sunset terminator divided the near side of the moon at that moment and he flew right along it, enjoying the dramatic shadows.

Then verniers fired to realign the lander for touchdown and the view shifted. The five engines came on abruptly and in less than a minute they reduced his velocity from about one and

a half kilometers per second to zero. A great cloud of dust and sand blasted into the sky as lander 2 settled onto a cleared pad the Chinese had prepared, four kilometers from their shelter.

“Lander 2 is down safely,” he reported, relieved.

“We copy, lander 2,” replied Mission Control.

“Welcome to Shackleton,” responded Commander Wang Deming, who was listening to the same frequency.

“Thank you. I’ll be egressing in a moment.” Will unstrapped himself, stood, and headed for the airlock. He had been wearing his helmet and gloves for the final descent, so all he had to do was walk into the airlock.

By the time he got outside and down the ladder, Dr. Yang Jiayi had driven up in the Chinese moon rover, accompanied by Sun Shilin, the third taikonaut on the expedition. Will walked to them and extended his hand. “Greetings!”

“Welcome to Shackleton, Dr. Elliott!” said Jiayi. “It’s good to see you and speak to you again!”

“Thank you, I’m delighted to be here with you!” They shook hands, then Will turned to his companion. “I’m very pleased to meet you, Sun Shilín.” He did his best with the Chinese tones and the man smiled in response.

“Thank you, pleased to meet you also, Dr. Will Elliott!”

“How has your first week here been?”

“Very good, thank you,” replied Jiayi. “We have gotten down to the floor of Shackleton and traveled ten kilometers to several small nearby craters.”

“That is an excellent first week,” agreed Will. He pointed. “Let’s get the ranger down off the lander.”

They nodded. Will called Houston and they lowered the vehicle ramp. The three of them checked and locked the ramp's joints, then walked up the ramp to the ranger. They unlocked the wheels and stood back while Houston started the motors and moved it slowly down the ramp. They disconnected the restraining cables once it was on the ground; Jiayi and Will entered through the airlock and drove it to the Chinese station while Shilin followed in the rover. When they arrived, Shilin made sure the ranger's circular docking hatch in the front of the vehicle was properly locked against the shelter's. He headed for the shelter's other airlock while Will and Jiayi entered through the hatch. Will paused briefly to grab a gift for the Chinese crew.

"Welcome, Dr. Elliott!" exclaimed Commander Wang Deming, extending his hand as soon as Will stood up inside.

"Thank you, I'm delighted to visit with you! It is a great honor!"

"Thank you, we are so pleased to have a cooperative arrangement with NASA. May our two countries work together peacefully here on the moon that all of humanity shares."

"That is my wish as well." Will offered a large basket to Commander Wang. "Peary now has a flourishing greenhouse and it is our pleasure to offer you a sample of the latest produce, including this beautiful bouquet of fresh tropical flowers."

"Thank you so much!" Deming took the basket and pulled out the bouquet of jasmine and bird-of-paradise. He inhaled. "Jasmine is one of our favorite flowers in China."

"I have a potted plant in the ranger to give to you as well. It has been growing very well at Peary. The eggplants, zucchini, and tomatoes were picked this morning."

"We will cherish them. Come, sit and have tea with us." Deming gestured at the table that filled a third of the common room in their shelter. Will glanced around it quickly and noted that it was a compact space three meters wide and long, a cylinder laying in its side with a floor a

meter above the lowest point so that the walls bulged outward from the floor. A very narrow hall extended backward from the common room leading to private rooms on both sides and a lab/suit donning area in the rear. The entire shelter was barely ten meters long. Except for its small portholes, the entire structure had been buried under several meters of regolith by the previous crew to reduce radiation exposure.

The four of them sat and drank green tea, made on the tiny two-burner stove built into one wall. “Your expedition to the Apollo 12 and 14 landing sites and to Copernicus was historic,” said Jiayi. “We yearn to make a similar trip.”

“It’s a matter of time and equipment,” replied Will. “I’m sure you’ll have both in a year or two.”

“Taiyingong—as we call this station—will receive a second inflatable module next year, if all goes as planned,” said Deming. “At that point, it will accommodate six, though it will be rather compact.”

Will nodded; it was public information. “This space is very efficiently designed, though.”

“Your shelters are much larger,” noted Jiayi.

“The important thing is that the moon has two poles, and they are the logical places to start its exploration because they have perpetual sunlight and volatiles, and now there are stations at both,” said Will. “This is a good thing for mankind. No doubt the day will come when taikonats will stay at Peary and astronauts will stay here.”

“With your ranger docked to Taiyingong, we already have the first international lunar station!” noted Deming, and they all laughed at that idea.

“As astronauts and scientists, we can get along better than politicians and diplomats,” added Will.

“That is certainly true,” agreed Commander Wang Deming. “But Dr. Elliott, I have one question I regret that I must ask you. It is prompted by the unfortunate incident back in January when NASA allowed an operative of the National Security Agency to come to the moon and visit us. I would appreciate your assurance that you do not have monitoring devices in your ranger or on your person.”

Will was surprised by the question. “I apologize profusely for Bruce Cordani’s presence here, but we had no choice. We also had no idea who he was until we read the article in the *New York Times*, though some of us were suspicious. I assure you that none of us up here have any instructions to spy on you and none of us have any spying devices. There are no spying devices in the ranger or on my person or anywhere else, as far as I know.”

Wang looked at him carefully, pondered a moment, then nodded. “Very well. Thank you, Dr. Elliott, for your earnest expression.”

“That’s alright; I understand your concern. While it is a small token of my esteem for your efforts, please permit me to cook a meal for all of you, before Jiayi and I leave for Schrodinger. We’ll have to eat it here, though; the ranger is rather small for four of us!”

“Thank you, that would be marvelous. We would like to treat you to a dinner as well in another hour.”

“I’d love it.” It was 9 p.m. for Will but 11 a.m. for the Chinese crew; their lunch would be his late-night supper. Then he’d go to bed and offer them a meal at 7 a.m. for him but 9 p.m. for them. Then he and Jiayi would head out and gradually synchronize with Houston time, by the time they got to Schrodinger. As the two vehicles returned to Shackleton they’d all adjust to Beijing time. The entire schedule had been negotiated in detail.

“What’s the news from Peary Station, Dr. Elliott?” asked Shilin.

“There are twelve of us there at the moment, because Northstar 7 has arrived. They’re planning further expansion of the facility because we’ll soon have twelve arriving at once and could have as many as thirty present at the same time, in a few years. I gather there is quite a discussion going on behind the scenes: how many tourists will be there, how many astronauts, how many from each country, how many will be Americans, what will they do, how many will be geologists, how many will be developing experimental manufacturing systems, how many will be engineers, what additional vehicles are needed, who will pay what costs, etc.”

“Questions we haven’t begun to consider,” said Deming.

“A second, independent presence is important,” exclaimed Will. “We can complement each other and rescue each other. I hope you develop your own lander because if one of ours crashes, the entire system could be grounded for a year.”

Deming shook his head. “If a lander crashes, we’ll all have to use the Gryphons. With the spreading global recession, China has had to make some cuts, and the lander is one of them, unfortunately.”

“That’s too bad,” said Will.

-----

An hour later, the Chinese microwaved four excellent prepackaged dinners; their life support system couldn’t handle cooking smells, so they didn’t have dried and frozen foods for boiling and baking. Will retreated into the ranger for seven hours of sleep, then cooked them some spaghetti, which the ranger’s life support system could handle. Then he and Jiayi headed down a trail the rangers had made when they had first visited the Chinese in January. They talked about school and careers for several hours and the geology of the area until 3 a.m. for Jiayi, at which point he set up a hammock—the easiest way to sleep in a swaying vehicle—and went to sleep.



When he woke up five hours later, he decided to think of the time as 6 p.m., which was what it was in Houston.

“So, what have I missed?”

Will shook his head. “Nothing dramatic; the usual rolling moonscape. We’ll make several stops here on our way back. Right now surface exploration support is helping Roger and David; they’re exploring a rille. I’ve been listening to the audio but haven’t dared to pick up the video while I’m driving.”

“We’re off the trail?”

“We reached the end of it about forty-five minutes ago.” Will pointed to an illuminated map on the screen that showed where they had been, where they were, and where they were supposed to go. “The proposed route has been quite good; no unexpected rocks. In about half an hour we’ll cross a crater with a south-facing cliff in permanent shade and it has volatiles.”

“Those are always really pretty spots. It almost makes you think you’re on Earth!”

“It’s a relief from the unrelenting gray.” Will pointed to the galley built into the wall on the passenger side. “Could you make both of us some green tea?”

“Sure.” Jiayi walked over and pulled out the kettle, which he filled with water in the tiny sink and put on the stove. He also put in the microwave two ham and cheese sandwiches that Jerome had packed for them. “A perfect breakfast-dinner for me!” he said, bringing everything over to Will, who stopped driving to pull out a little table to fit over the bucket seat next to his. Jiayi arranged the two meals.

“I’ll set the ranger on autodrive; it can follow the preplanned route at 15 kilometers per hour,” Will said.

“You are so fortunate to have a real cook at Peary! We’re already getting tired of frozen dinners!”

“We are fortunate. He arrived to serve the tourists and decided to stay one year, renewable for a second year. Jerome already has a kind of seniority, too, which gives him a voice that a cook usually wouldn’t. He provides continuity between the missions.”

Jiayi smiled at the thought. He took a sip of his tea while Will turned back to the controls and set the ranger on autodrive. They started moving forward at a fast jog. “So, what do you think the future holds for space exploration?”

Will smiled. “Your guess is as good as mine! The commercialization of space changes everything. In a way, Jerome symbolizes the change; the person who stays at Peary from mission to mission is a company employee for serving tourists.”

“China is having a hard time keeping up, but now it’s pushing its universities and companies to innovate.”

“That’s the way to go. NASA can’t keep up either. Consider the situation with Mars exploration. NASA’s Project Columbus is supposed to go there in the early 2040s; meanwhile, Swift’s Project Redstar already has a vehicle on the way, plans for more cargo and backup vehicles in 2033, and a six-person mission in 2035.”

“And NASA will spend how much more? Ten times?”

“More, depending on whether you include the Liberty flyback shuttle and the deep space reactor system. Of course, to be fair, the commercial successes would have been impossible without NASA spending tens of billions on research and development.”

“But how sad to see them developing vehicle after vehicle, then canceling them.”

“Yes, very sad. Exploration priorities can’t be driven by research and development; exploration need to be set based on practical considerations and pursued practically, with the research and development following.”

“With a long term vision. That’s impossible, even in China!”

“Our governments have become arenas for fighting over money. That makes everything inefficient.”

“So, where do you see your career going?” asked Jiayi.

“I have a sort of five to ten year plan,” replied Will. “I’ll continue to focus on lunar geology. I’ve applied for the position of Director of Lunar Surface Exploration and if I get it, I won’t be coming back here for 2 or 3 years, but will be able to help develop the plans to explore this place. Then I’ll come back at least once more; I hope twice. After that, I don’t know, but I want to cut back on lunar work so I can get married and start a family. Perhaps I’ll go teach at a university.”

“That’s a good plan. I’ll be back in space in a year or two at Tiengong 4 in low Earth orbit, then back here a year or two after that, maybe as commander. They try to give us a flight once every year or two.”

“NASA also, but a lot of astronauts want to go to LEO because the missions last only three months. But now there’s the possibility of four-month missions up here and a lot want to have lunar training.”

“How many foreign astronauts are coming through Houston for training now?”

“Dozens, and in the last six months I hear there are even more. Swift has cut the fee for flying here on the Gryphon to \$20 million and there are twenty or twenty-five countries who want the privilege. Supply exceeds demand and they’re paying bonuses to get a seat sooner!”

“Yet another source of profit for his Mars project,” said Jiayi. “But it would seem that he can’t add Chinese astronauts to his Project Redstar.”

“Ironic, considering the name, isn’t it? NASA won’t let him. But that will change eventually because the technology will no longer be cutting edge. Swift wants to license his system to others, especially to the Indians and Europeans. Once it’s licensed, others will be able to improve it.”

“That will be a big change, and Mars won’t be the only destination.”

“I think that’s true. We’ve now kept humans in low Earth orbit continually for about forty years; that technology is fairly mature. No reason why we can’t put a station in orbit around Venus. Any rocket that can land on Mars can land on Mercury; the gravity’s the same. And the technology for a station at Mercury’s north or south pole, where there’s perpetual sun and volatiles, has been developed here. The asteroids and Callisto aren’t that much harder. We’ll live to see humans expand across much of the solar system.”

“That’s quite a thought.” Jiayi pointed to a dark spot ahead of them. “Is that the cliff with the snow?”

“Yes, I think so.” Will glanced at the map, then nodded. “Two kilometers ahead.” He had finished his sandwich, so he grabbed the wheel, turned off the autodrive, and sped up to twenty-five kilometers per hour, a speed that threw up quite a cloud of dust behind them. Five minutes later he slowed as they entered the shadow. With the sun’s glare eliminated, their eyes adjusted rapidly to the dark moonscape.

“Yes, there it is,” Will said.

“I see it.” Jiayi nodded. “That’s a big area of snow!”

“We’re still at 85 south, so the areas exposed to sun aren’t heated up much and don’t radiate much infrared. But on our trip to Plato two years ago we found a very small, deep crater at 58 north with snow in a small area of permanent shadow. We were quite surprised.”

“There are a lot more volatiles up here than anyone thought.”

“That’s true.” Will stretched. “I’m tired of driving. Let’s suit up and go outside for half an hour. We can search for terraclasts, and there’s an outcrop over here—” he pointed to a spot on the map, “where we can sample the bedrock. We can zap the volatiles with the ranger’s laser, also, to get a composition.”

“That’s a good plan, I’d like to do some field work as well.”

-----

Three days later they met up with Roger and David in the northeastern part of Schrodinger crater. After a lunch in the shelter, they explored a small rille together. The next day they moved to a dark, fresh crater in the center of Schrodinger that represented some of the most recent volcanism on the moon; even more recent than the Aristarchus volcanic province. The next day they headed farther southwest to a huge rille cutting the inner ring of uplift, for Schrodinger was a double-ringed walled plain over 300 kilometers in diameter. All four of them set out to explore the bedrock exposed where a long, wide graben—a separation of the lunar crust—cut through the inner ring of mountains.

“This is very exciting,” said Will, examining the first outcrop they come across. “It’s still anorthositic lunar crust, but it has some streaks of mafic minerals in it.”

“Lunar mantle,” agreed David and Jiayi at once, and they looked at each other in surprise. “We’re close.”

“This is to be expected,” agreed Roger. “The mountain ring is a rebound from the impact, and this was a huge excavation into the lunar crust.”

“And on the bottom of a huge excavation; South Pole Aitken,” added Jiayi, referring to the largest, deepest, and oldest impact basin that had been recognized on the moon, 2,500 kilometers across and 13 kilometers deep.

“We encountered a lot of material of this sort on our trip from Von Karman, which was in a deeper part of the basin,” reminded David.

“In place, like this?” asked Will. He swung his rock hammer and broke off a chunk.

“Not usually,” replied David. “Lots of float.”

They continued up the graben, steering around huge slumps of debris, the TROVs scurrying from rock to rock and zapping them with lasers to measure their composition, the rangers slowly following on autodrive. In several kilometers they came to a smaller crater—three kilometers in diameter and a half kilometer deep—cut by the graben as well. The ground grew too rough for the rangers and the TROVs, so the four of them picked their way down the wide gap in the crater rim, watching their heart rates go way up and their oxygen supplies drop.

After an hour they reached the crater floor, which was still cut by the graben. But the crater floor was mostly impact melt and fallback; no basement rock. “We’ve used up two hours of oxygen and we’ll use up two and half to get out of here,” observed Roger. “We’ve got plenty of oxygen, but I’m not sure if we have plenty of muscle!”

“This is just about far enough for me,” agreed David.

“Me too,” said Will. He pointed. “But there’s a crater inside a crater, cut by our graben, and it’s just ten minutes farther. Let’s get that far.”

“That far and no farther,” suggested Roger, between breaths.

The four of them continued along the rough floor of the graben, which was nearly a kilometer wide. The crater on the floor was over a half kilometer across and had smashed into the moon after the graben had opened, so it exposed even deeper material. As they climbed over the crater's rim they saw darkish rock exposed in the inner rim's lower slopes. "Jackpot," ventured Will.

"Your persistence has paid off, Moonman," agreed David.

They descended the rough slope in a series of big leaps that Jiayi, who had been on the moon much less time than the others, didn't dare imitate. The three astronauts reached the bottom in less than two minutes and stopped at the first darkish outcrop. They all whacked pieces off the exposure and raised them to their helmets, where they could rotate a magnifier in place inside the helmet, set up to bring a rock into focus just outside.

"No question," said Will. "This is an exposure of lunar mantle, a *big* exposure of lunar mantle. We have finally found some."

"It's probably isolated," said David. "And dragged upward into the crust by the various impacts."

"But we're not talking about a little chunk that flew through the air and landed far from its source," said Jiayi. "This is in place, more or less."

"Exactly," said Will.

"Yes another historic discovery," said Roger.

16.

Canaveral

Early July 2031

He felt heavier than lead.

Will tried to raise his head off the acceleration couch, then relaxed and let it sink back into the cushion. He rolled his head to the side to watch a sheet of flames flash by the Polaris capsule's window. After ten months on the moon, even terrestrial gravity was difficult. The three gees of deceleration that had hit them so suddenly was a shocker.

The Polaris capsule, falling all the way from the moon for three days, hit the Earth's atmosphere at 40,000 kilometers per hour—25,000 miles per hour—and in a matter of seconds the gee force had begun to build up. The compressive weight of the Earth's atmosphere caused its pressure to double roughly every 11 kilometers, and the capsule was moving at 11 kilometers per second; no wonder the gee force built up so fast. Thank goodness they were moving close to horizontal; a vertical entry would crush them. Will glanced at David, seated next to him, and Ethel beyond him. They both sat grimly, enduring the force.

But in a few minutes the force began to wane. The capsule turned closer to vertical and soon was falling at its terminal velocity, which was slower and slower as they approached the thick air of sea level. They heard a bang; they had slowed below the sound barrier. About that time the eight powerful engines built into the sides of the capsule came on with a roar. Roger nodded approvingly; he was watching the systems, though to call him the pilot would not be correct. The Polaris capsule could pilot itself far better than any human could. They watched the screens showing the Cape Canaveral landing pad looming closer and closer as the altitude dropped . . . 500 meters . . . 400 . . . 300 . . . 200 . . . 100 . . . 50 . . . 30 . . . 20 . . . 10 . . . 5 . . . 3 . . . 0 .



With a slight bump, the legs touched down and the engines fell silent.

“Welcome home, Northstar 6,” exclaimed Mission Control.

“Thank you, it’s good to be home,” replied Roger. He looked at the five others in the capsule and began to unstrap from his seat and stand. It was a tight, crowded space until they retracted their seats into a more vertical position against the sides, and they were all stiff.

“That was quite a landing!” exclaimed Rostam, and Seoyun nodded vigorously. It was their first.

“I hope they switch to a spaceplane some time,” replied Will. “It’s almost as scary as launch.”

“No, it’s worse,” replied Ethel. “If something goes wrong during launch, the engines will pull us away, but if they fail during landing . . .”

“Fortunately, there are eight of them, and we can land on two, with the parachute backup,” said Roger. “I want to thank all of you for this fantastic mission. We accomplished more than I ever could have imagined we’d accomplish. We were a great team. We completed two extremely important expeditions, discovered crucial pieces of the history of the moon, strengthened international cooperation, achieved a milestone in lunar three-d manufacturing, and advanced methane production substantially. It was full of historic achievements. We have a lot to be proud of.”

“Thanks, Roger, for your leadership,” said Ethel. She hugged him and that set up a round of hugs as they all hugged each other, even rather prickly Rostam. There was even a tear in his eye.

“Thanks for a great expedition,” Rostam said to the others.

“It really was fantastic,” echoed David.

“Thanks for adding me!” said Will.

“Thanks for getting rid of Bruce early!” replied Roger. “He had his mission, but his presence was guaranteed to diminish our accomplishments and put a stain on Northstar 6.”

“I agree,” said Rostam.

“Never mind; let’s get our flight bags,” said Ethel. “The stair is approaching.” She pointed out the porthole near her.

They grabbed their flight bags; for Will, it was clothing he had worn for ten months, not six, plus his tablet and phone, a few photos, a book, and five kilograms of moon rocks he had brought back to give away. They made his bag noticeably heavy in terrestrial gravity.

The stair was in place; Roger worked the controls and opened the door. He stepped out and waved, followed by David, Seoyun, Will, Ethel, and Rostam. They all moved slowly down the stairs—terrestrial gravity was startlingly strong, even after wearing “Earth suits” equal to their terrestrial mass to double their lunar weight—and into a waiting bus, where Dr. Redding Desmarais, director of the Northstar Project, waited to shake their hands and a physician stood by in case any of them had problems. The physician watched the heart rates of all six of them at once on his tablet, but none of them showed anomalies.

The bus took them to the welcoming area where a crowd of family members, journalists, and employees awaited. They all stepped out and walked in, waving. Madhu was there to hug and kiss Roger; Aisha and the kids greeted David, as did Rostam’s wife. Ethel’s tall, blond, dashing handsome husband gave her an affectionate kiss on the cheek. Will maneuvered past Seoyun’s parents to his own. Catherine and Stephen gave him a big hug, simultaneously.

“Welcome home, son,” said Stephen.

“Thanks, dad.”

“Ten months on the moon! A record!” said Catherine.

“And ten months with some pretty good geological accomplishments,” replied Will.

“Records! The oldest and youngest lunar rocks ever recovered!” said Stephen. “Chunks of the lunar mantle, samples from the most recent lunar volcanism, plus a spy to deal with, and the Chinese!”

“The Chinese were great; Jiayi Yang and I became friends. Commander Wang and Dr. Sun were very hospitable once they started to trust me. The Yueliang 2 crew was very friendly as well, though Bruce’s presence complicated the relationship. I hope we were able to start cooperative efforts that can continue.”

“I hope so, too. It’d be crazy to have competition in a dangerous place like that,” said Stephen.

Catherine poked Will. “So, that’s Ethel?”

“Yes. A remarkable woman, very talented and down to earth at the same time. That’s her husband, Reginald. They’ve had some troubles, but they’re going to try to patch up the marriage.”

“Good for them,” said Stephen. “All this separation is hard on a marriage.”

“And he’s a pilot.”

“And that’s Seoyun?” Catherine persisted.

“Yes. Very capable and talented, but looking for a Korean husband, ideally, and one who doesn’t want kids.”

“I see. So you’ve talked to both of them.”

“Oh, quite a lot.”

Desmarais began to shout over the din that everyone should move into the auditorium, so the crowd began to move. “I have news,” said Will. “Two hours ago, as we were approaching Earth, I got a call from Desmarais. I got the job as Director of Lunar Surface Exploration!”

“Really! Congratulations!” said Stephen.

“And just 30 years old!” Catherine kissed him.

“I’m sorry I didn’t call you, but there’s not much privacy in the capsule and we were preparing psychologically for atmospheric entry. I have a two month vacation coming up and will start the new job after Labor Day. I’m planning to come home to Stamford for a week or two, if that’s alright with you.”

“That’s fine, of course!” replied Stephen.

“And you need to go to Bolivia. Molly and Taraz want to arrange a tour for you, sponsored by Universidad Nur and the Bolivian Bahá’í community.”

“Sure, I’d love to do that. I brought back five kilos—eleven pounds—of lunar samples, and I plan to get them all laminated with an identifying tag. I’ll have at least fifty gifts to distribute.”

“So, you’ll be in Houston at least two years?” asked Catherine.

Will nodded. “The Director can’t fly to the moon, which strikes me as stupid, but I can meet each crew before they depart and meet with them by video during their missions. I have some ideas, too.”

“And after that?”

“I want to go back to the moon at least one more time, maybe twice. My radiation exposure is still fine; we’re in the shelters 95% of the time. I can’t say after that; maybe

Northstar administration, maybe work at the Lunar and Planetary Institute in Houston, or maybe a university position. We'll see."

"What about Mars?" asked Stephen.

Will smiled at the suggestion. "I don't know. Maybe. Two years ago I would have said no, the moon is my thing; I'm the 'Moonman.' But now . . . who knows."

"Good," said Stephen. "That's the place with real potential."

"And with mystique; Mars is the subject of dreams the way the moon isn't," noted Will.

"And I have to admit, it is intriguing. Very intriguing."

Mars opposition, March 25, 2029 (launch of TROVs and satellites, Jan 2029; arrival, late Sept. 2029)

### **Northstar 3**

Objectives: move into shelter 2; expand greenery; continue exploration of polar zone; achieve a 3,000 + kilometer round trip expedition; set up cryo 5 and 6 units; upgrade equipment to handle 20 Kelvin

### **Northstar 4**

Feb.-Aug. 2030

Set up a pilot greenhouse; deploy carbon dioxide and nitrogen processing units; water and propellant production achieves doubling from Northstar 1 (250 tonnes of LH<sub>2</sub> and LOX, 400 additional tonnes of water, 20 tonnes CO<sub>2</sub>/30 tonnes methane/LOX, 1 tonne nitrogen/ammonia); three 1-tonne refueling depots arrive and are deployed in a line (to 15 degrees north?).

May 2030: Will sells house; talks to Lurleen one more time because they are divorced; Will runs TROV during trip to Alpine Valley and talks to Rick Page; Jerry is upset he's giving so much advice; talks to his parents again about what?; interacts with the NS5 crew for first time at end of May;

### **Northstar 5 (August 2030-Feb 2031):**

Portahab arrives June 2030; NS 5 is the first group to use it. Introduce Conestoga at end of Northstar 6 in May 2031 (December 2030-June 2031).

Lunotel arrives in pieces, early April, June, late July 2030; Northstar 4 does most of the set up, but Northstar 5 finishes it, September through October

October 2030: Sergei Landsberg works on a chondrite digester to make methane/oxygen fuel.

Late November 2030: first tourists arrive, including a Chinese businessman testing Chinese equipment

Mid December 2030: Sergei goes to orbit depot to experiment with chondrite digester in zero-gee using the lander that will take Northstar 6 to surface. Comes back down with NS 6.

Late December 2030: Northstar 6 arrives, including a mystery expert (and David Alaoui and Ethel McGregor)

January 8, 2031: Chinese land at South Pole using a rented cargo lander; Will, David, and Cordani fly down to “do geology”

February 2031: Thunderbird lander, ranger, TROVs, solar array launched to Mars

Mid February 2031: MDAV/Gryphon capsule lands on the moon as a test of the Mars transportation system

Late February 2031: Northstar 5 leaves, including mystery expert; Will stays in his place

March: Polaris 2 tourist flight

Late April 2031: Northstar 7 arrives

April: Swift tells Stetson Northstar 8 will fly to moon in a Gryphon in August; Stetson is angry. Tourist flights (18/2) to LEO in Gryphon begin in June.

May: Will takes lander to Schrodinger. Will gets position of Director, Lunar Surface Exploration, for 2 years, renewable, starting in September 1

Mars opposition, May 4, 2031; (Thunderbird lander, ranger, TROVs, solar array launched, Feb. 2031; lands at Aurorae, October 2031).

Early June: First Gryphon shuttle takes 18 tourists and 2 crew to LEO hotel

Will stays 10 months, returns with Northstar 6, June 29, 2031.

Will takes 2-month vacation

September 2031: Will takes position of Director, Lunar Surface Exploration, for 2 years, renewable

August 2031: Northstar 8 (9 total) goes to moon in a Gryphon capsule

Will begins to date someone; it doesn't work out

December 2031: Northstar 9 (7 total, 5 tourists) goes to moon in Gryphon

April 2032: Northstar 10 goes to moon with 12

Mars opposition, June 27, 2033; (launch of MDAV and Thunderbird cargo lander, March 2033; arrival, December 2033)

August 2032: Northstar 11 goes to moon with 8

November 2032: Gryphon 3 tourist flight with 10 tourists, 2 crew (2 weeks)

December 2032: Northstar 12 goes to moon with 9

March: 2 Gryphons go to moon with 10 tourists and 2 crew each

April 2033: Northstar 13 goes to moon with 12 astronauts

Columbus 1 crew selected, summer 2034

Mars opposition, Sept. 15, 2035 (Launch, July 24; arrival, February)

Travel calculation: Thunderbirds can put 11 tonnes into orbit for \$30 million (\$2,800 per kilo);  
Thunderbird heavies can put 35 tonnes into orbit for \$60 million (\$1,700 per kilo)

Lander "rental": \$15 million from depot to Peary and back

Polaris capsule: \$25 million from Earth's surface to depot and back

Lunar propellant: \$75 million

Total with Thunderbird: \$145 million

Five paying passengers: \$29 million each, \$32 million with 10% profit, \$35 million with 20% profit

Travel calculation with Gryphon:

Gryphon and 12 passengers get to orbit for \$20 million (because of full reuse of launch vehicle)

Gryphon capsule cost: \$10 million (\$100 million capsule able to be reused many times)

36 tonnes methane/oxygen fuel from Earth (cost \$50 million) plus 25 tonnes on or from moon (\$25 million)

Total cost of lunar flight: \$105 million

Started November 3, 2013; completed December 14, 2013; reread and edited, July 2,  
2014