The Lunar Frontier

Vol. 3

Project Columbus

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Table of Contents

1.

New Acquaintances

Mid Aug./early Sept. 2031

"I'm surprised you came with two weeks of your vacation left," exclaimed Jerry McCord to Will Elliott. "I feel pushed out prematurely."

Will looked around the busy cubicles of Lunar Surface Exploration Support. "Don't worry, Jerry, I'm not here to start work. I'm still on vacation until September 1. But Doug Morgan and the Northstar 8 team is in Houston for a few days and they want to meet with the person who will be Director of Lunar Surface Exploration after they land at Peary, so I agreed to come through to meet with them. Then I'm leaving again; I have a 10-day swing through Bolivia coming up."

"Bolivia? Why there? They want to send a geologist to the moon as an astronaut, and his expertise is oil and gas exploration!" Jerry laughed.

"I know; we're going to be getting quite a few astronauts from small countries over the next few years whose ability to contribute to our understanding of the moon will be limited. It worries me; I think I'll have some interesting tasks to carry out, as Director of Lunar Surface Exploration, that you didn't have to do! I plan to meet the professor and speak to his students at the Universidad Mayor de San Andres. My sister lives in Bolivia with her husband, who is a physician, and they've arranged for my trip."

"Oh; the Bahá'ís?"

"Yes, the Bahá'ís of Bolivia will sponsor quite a few of my talks and are arranging the others. It should be a fascinating visit. I'll tell you all about it when I get back."

“If you can find me; I’m leaving on September 1. I hope you plan to be here a few days early, so we can discuss the transition.”

“I can get here on Wednesday, August 27th, if that helps.”

“Yes, that’s good.” Jerry pointed around the control room. It had been expanded again and could operate twelve Prospector-350 and Prospector-375 telerobotic vehicles or TROVs. “It’s not much of a domain, especially since half the TROVs are being driven by universities. We only have fifteen staff.”

“I know, but we also have NASA contracts with seven universities, ESA contracts with two European universities, and three other universities in Korea, Japan, and Singapore driving TROVs for their national governments. I’ve been visiting some of them already. Earlier this month I was in Uppsala and Bordeaux. I plan to get to the Far East in a few months, also. There are over 100 professors and graduate students involved in lunar exploration, and I want to engage all of them. We need a plan.”

Jerry shook his head. “You’re trying to herd cats, Will.”

“I know. I have some ideas about that, too.”

“Well, good luck with all that. The last two years have been pretty frustrating for me, I can tell you. No one wants to take direction. The universities and their students have their own projects, the geologists on the moon want to set the agenda, and the people here in terrestrial support have their ideas.”

“I know, I’ve been up there twice! I’m not aiming for minute coordination; just a sense of vision and where different research projects can fit into it.”

“Well, I can’t think of someone more qualified to take over the job.”

“Thanks, Jerry.”

They shook hands, then Jerry walked back into his office, leaving Will in the TROV control area. Will glanced at the ambitious, 42-year old astronaut and wondered whether there was one thing he had done that had earned him respect. Jerry had always treated him like a young whipper-snapper, and Will was just 30. He got that treatment from a lot of the older astronauts.

Will looked at Jerry's small office. The Director of Lunar Surface Exploration didn't get much room; no corner office with a view. TROV control was in the basement of the Northstar Building, next to the offices and labs of Project Redstar, Zeke Swift's private project to land human beings on Mars. Mission Control, which was under contract to the Swift Company, occupied the first floor; it controlled all of Swift's flights using the new gryphon spacecraft, which was also shuttling tourists to the two hotels in low Earth orbit. The top floor contained Swift and NASA offices. It was a remarkably compact facility for such ambitious efforts, but commercial space flight had always been far more efficient and streamlined than government efforts.

Will walked around the TROV area, stopping to talk to several operators. One was a very young man who looked vaguely familiar who had rather long, shaggy, unkempt, curly brown hair. When he walked by, the young man looked up from his controls. "Dr. Elliott! It's good to see you!"

Will saw the young man's name on his identification badge. "Oh, you're Charlie Vickers! I remember talking to you on several occasions on the Aitken expedition." Will extended his hand. Charlie stood up, excited, and shook his hand.

"Thank you; I'm glad you remembered me! That was quite a trip. I was just starting here at the time and they let me run a Prospector-350 in Schroedinger."

"You're in college?"

"I'm at Brown; I'll be starting my junior year next month."

"Oh, I remember you in a class I taught there!"

"And three years ago I saw you at the airport and you gave me your autograph! I'm planning to get a Master's at least and apply for the astronaut corps."

"Fantastic! Well, you're in the right place and getting the right training and experience. I hope you plan to come back; sounds like you'll be leaving for Brown about the time I start here as Director. I look forward to talking to you further."

"Thank you! Maybe we can have lunch some time?"

"Definitely, but I can't do it today; I have a meeting in a few minutes, and it may go most of the day. I'll be back on the 27th. Maybe some time after that. Or maybe at Brown; I'll be visiting there later in September."

"Great."

Will kept walking around the room. He did remember Charlie had asked several smart questions in the class he had taught at Brown two years earlier; he must have been a freshman, too.

After a conversation with Theo Brown, an astronaut scheduled to go to Peary on Northstar 9 in December, Will headed upstairs to conference room 2. He arrived the same time as Douglas Morgan, the commander of Northstar 8, which was scheduled to head to the moon in two weeks.

"Commander Morgan, I'm delighted to meet you. I'm Dr. Will Elliott." He offered his hand to the handsome, blond, 46-year old astronaut. He sought to project warmth and confidence to counteract any impression that his youth and light African-American complexion might give.

“Pleased to meet the ‘Moonman’ with the most impressive publications list in the astronaut corps. Come on, let’s sit down. So, you will be Director of Lunar Surface Exploration starting the day we land at Peary.”

“Correct. I start September 1 and you land September 2. I’m looking forward to strengthening our terrestrial support and coordinating lunar exploration more effectively.”

“We’ll really need the terrestrial support. Have you met Kwaku Sawyer?”

“No, not yet. I gather he has published a paper about a meteor crater in northern Ghana.”

“Correct; that’s the extent of his qualification to be a lunar geologist! That and twenty-five million bucks from the government of Ghana to pay for an astronaut slot, so they can beat Nigeria to the moon. Don’t get me wrong; he’s very smart, his English is impeccable, and he’s a team player. But his geology skills really are inadequate, and he’s been in training here, running TROVs and talking to geologists for almost a year! It’s a crazy way to move science forward, to allow a bunch of poor countries to get prestige points by sending unqualified personnel to the moon.”

“I agree, it isn’t ideal, but it’ll get more people up there, will make the whole system cheaper, and we can make it work. I haven’t been around here since early July last year. How have they been training him?”

“They gave the job to Jerry, so he assigned Dr. Sawyer to the TROV control room. I think the TROV drivers have mostly been training each other. Warren Jansen has been tutoring him, too. Pauline Gonzalez has helped; her lunar geology isn’t stellar, but it’s adequate. He took a course or two at Rice University, too.”

Will nodded. “Warren’s solid, and he’s patient, so I’m glad he’s involved. Pauline should be able to help, too. The three of them will work fine together on the moon. We have a

Malaysian geologist flying on Northstar 9 and a Bolivian geologist on Northstar 10, and I'm not sure they'll have the support from other geologist astronauts. I've been thinking about the problem, which is something Jerry never had to deal with because we had some very well trained lunar geologists in the astronaut corps. It's a task I plan to add to my job description."

"I hope so! NASA's training currently focuses on things like how to use a suit and run life support controls. I doubt you'll get more money, though."

"Probably not. NASA's not even able to fly three astronauts per mission instead of two, even though three is cheaper than two were before! It's crazy."

Doug shrugged. "It's government debt; it's eating the country alive. I may be able to do something about it next year."

"Oh?"

"I'm being courted to run for Senate from Ohio. I'll be back from the moon in February, which is plenty of time. We'll see."

"We could use more friends in Congress."

"I know. But politics is very complicated, now, and the risks to the country are enormous. I'm not sure anyone can do anything. But back to the moon. I want to take an expedition to the Marius Hills and Flamsteed-P. We'd land at Marius first, explore the lava domes and rilles, check out the 'skylight'—the latest estimate is that the lava tube underground is 100 meters across and at least 50 meters high—then go to Flamsteed itself and see whether we can get inside the crater. We'd explore Flamsteed-P's flooded floor—some of the moon's most recent lavas—stop at Surveyor 1, then travel west to the highlands, the Grimaldi rilles, Grimaldi, and maybe Mare Orientale's outer ring."

Will nodded. “That’s a good expedition. Marius Hills beg to be visited; I couldn’t add them to our Aristarchus or Copernicus expeditions. The Flamsteed lavas need to be dated, Surveyor should be studied, Grimaldi has been the site of transient gas releases, and we haven’t reached that part of Orientale. Isn’t that in the plan?”

“No; a trip to Mare Crisium and the site of the Luna 15 crash is instead. Geologically much less interesting, maybe because one of our two geologists is underqualified.”

“I’d favor your Marius-Flamsteed-Grimaldi expedition; it’s more important. There should be time for both.”

“With the cut in funding?”

Will nodded. “I’d favor it anyway. I’m hoping we can get more support from the universities, and we can manage with less terrestrial support overall anyway. We can’t spend a hundred fifty million to fly a team to the moon, then strand them inside Peary’s shelters. They are the eyes of researchers on Earth. Sometimes they are researchers themselves and can publish, but most of the time the primary authors are not the astronauts. We need to coordinate lunar exploration much better.”

“Well, if anyone has credibility, it is you. Good luck with your plans.”

“Thanks.”

Morgan glanced at his watch. “Northstar 8’s assembling in twenty minutes. Why don’t you come along and brief us about the geological accomplishments of Northstars 5, 6, and 7, and what you hope to do as Director.”

“I’d be glad to. And I’m looking forward to meeting Dr. Kwaku Sawyer.”

“So you come here for a few days, brief Northstar 8, then go to Bolivia for a whirlwind tour, then back here to take over Lunar Surface Exploration,” said Dr. Redding Desmarais, NASA’s head of the Northstar project, several weeks later. “And while in Bolivia, you seem to have made some promises. What did you say?”

“No, no, no promises,” replied Will, put on the spot by his boss. He wondered why, less than an hour before Northstar 8’s landing on the moon, he had suddenly been summoned to Desmarais’s office. “I went to Universidad Mayor de San Andres in La Paz, Bolivia’s capital. That’s where Dr. Moises Arroyo teaches geology; he’s the Bolivian astronaut that flies to the moon on Northstar 10 next April. He’ll be here for training in two weeks. I told him that Lunar Surface Exploration would offer him a series of seminars and classes about the latest developments in lunar exploration. The first week at Peary will be devoted to local field trips to review the basics.”

“And how will you pay for the classes?”

“Pay? There’s no cost. These will be long lunch seminars, unless we’re working with an expedition; then we’ll reschedule. I’ll give some of them, other lunar geologists will give others, even the TROV drivers will give some, and we’ll have Arroyo give one. It’ll use up half an afternoon a week, but it’ll make the support staff smarter, so it’ll be good overall.”

“Alright, give it a try. But keep in mind that we’re under intense pressure to cut costs. Anything that looks superfluous may mean it’ll have to be dropped, and one position as well. I suppose you’ll have other ideas for me?”

“Give me a month or two to talk to people. I’ve already had quite a few conversations, but I have a few more to go.”

“Needless to say, we can’t spend more money. I think we’ll manage to get an increase on the moon from two astronauts to three; it’s a question of national pride. But that’s it.”

Will nodded. “Okay. Keep in mind the Bolivian government is paying for Arroyo’s training.”

Redding Desmarais smiled. “So, now the third world is paying for our lunar exploration?”

“Partly. They get the prestige and progress forward. We remain in the center.”

“For now.”

“For now.”

“Well, don’t go fund raising, either.”

“I won’t, but Swift is actively recruiting astronauts. We need to train them and they need to pay. Keep that in mind.”

Redding looked at Will, then laughed. “You’ll get a few pennies—or bolivars—that way.”

“It’ll have to be enough.”

Redding looked at the chronometer. “Let’s go watch the landing.” He stood and led Will to the control room.

When they entered, Will saw only one person in the VIP viewing area. “No Swift or Stetson.”

“This is Northstar 8; we’ve done this seven times already. But we do have a Swift.” He led Will into the VIP area and they sat next to a 40-ish man who looked like a younger copy of Zeke Swift. He turned. “Dr. Elliott, pleased to meet you!”

“Pleased to meet you as well!” They shook hands.

He saw Will’s puzzlement. “Asaph Swift; I’m ‘the son.’”

"Ah, I didn't know. Very pleased to make your acquaintance. I suppose you were named for Asaph Hall?"

"That's one version. My father also has said that since his name starts with Z, he wanted a son whose name started with A."

"Alpha and Omega."

"Something like that." He saw Redding Desmarais's frown. "Asaph Hall was the American astronomer who discovered the moons of Mars."

"Oh, I see." Redding looked at the countdown to landing. "Twenty-four minutes to go."

"The initial descent burn was nominal," said Asaph. He turned to Will. "So, you're the new Director of Lunar Surface Exploration."

"I sure am, as of yesterday, officially. I suppose you work for the Swift Company?"

"Indeed; I'm Vice President for Earth Orbit Services, especially tourism."

"The gryphon's been a breakthrough. I was inside the one that landed at Peary. An absolutely beautiful vehicle; I was so impressed."

"I'm glad to hear it. That was the 'bloc-1' version; the type going to Mars. It's really not well designed for low Earth orbit tourism, or even for lunar transportation. But we're proceeding with the 'bloc-2' version and it should be ready in a year or two."

"Excellent; what's the difference?"

"The bloc-1 has a three-level passenger module on top—44 cubic meters—and a propulsion module underneath with 44 cubic meters of propellant storage and 40 cubic meters of cargo space. The cargo space is underneath the propellant tanks so that it is just a meter off the ground. This is essential for automated unloading on Mars, when the propulsion module is flown by itself as the hippogryph automated cargo vehicle. The bloc-2 has slightly larger propulsion

tanks, moved down to the cargo bay, and a fourth passenger level above, thereby nearly doubling the passenger volume. The propellant tanks also have a simpler design because the bloc-1 has to store hydrogen for transport to Mars, where it can be converted into methane. The bloc-2 can move twenty-four to forty people to LEO and eighteen to thirty to the moon, depending on the configuration we choose. We're also looking at a propulsion module with twice as much propellant—the cargo would go on top where the passenger module is—and a propulsion module using hydrogen instead of methane."

"Lots of possibilities."

"It's a versatile vehicle. In some ways, I wish my father had developed the bloc-2 first; it's more useful for orbital services. Even the gryphon-hydrogen would be more useful for lunar transport because methane is expensive to produce there. But we'll develop them all eventually."

"What do you think of Project Redstar?"

Asaph didn't answer right away. "My father is a brilliant entrepreneur, but Mars is a fixation. The money's on transportation to low Earth orbit."

"Yes, that's true."

They stopped talking because the gryphon carrying Northstar 8 to the surface began to fire its engines for the final descent. It was a routine landing and everyone burst into applause when it touched down. "The third flight of the *Pavonis,*" said Asaph. "When this gryphon goes to Mars, it'll be totally broken in."

"Used," commented Will.

"No; broken in. When we fly in a passenger airliner, we don't think of it as used. These gryphons should fly at least dozens of times, with maintenance of course. Our Thunderbird first stages can now be turned around in 48 hours. We can get launch costs down to $500 per kilo, and

maybe lower." He glanced back at the screen; the TROVs were moving into place to salute the arrivals and the Peary crew was maneuvering a pressurized tunnel into place against the gryphon so the arrivals could exit without a spacesuit. One of the screens in the control room switched to a camera from inside, pointed out a window. The TROVs saluted and Doug Morgan said, "thank you, we salute you as well," from inside the gryphon.

"So, is lunar surface exploration ready to support them?" asked Asaph.

Will nodded. "We've got a good, experienced team. In fact, I should get down to the TROV area. I think some of them want to go out for a 'walk' in an hour or so, so we'll be providing geological support."

"Northstar Control mostly deals with equipment," added Redding.

"Yes, I know; Northstar Control is a service of Swift Space!" exclaimed Asaph.

"Lunar Surface Exploration actually is one of NASA's biggest support activities," said Will. "We're also able to talk to everyone up there. If you gentlemen would like, you are welcome to come down and watch."

"Sure!" said Asaph. Redding nodded as well, reluctantly, and they followed Will out of the control room. Downstairs, surface exploration was a beehive of activity. The 12 TROV stations were all occupied, though four of the TROVs were not active at the time; their operators were on standby to access support information quickly. Will sat his guests and walked around the room, talking to people, making suggestions, then he called Morgan and three geologists—Warren Jansen from Canada, Pauline Gonzales from Mexico, and Kwaku Sawyer from Ghana—and reviewed their plans.

"We're just about done unpacking," said Warren. "The welcoming dinner is still three hours away. I think we want to go out!"

"Definitely!" added Kwaku.

"Alright," said Will. "We'll assume half an hour to suit up and an hour to take the suit off and get ready for dinner, so you have 90 minutes for EVA. I suggest a trip to Armstrong RR, about twenty minutes from Peary. You can suit up on your way." He looked at Desmarais and Swift and added for their benefit, "It's got a mild cold trap next to it, Armstrong RJ, and RR is a cryo cold trap. You'll see the difference in the character of the ices, there's impact melt and impact breccia, secondary craters, RJ preserves bits of the chondrite impactor, and RR has scattered chunks of the nickel-iron impactor in its ejecta blanket. There are also some typical anorthosite boulders."

"We remember the briefing you gave us two weeks ago by video when we were in Hawaii," said Kwaku. "It's a great introduction."

"You gave them a video briefing two weeks ago?" asked Redding. "Weren't you in Bolivia, two weeks ago?"

Will muted his contact with the astronauts. "I was; it was via the internet."

"Don't you ever *really* take vacation?"

"Sometimes, but not as much as it looks."

"I guess not."

"So, do you have a series of trips for them?" asked Asaph.

Will nodded. "We need field geological work of high quality and we're now getting astronauts with lower levels of experience. I've planned five field trips of six or seven hours each. They're just outlined at the moment; I haven't had the time to plan them in detail. But I've spent sixteen months on the moon and I've visited just about every cold trap in the north polar region, so I know the territory pretty well. The idea is to start with a few basic field stops and

work our way up to more complex ones. In two weeks, they'll be ready for a trip of several days to something new. Angela Braun is still Commander, and while we train the Northstar 9 geologists, the Northstar 8 team will continue their work, which includes a lot of engineering, construction, and science support from the arrivals. It'll be her call, ultimately, but there are three possibilities and I suspect we may be able to suggest a few others. I'd favor a 780-kilometer trip down the Serenitatis trail; there's a fumerole with transient gas emission that needs to be checked out. After that, Northstar 8 leaves, Morgan's in charge for four months, and it'll be a negotiation between him and me."

"Well, it's really his call," replied Redding.

Will nodded. "It is, but I know what all the geologists want; it's the job of the Director of Surface Exploration to know that. And I coordinate the support resources. So I dare say that he and I need to talk."

"I see what you're saying," said Redding. "I agree with you. I'll back you up, too."

"Thanks."

2.

Condor

Mid-late October 2031

"The new shelter looks pretty comfortable," said Moises Arroyo to Will, as they watched the moving video on the big screen in the TROV control area.

"It does," agreed Will. "I'm intrigued by the biology facility in the lower level; it'll grow enough food for at least two people, if not three."

"I wish they added quinoa!"

"They should; it's a great grain to eat." Will moved his cell phone closer to his mouth. "Kwaku, can you take us upstairs? I want to see the rooms."

"Sure, Will, give me a moment." Kwaku Sawyer leaped up the ladder well to the second level; it was sudden and rather dramatic video. "We changed the layout, compared to shelters 1 and 2. It's got sixteen rooms, eight on each side of the central hall; no common areas. Two are bathrooms, ten are crew cabins, and four constitute the new sick bay. We've got an examining room, a robotic operating room, a room with an MRI, and a doctor's office."

"So Peary can accommodate . . . thirty-two?"

"Yup, six in the Lunotel, eight in shelter 1, eight in shelter 2, and ten in shelter 3. The basement of shelter 1 is dedicated to geology and the basement of shelter 2 to engineering. Shelter 1 has the control area now and shelter 2 has offices."

"The walls look hard," said Will. "Are they plastic panels?"

Kwaku tapped on a wall next to him; they could hear the thunk. "Yes, lunar-manufactured plastic, and the top level is supported by lunar nickel-iron beams underneath. Ethel MacGregor

manufactured them for us on Northstar 6. It's really great that we can now make our own stuff up here!"

"Ethel worked really hard, too; I was there. It's a great looking facility, Kwaku. Thanks for the tour. Are you ready to go out on an expedition?"

"We can't wait for the Crisium trip early next month, and the Marius Hills-Flamsteed-Grimaldi trip in January!"

"Great! It looks like the latter can indeed stay out close to a month; you guys will set a travel duration record. We think the Crisium-Proclus trip can be extended to Mare Fecunditatis and Tranquillitatis, too. We've got a team looking at important supplemental routes."

"That's great. I wish we could drive down the Serenitatis Trail and extend it to Crisium, but it's hard to drive east; the dayspan gets shorter rather than longer."

"We're not driving the rangers thousands of kilometers any more, either; better to fly them to a destination and explore from there. We're wearing out the landers instead!"

"Yes, that's true. Thanks for your help with all the field trips around here, they have been very valuable."

"You've become the leading expert on lunar geology in Africa, Dr. Sawyer. Glad to work with you."

"Thanks. Talk to you tomorrow. Bye."

"Bye." Will pushed an icon on his phone and ended the call. "Well, that's shelter 3."

"It took them most of six weeks to set it up!" exclaimed Jenny Chase, one of the TROV drivers. Everyone had stopped moving TROVs for the ten-minute tour.

"That's actually pretty fast," replied Will. "When we set up shelter 2 on Northstar 2, I think it took us seven or eight weeks. There's a lot to do."

She looked at him with admiration. “It’s so nice to hear the actual experience. It’s much more real than reading it on a website!”

“It’s all pretty real to me,” replied Will. He looked around at the others. Most wanted to be astronauts. “And I hope it’ll be real for all of you, some day.” He headed back into his office to finish the presentation he had to give to Redding Desmarais in another hour. At one point, he stepped out to grab a second cup of coffee. Jenny Chase was at the coffee maker as well and looked up at him with a smile.

“Big presentation?”

He nodded. “And I need to be persuasive; we need a bigger budget.”

“We do, and if anyone can make the case, it is you! So, are you here every evening? I was surprised to see you here the other evening, when I stopped by to pick up something I had left at my desk.”

“I’m here several evenings a week. We have a lot to get done, and I love the work.”

“But the cafeteria’s usually closed, what do you eat?”

“I bring in something and put it in the refrigerator, then microwave it.”

“Don’t you ever relax?”

“Sure, later in the evenings and sometimes on weekends. I’m afraid right now the moon is my hobby, as well as my work.”

“I apologize if I offend you, but don’t you think that’s unhealthy? You need to relax, you need some love . . . you shouldn’t just work all the time.”

“This is the start of a new job for me and I need to work long hours while I get up to speed. I’m sure I’ll be able to cut back in a few months.”

"Well, I hope so. If I can be of any assistance to you in relaxing, watching a movie, whatever, let me know."

Will smiled. "Thank you, Jennie, that's kind of you." He turned away, wondering what her "whatever" was meant to include. She was pretty, but he felt a lot less attraction to her than she felt for him.

He finished the coffee in his office reviewing his talking points, then headed up to Redding Desmarais's office. "So, how do you think things look at Peary?" asked Redding, as Will entered.

"Pretty good. In the six weeks since Northstar 7 arrived, they got all their construction goals done. Shelter 3 looks really good; Kwaku Sawyer just gave us a tour. If we can manage to increase each Northstar flight to 12, we'll have plenty of accommodation, plus redundancy."

"It does look good. I'm pretty sure we'll manage to send three astronauts from now on, and the Europeans will as well. Swift's working hard to drum up private business and scientific grants; harder than we are, frankly. He's got a manufacturer interested in sending up two technicians for six months to explore plastic production from lunar materials for export to low Earth orbit. I think next summer the Russians will send up a team to explore production of sintered basalt. It'll take a lot of power, but could produce some cheap construction materials. So, what do you have for me?"

"Two matters: lunar geology training for each team, and plans to develop surface exploration further." Will sat at a chair across the desk from Redding. "It took six weeks, in and around construction and repair tasks, to get Northstar 7 up to speed on lunar geology. It wasn't just Dr. Sawyer; three of the engineers will be going out on expeditions at different times and the more they know, the better. With Northstars 1 through 6, there was lengthy training on Earth, and

some astronauts flew twice, so they didn't need much updating. But now we're moving into a phase where we have a lot of astronauts from smaller astronaut corps and they aren't getting any local training in lunar geology at all. The emphasis on engineering and mechanical skills, also, has shifted the focus away from geology; we want everyone to know something about life support systems, but not about geology. We need to establish certification in some skills, and one of them in lunar geology. We have the resources; there's a pool of astronauts trained in lunar geology already, there are professors we can invite in for a fairly small honorarium, there are the TROV drivers, and graduate students."

"We can't spend much."

"I want enough for one honorarium for a visiting geologist, plus housing and food. Most of the training will be provided by me and by other lunar geology astronauts in Houston. The idea is to plan three training sessions per year, each one right after a new landing. Northstar 8 launches in late December, so the next training would be in January for the Northstar 9 and 10 crews. Northstar 8 would do a shorter version of the training expeditions I just ran for Northstar 7, but it would be a refresher for them and an introduction for Northstars 9 and 10, here on the ground. When Northstar 9 lands, they'd run through the refresher face to face for the benefit for Northstar 10 and 11 crew members. The training would include providing some of the TROV support for the crew on the surface, also. It's essential that each crew knows from experience the capabilities of the TROVs."

"Have you talked to Pamela about this? You'll throw off her training schedule rather seriously!"

"I have; we've started negotiations over time. This wouldn't be a required training; it'd be a certification for personnel going on expeditions. Ideally, I'd like eight weeks—"

"I might get you six."

"Then six weeks, but right after a landing. The current training is piecemeal; a lecture and slide show here and there, a trip to Sunset Crater and Meteor Crater in Arizona, etc. We still need the trip."

"Can you run it?"

"Sure."

"I suspect most of the crew will want the geology certification."

"Probably; everyone wants to get outside and see a bit of the moon, and to do that, they need to be useful on an expedition. The more useful, the better."

"Okay, we've needed this for some time. I think even Pamela will agree that the geology training hasn't kept pace with our needs. The first few Northstars had people with solid geological training. Some of them, like Pete, Jerry, and Roger, spent more than a year studying, even though it wasn't their field."

"And it gave them an edge over the astronauts going to low Earth orbit all the time, who didn't need geology."

"Exactly. But now we need geological specialists. Europe has sent several, like Angela Braun. You may want to recruit some American lunar geologists to apply to the corps!"

"I have been. Next year, after I'm more settled in here, I want to make visits to all the university lunar geology programs in the U.S."

Redding shook his head. "No money in the travel budget."

"I'll pay myself or the university department will pay; they have budgets. I'm not worried about that. I need to visit them to discuss exploration priorities anyway. I'll be going to Caltech in about ten days to talk to researchers there and at JPL. If a graduate student wants to study, say,

the formation of the Imbrium Basin, he or she should know when there will be fresh data. That gets me to the second subject: planning and expansion of our surface exploration efforts."

"Okay, but I'll need a written version of the training program. Go ahead."

"I've already stated my plan to visit all the U.S. universities with lunar geology programs to give talks, meet students, and lead a brainstorming. With overseas universities, I may be able to get to a few of them next summer, but a lot of the discussions will have to occur via web video, which I'll also use to discuss priorities with U.S. experts as well. We already have a list of 30 to 50 expeditions, which we can expand. I plan to prioritize them, negotiate with the Commanders, schedule them, and plan the certification training so that it focuses on the geology expected at particular sites. I've already started an email exchange with Larisa Tatarinov, Commander of Northstar 9 and an old friend of mine from Northstar 2, about destinations. She's very accommodating. I'm preparing lists to submit to the Northstar 10 and 11 teams in the next few weeks."

"Excellent. Jerry started coordination of this sort, but it was limited."

"Proper surface exploration requires a lot more than planning of live expeditions. Ideally, a site should be visited by TROV for a few months and samples collected; a series of stops for astronauts are planned, based on the locally generated data; the astronauts visit and retrieve the samples; then TROVs continue to provide follow up for as much as six months afterward. We currently have twelve TROVs on the moon and at most we can plan six expeditions per year. If each expedition involved two TROVs out for twelve months, we'd use all 12 TROVs. If the TROVs are out four months in advance and five months afterward, for a total of 9 months, we'd keep 9 of the 12 Prospector TROVs busy. That's what I'd favor."

“But it’d be pretty expensive to send out a three-tonne lunar lander just to deploy two 350 kilo TROVs and pick them up afterward.”

“I know. Ideally, we need a mini-lander, something with three or four tonnes of propellant, that could fly out, deploy two TROVs and perhaps a tank with 500 kilos of methane and oxygen—because the TROVs will be much more useful if they can supplement their solar cells with their fuel cells—and then fly home.”

“That’s a great idea, but you’re talking about a development budget of several tens of millions of dollars and several years, plus the cost of getting it to the moon.” Redding shook his head. “That’s out of the question.”

“That’s a shame, because if there’s anything that could improve the quality of our exploration, it’s a mini-lander.”

“I know; it’s been proposed several times. But it just isn’t in the budget.”

“As I understand it, we get hydrogen and oxygen propellant from Peary Resources at a discount if we use it on the moon. Could we use the landers instead? For example, two landers deliver two rangers and four crew to one spot on the moon to start an expedition, and on the way back to Peary, each lander delivers two TROVs to another spot on the moon to scout out a future landing spot.”

Desmarais pondered the idea. “We might be able to do that. We’d have to look at the budget and whether there are any exchanges of services possible.”

“Good. I’ll check with mission control about several possibilities, so we’ll have concrete examples to consider.”

“Yes, that’s what we’ll need to negotiate with Peary Resources. What else do you have?”

"That's it, for now. Dr. Arroyo has come along quite quickly, in terms of lunar geology and TROV operation. He'll be in much better shape when he reaches Peary in April. Dr. Kwaku Sawyer and I have been talking about him coming here next summer and assisting in training—paid for by Ghana I should add—and that will give me more support during that period. I still haven't spent more than a day with Dr. Zekeria, the Malaysian geologist going up in December. He's convinced he knows everything he needs to know. So that's going to be a problem."

"Pamela mentioned that to me. NASA has complained to the Malaysian government. I'm afraid he's a glorified tourist. We're talking to Swift Transportation about clearer criteria for separating tourists and astronauts, since they've gone around and recruited both." Redding sighed.

"It's a question of who signs the contract and enforces the provisions. We signed it, so we need to make sure the provisions are clear."

"Yes, but with the cutbacks, we're desperate for cash, and we have fewer people in the legal division and in the foreign liaison office. This could happen again."

Will rolled his eyes. "Alright, good to know. I'll get you the proposed flight plans in a week or so."

"Great, and get me the training plan. Thanks, Will."

"Thanks, Redding."

"So, how was Caltech and JPL?" asked Jenny Chase. Will had just returned from the trip and hadn't even managed to get into his office yet.

He stopped in front of her TROV control station. “It was pretty good. I spoke to two graduate seminars, gave a talk about the current state of lunar geological research at JPL, and had a lot of meetings. I should be getting a dozen emails from people offering various ideas, expedition routes, and technological solutions.”

“That’s excellent! I bet you’re an excellent speaker.”

Will shrugged. “I don’t know, I can’t listen to myself. But the audience asked a lot of questions. I didn’t put them to sleep.”

“Oh, I’m sure you didn’t. I suppose you’ll be in late tonight, and the cafeteria will be open for supper; would you like to eat with me?”

“Gee, I apologize, but I’m not sure what my schedule will be, because I have several important tasks and they will involve meetings. Here it is, already Wednesday, and I was out all of Monday and Tuesday. I have a lot of catching up to do!” He looked at the lunar scene on the screen in front of her. “Where are you, right now?”

“Whipple Crater, providing support for exploration of part of the floor that no one has visited before. The TROV’s having trouble with the cold.”

“I had better leave it to you, then. I’m glad they didn’t move up that three-day expedition; I might have felt I’d have to leave California a day early. I don’t want to be away whenever we’re providing ground support for a major expedition.” He waved goodbye to Jenny and hurried to his office.

He settled in and opened email. An engineer in Mission Control had finally sent him the data for several possible routes for landers; it was indeed possible to fly out people and rangers to one destination, then drop off TROVs at another on the way back to Peary. In some cases it was even possible for the people and rangers to make a stop to deploy the TROVs and make a

quick preliminary exploration, then fly on to their primary science destination. That was encouraging to see. It would be possible, for example, for the Marius-Flamsteed-Grimaldi expedition to start at Grimaldi for a day or two of exploration in predawn Earthlight and to deploy TROVs, then fly eastward to the Marius Hills and start their expedition across Oceanus Procellarum to Flamsteed and Grimaldi. But at that point the lander would have to fly back to Peary empty to refuel before it could fly to Grimaldi to return the expedition to the North Pole. A similar flight plan was possible for the Crisium – Proclus – Tranquilitatis expedition in a few weeks.

That was good news; it made some of the new exploration plan possible. The other emails that had come in that day were about possible expeditions and their objectives. He had stimulated a lot of people to think about destinations and routes.

There was a knock at his door; Moises Arroyo stood there. “Are you planning to stay for the landing at Aurorae?”

“When?” asked Will. The Swift Company had launched a hippogryph lander to Mars seven months earlier and it was scheduled to take fifteen tonnes of equipment to the site of the outpost they planned to establish in four years.

“Eleven p.m. tonight. Mission control is handling it; they coordinate the flight of all gryphons, and a hippogryph is basically the propulsion module of a Gryphon, minus the capsule.”

“Yes, I’ll plan on it. I’d love to see the landing.”

“Good. Can you email mission control and ask for passes for several of us as well? They want your approval before they admit us to the VIP viewing area.”

“Sure, I’ll do that right now.”

With the permission of the Director of Lunar Surface Exploration, several staffers—all astronauts—were approved to sit in the VIP area in the back of Mission Control for Project Redstar's first major Martian landing.

Twenty-six months earlier, three small landers had brought Prospector-400 teleoperated rovers to the Martian surface for the private exploration effort of Zeke Swift. Now he sat nervously in the VIP area for the hippogryph landing. The "hippo," as it was affectionately called, was six meters in diameter and five meters high, with a curved heatshield bottom and four pairs of methane-oxygen engines built into the lower side walls of the vehicle, so that their rocket flames exited at an angle from vertical, thereby preventing the vehicle from flying through its own rocket exhaust as it plunged toward the ground. The lower half of the hippo was a cargo bay holding 15 tonnes of payload; the top half consisted of seven fuel tanks holding two tonnes of liquid hydrogen and ten tonnes of methane and oxygen landing propellant. The flat top and sidewalls were covered with solar panels able to make up to 4 kilowatts of electrical power.

A Martian landing was aptly called seven minutes of terror. The hippogryph had already hit the Martian atmosphere once, burning off its excess arrival speed and settling into an elliptical orbit around the Red Planet. Now it encountered the thin wisps of carbon dioxide, nitrogen, and argon at 4.5 kilometers per second, sufficient to envelop the vehicle in red-hot plasma within a few seconds of its descent toward the surface. The atmosphere won the first round a minute later and aerodynamic lift reversed the fall, sending the vehicle upward another twenty kilometers; but at the altitude of forty kilometers it stalled and began to drop again, slower but more vertically, inevitably toward Dusty Red's cratered, rocky, ruddy surface. At thirty kilometers, falling at over a kilometer per second, the eight landing engines blazed alive,

expelling a hundred meters of blue tinged orange flame, slowing the hippogryph's otherwise fatal plunge. The landing legs extended, verniers fired to adjust the course a bit, and the unmanned cargo vehicle set down just five meters from the center of its landing circle, guided by radio beacons on the previous lander and on the TROV the earlier vehicle had brought. The TROV, parked 100 meters away, capture the whole landing on live video, complete with the muffled sound, transmitted through the thin Martian air.

"Yes!" exclaimed Zeke, leaping to his feet and punching the air with his fists. For a man in his sixties, he exhibited remarkable energy and enthusiasm. Will leaped to his feet as well two seats away and Zeke turned to him for a hand slap, which they exchanged.

"Congratulations!" he said.

"We're on Mars! We are on Mars! The equipment that can land a gryphon and human beings; on Mars!" He jumped into the air a bit and did a dance.

"You've done it!"

The entire Mission Control area was screaming and applauding. Zeke hurried forward after shaking hands with everyone in the VIP area. A bottle of champagne was opened and allowed to foam all over the room; some computers got wet, but no one cared. Phase 1 had involved exploration of three candidate landing spots; now phase 2 would prepare a place in Aurorae Chaos at the eastern end of the Mariner Valleys for an outpost. Phase 3, 26 months later, would land the gryphon *Pavonis* to provide a backup launch vehicle and 15 more tonnes of consumables and equipment; Phase 4, yet another twenty-six months later, would see two gryphons with three crew each land and set up Aurorae Outpost.

The excitement was contagious. Will and Moises joined the others in back slapping, hand shaking, fist bumping, and cheering. It ended after a minute, however, because there was work to

do. Everyone returned to their seats and monitored the shut down of the propulsion system while the VIPs returned to their area.

"What does the hippo contain?" asked Moises.

Zeke smiled, happy to boast about his mission. "It has three rolled up half-tonne solar panels, four meters wide and thirty meters long, each able to make 20 kilowatts of power at noontime. It has a Sabatier reactor able to convert two tonnes of hydrogen into as much as eight tonnes of methane; it can also produce and store up to twenty-eight tonnes of liquid oxygen. The combination is sufficient to push a gryphon to low Mars orbit. This is our first test of the full system, over four years before people arrive. It has a standard lunar ranger equipped with a bulldozer blade, two manipulator arms, a tunable scientific laser, and a rooftop crane, assuming we can get the crane onto the ranger's roof, since the cargo bay is too low for it. It has a trailer packed with scientific equipment that we can use remotely or with astronauts present. It has a Russian-made drill like the one we deployed on Phobos and tested on the moon, able to drill up to one hundred meters into Mars if we can change the casings. It has three more Prospector-400 TROVs. It has a kilometer of power cable and other assets for Aurorae spaceport. We'll use the ranger to clear a series of landing pads and string power cables between them, so we can shunt solar power from vehicle to vehicle. It has an extra tonne of deployable solar panels. It even has a tonne of spare emergency consumables. If, right now, we could parachute three astronauts onto Mars at Aurorae, they probably could survive; they'd have a year of dehydrated rations, power, water, oxygen, and the ranger would provide living space."

Moises stared at the screen, then laughed. "That's amazing!"

"And you're planning to deploy the drill, the TROVs, build the spaceport, etc.?" asked Will.

Zeke shrugged. “We’ll see. Rangers and TROVs are pretty slow to use, with a time delay of many minutes. But all of them can plug into the hippo to recharge their power supplies, so they have a lot more power than anything we’ve ever deployed on Mars before.”

“How will you get items out of the cargo bay?” asked Moises.

“One of the side quarters of the hippo folds down. The side panel is five meters high and the cargo bay is just a meter off the ground, so it makes a pretty good ramp. The ranger will back down the ramp. It can reach into the cargo bay with its manipulator arms, grab items—they all have wheels—and pull them out.”

“It sounds like you’re going to have a lot of personnel working on Aurorae Station from now on,” said Will.

Zeke nodded. “Two for each of the TROVs, making a team of six, three more running the ranger, and specialists working from time to time on the crane and drill. These are almost identical to the Prospectors on the moon, except they’re heavier because of the higher gravity and the need for larger solar panels. Come on over and help drive one some time. I understand, Dr. Elliott, that you already have driven the TROV at Aurorae.”

“Yes, my friend Larisa invited me to do so, when they were being run from here.”

“So I heard. You know, I never wanted to go to the moon first, but it turns out we learned a lot about how to build Prospector TROVs and rangers by running them there, first remotely, then with real people. The lunar shelters have helped us with the design of the Martian shelter—which will be much nicer and bigger—we’re getting flight experience with the gryphons, we’re making methane on the moon using a Sabatier . . . it has really worked out quite well!”

“Is that what made you change your mind?”

Swift shook his head vigorously. “No, I didn’t want to have anything to do with the moon; I saw it as a distraction. But the C.E.O. of Peary Resources was a good friend and he asked me to serve on the Board. I agreed and found he was not running the company very well; he had no vision. He wanted to spend six billion on a lunar landing system! So I deposed him and became C.E.O., and that meant I had to make a commitment to the moon.”

“And you got there for a fraction of the money NASA would have spent!” said Will.

Zeke chuckled. ‘That’s true. I had to develop hydrogen-oxygen engines and vehicles; I didn’t want to do that. I wanted to go for methane, and as it turns out, that would have worked fine.”

“Yes, there’s plenty of carbon dioxide on the moon, just like water.”

“Exactly. So we made a partnership with NASA after they wasted 40 or 50 billion on moon plans that never went anywhere, and we got them to the moon.” He sighed. “And at the rate things are going, we’re going to get to Mars without them.”

Just then, the main screen in Mission Control switched to an image of the Martian landscape, coming from a camera mounted high on the hippo. A small silvery glint was visible near the middle of the scene and the camera began to zoom in on it. In a few seconds the condor lander, a one-tenth scale version of the hippogryph, came into focus.

“That’s part of the programming,” explained Zeke. “We know exactly how far away the condor is and exactly what it looks like, so the hippo is programmed to go focus its cameras on it first.”

“It landed the Prospector-400 two years ago,” said Will, suddenly alive to the potential of a condor on the moon.

Zeke looked at him, puzzled. “Yes, of course. The condor was part of our program to develop the hippogryph, and was used to land the first TROVs at the lunar north and south poles.”

“That’s right,” said Will. “It’s just what we need.”

“Pardon?”

“Redding and I have been talking about ways to strengthen our lunar surface exploration program. One important capacity we lack right now is an easy way to deploy TROVs remotely. If we could fly one or two TROVs to an expedition landing site a few months early to explore the site, when the astronauts arrive they could carry out their work faster. TROVs could also complete follow-up investigations and scout potential expedition sites. The moon’s the size of Africa and there are thousands of important spots to investigate.”

“And the landers, which are designed to transport fifteen tonnes at a time, really are unnecessarily large for the task.”

“Exactly. It’s a waste of propellant and of assets.”

Zeke pondered. “Well, you have two condors up there already. Of course, they landed six years ago. But they were designed to be reused, and they may still work.”

“They’re *reusable*?” said Will, shocked.

“Yes, of course. No reason to develop a non-reusable engine first, then a reusable one! That would require two development programs. The condors have two Mustang-1 engines. The gryphons and hippogryphs have 8 Mustang-2s, which are twice as powerful.”

“Could a Mustang-2 be put into a condor if the Mustang-1 is old and broken?”

"Probably, and the avionics could be replaced as well. I'll ask Mission Control to check the status of the condors on the lunar surface. We also have two condors in storage in California, backups in case one of the lunar or Martian condors couldn't be flown."

"But NASA has no money at all to purchase them, right now."

"That's for sure, they're totally broke." Zeke considered. "But I could lease them; a ten year contract would spread out the cost over many fiscal years. Each one cost me ten million to build, and they're a useless asset right now. I bet we could even get them to the moon cheaply. Each one masses half a tonne without propellant and is designed to land a tonne on the moon. It might be that if I can get them to LEO and fuel them up, if they have no cargo they may have enough delta-v to get to lunar orbit, where a refueling would be sufficient to land them at Peary."

"You could do that?"

Zeke's eyes sparkled. "Well, Administrator Stetson and I will need to talk about it. Get me a copy of your proposal. And if the Moonman could offer me some advice and support for Aurorae, in and around your other duties . . . it may be possible."

Will smiled. "You've got a deal!"

"So, what did you say to Swift?"

Will looked at Redding defensively. He did not like a sudden summons to his boss's office. "That was nine days ago! Several of us sat with him in Mission Control during the landing of the hippogryph at Aurorae. We talked about a bunch of things; mostly his plan to explore Aurorae and build toward a manned outpost in 2035-36. But when the hippogryph focused its first images on the condor lander that had brought the first Prospector to Mars two

years ago, I said out loud, ‘That’s what we need’ and he said, ‘Pardon?’ so I mentioned the need.”

“Ah.” Redding looked at Will Elliott, not certain whether to admonish him or commend him. “Well, it appears you’re getting your condors. The condor at Shackleton responded to commands from Mission Control. Its propellant tanks are now empty, but they ran a countdown and the tanks even pressurized. If we can get some methane there and add some locally made oxygen, Swift will try to fly it to Peary. The condor at Peary isn’t responding at all to commands, but it’s located just two kilometers from the station. Northstar 9 goes to the moon in late December and Larisa Tatarinov is commander. As you know, she has been an active employee of Swift Space, as well as being a member of the Russian cosmonaut corps, and she’s an engineer. She’ll get some quick training in California on the condors there. A swap-out of some parts from the California vehicles and it’ll probably work as well.”

“Fantastic! Thanks!”

“Don’t thank me! I had nothing to do with it; that’s what makes me mad, Will! You should have at least told me of your very persuasive ‘casual conversation,’ especially since you sent Swift a copy of your proposal! You didn’t mention that just now. Swift talked to Stetson.”

“That didn’t take long!”

“Don’t flatter yourself. They’re negotiating Swift’s Project Northstar and NASA’s Project Columbus again. I think they negotiate every month or two. What a ridiculous idea to send American astronauts on a project named ‘Redstar.’ What does Swift think we are, Communists? Yes, I know, it’s just a follow-up on ‘Northstar,’ and there are no Communists any more. But the name still doesn’t work.” He shook his head. “Anyway, I guess Swift did some homework and mentioned it. He’ll make a profit, of course. We can have the two condors on the moon for an

annual support contract at a reasonable rate, including spare parts. We can lease the two condors in California for 1.4 million per year for a ten year contract, then an annual support contract, if they're still functioning. We can purchase methane from Peary Resources for half a million per tonne; the oxygen's free because it's surplus. Each condor flight needs about a tonne of methane."

"How many flights per year can we fund?"

"We'll see. Right now we don't have a functioning vehicle. If we have a vehicle, we'll probably get a budget for half a dozen flights, for starters."

Will smiled. "That's fantastic! We can do a lot with that. This changes everything, Redding. We can now send out TROVs to scout potential landing spots. If they aren't interesting enough, we pick up the TROV and that's the end of our exploration of that spot. If they're interesting, they can get a second TROV or a ranger and three astronauts. The ranger could stay three or four days, or make a short expedition to another spot nearby and stay longer. The condor then flies the TROVs back to Peary or on to another spot. This opens up the whole moon to us."

"How will you get the TROV on and off the top?"

"The condor comes with a deployable ramp. The original TROV was clamped down with explosive bolts, and that won't work with a reusable system. We'll need a different mechanism, but the Swift people are ingenious; they'll come up with something."

"For a fee, of course. Good. Let me know how this progresses, Will."

"I will, Redding. Thanks for letting me know."

"And next time, tell me about your conversation! I'm tolerant of these things; not all administrators would be, but we know how informal Swift Space is, and we're in the same building as they. Update your exploration plan and get it to me as soon as you can."

"I will." Will rose from his chair and headed out of Redding's office, almost vibrating with excitement. It changed everything.

3.

Expeditions

Early Dec. 2031

"So, you got into Proclus!" Will said to Douglas Morgan.

There was a flicker in the transmission, then Will saw Doug smile. He was relieved; he had started with the expedition's high point. The sounds of the safe return party in the top floor of Peary's Lunotel drifted in over Doug's audio. A similar party was going on outside Will's office for his staff. "We did. A big, fresh crater; the first time an expedition has managed to get into one overland! Your team found a great route. I'm glad we held both parties at once, so we could congratulate them. But I think we have some problems to review."

"Yes, I agree."

"You start." Clearly, Doug was mad.

"Too many possibilities, not enough screening beforehand."

"Bulls eye! And you've spent *sixteen months* on the lunar surface, Will. If anyone should have a good idea what is a reasonable expectation, it was you. This is my first trip; I hadn't run an expedition before. I was relying on you, and now I look like a fool to part of the lunar science community. And don't think this won't leak out farther, too; there are articles being drafted by various science journalists that will be published in respected mainstream publications. This effects my reputation, Will. People will ask how I can run for Senate if I can't manage a lunar expedition."

"I'm sorry, Doug. It did get away from us. Being able to land TROVs at your starting point, at Proclus halfway through, and at Rupes Cauchy in Mare Tranquillitatis was a fantastic

opportunity for advance planning of the exploration. But we had no idea it would give us so much data that we would have an embarrassment of riches."

"Prioritizing, Will. You can't recommend 14 hours of exploration per day. We even advanced the landing in Crisium by two days, which means we were stumbling around in faint earthlight! That did *not* work and meant we had to use the headlights too much and drain off more hydrogen and oxygen from the lander in Proclus than planned; we came close to stranding it there. And then we didn't even get to Rupes Cauchy! We got very nice shots of the 300 meter escarpment from the TROVs, but when the sun set, we were still 100 kilometers away, and there was almost no earthlight then. Will, *that's* what I really wanted to get to!"

"I know, Doug, and I'm sorry; very sorry. This won't happen again, I assure you the Marius-Flamsteed-Grimaldi trip will be planned *much* better."

Doug pointed a finger at him. "It better be, or I'll recommend to Redding that he give the Director's position to someone else."

"Doug, keep in mind that your team did get almost a third less done per day than the expeditions I was on. Part of that is because people were green."

"Will: this is *your* fault, not mine."

"I'm sorry, Doug, that the Crisium expedition was not up to all of our expectations. But it was extremely successful; let's remember that. As for Marius-Grimaldi, we'll cut back on recommended stops. But please remember that you are the one who proposed the expedition. It is thirty percent longer than the Crisium expedition and the Marius Hills are worthy an entire month of exploration all by themselves. If we shortened the expedition, we'd—"

"Don't even think about it. We're going from Marius to Flamsteed to Grimaldi, minimum, and if we can get to part of the Orientale outer ring, that's even better. Yes, it's long.

But we can send expeditions back to Marius or other destinations later. We can leave some TROVs behind and Larisa can do follow-up."

"Alright, whatever you say, Doug. You're commander; it's your decision. But remember if you skim the surface and ignore important science, you'll be criticized by the journalists and scientists for that, too. The ability to deploy TROVs before an expedition really changes the game. I won't say that the day of the long-distance expedition is over, but its days are numbered. We'll be planning one-week stays in areas from now on, or perhaps two one-week stays with a short drive of a few hundred kilometers in between. It used to be, we bumbled from one possibly informative site to another, based on orbital data, and hoped we'd stumble upon something significant by chance in between. Now our problem is too many possibly informative sites based on ground truth from TROVs. We'll balance things; we'll figure it out. But—"

"*You* figure it out, Will, and figure it out in the next month. I've got three more months up here, and it's all chopped up. The schedule we have is crazy; you arrive and for the first two months you do what some other commander says; then for two months you are in charge of your own team, but it's small; then another team arrives and you're in charge of them as well, but you have to train them and meld the teams together; and once you succeed, you leave! I'm going to press for two six-month flights per year of twelve astronauts; you arrive, in one week the outgoing team briefs you, then they leave and you have five and a half months, then another team arrives and in a week you brief them and you leave. When Northstar 9 arrives, I'm leaving Larisa and her team here to do their thing and I'm heading to Marius, even if I have to go twice!"

Will nodded; he wasn't going to argue with the Senate hopeful. "Okay, Doug, we'll look at the plans for the Marius-Grimaldi expedition—"

"Marius-Flamsteed-Grimaldi-Orientale," corrected Doug.

"Okay, Marius-Flamsteed-Grimaldi-Orientale. We'll optimize the schedule."

"Optimize: I like that word. I'll look for it in two weeks. Thanks, Will. Bye."

"Thanks. Bye." Will pushed the icon to end the conversation and stared at the blank screen. It was not all his fault; mechanical breakdowns had slowed the expedition, the earthlight was less than it had been in any previous trip, and the expedition had stayed out 22 days, which was a record. Doug had been very agreeable and low pressure, but apparently the pressure to maximize his public image in preparation for a Senate campaign had stressed and pressured him. That was unexpected.

Will got up and walked out of his office. The party was winding down and most people were getting ready to go home. He said good bye to people, then walked out of the building and around a reflecting pool outside; it gave him a nice, five minute pause in his schedule. He said some prayers and reflected on how he could do better next time. Then he came back into Northstar Control. The Lunar Surface Exploration area was almost deserted, except for Jenny Chase—whom he did not want to talk to—so he walked across the hall to Aurorae Control. It was early morning at Aurorae at the time and three people were trying to set up the drill using the ranger's remote manipulator arms while three others were driving TROVs around the area. Watching the effort with the drill was Larisa Tatarinov.

"Good evening," Will said to her. "Taking a break from team training?"

"We're pretty well trained. Most people are now getting training in fuel cell and vehicle maintenance, and I know that already. And a few are getting lunar gravity acclimatization."

Will nodded. "Dr. Zecharia. And he still hasn't come here."

"I've been training him in lunar geology, believe it or not. He doesn't want to feel inferior to you, I think. You know *so much*! It'll hurt his pride to look ignorant. He's a proud fellow."

“Well, pride won’t get him up to speed about mare basalt extrusion history or major tectonic developments.”

“He’s reading. He’ll have no choice but participate in the orientations once he’s at Peary, where he can listen to your voice but doesn’t have to look you in the eye.”

Will looked Larisa straight in the eye. “So, do you think there’s a religious motivation, too?”

Larisa hesitated a moment. “There may be. He tried to explain the Bahá'í Faith to me and he said things that I simply couldn’t believe; something about a Bahá'í father being under an obligation to be the first one to have sex with his daughter.”

Will nodded. “I’ve actually been told that by Muslims. It’s one of those ugly rumors that are spread about persecuted minority groups. I assure you it is utterly groundless.”

“I know some women in Moscow who are Bahá'ís and raised in Bahá'í families. I can’t imagine they were molested by their fathers. Utterly ridiculous. Don’t worry about Dr. Zecharia.”

“Don’t blame me if he’s an ineffective geologist. I’m glad you’re training him, because it sounds like you’ll be doing a lot of it at Peary. I was just talking to Doug Morgan and he said he wants to leave the training of your team to you, so he can complete his geological objectives.”

“That’s fine with me. The station’s big enough for the teams to operate semi-independently. We do have some common engineering objectives to accomplish, but that’s easy enough.” She shook her head. “He’s already focusing on his Senate campaign. I thought he was a bit distracted on the Crisium expedition.”

“Perhaps, and he’s blaming the problems on me.”

“That’s not fair! You did have too many daily objectives; that was obvious by day three. But he never said to you, ‘Will, today, just give me your top four choices.’”

"No, he didn't. But I also didn't cut back when it became obvious they couldn't keep up."

"Well, you live and you learn. Don't let it get to you. You've rearranged surface geology support in some important ways in just three months."

"Thanks." He looked around. "You're not doing anything here?"

"Just watching. I don't think they'll ever get the drill working very well. The parts are not designed properly to be moved by the TROV's manipulator arms. It's a fundamental problem. Otherwise, things are moving forward pretty well on Mars. You almost wonder why people are needed."

"Well, not really!"

"You're right; not really. But the automated systems get better every year. When we go to Mars, the people there will be able to augment their capacities pretty impressively."

"So, do you want to go?"

"I think so; what about you?"

Will considered. "Yes, I'll probably put in. Of course, I'll have to wait for Project Columbus."

Larisa shook her head. "There won't be a Project Columbus. Once Swift gets humans to Mars, no one else will develop their own system. I suggest you go work for Swift."

"I've been helping a little, off and on, and maybe I will."

She looked at him. "Look, let's get some ice cream or something and relax. How does that sound?"

"Great; I could use that. I'm curious: do you jog? Because I go out five times a week before work, but I don't have anyone to go with at the moment."

"I've been working out in the hotel gym every morning, but sure, I'd be up for a jog. I need to keep myself fit for the launch."

"Good, I'd appreciate the companionship."

"Zeke, you aren't helping enough," said Dorinda Stetson.

Zeke Swift looked at her, startled. He sipped his latte. "You came all the way to California to tell me that?"

"Sort of. We're losing the battle in Congress to keep the Liberty shuttle funded. Four more years and fifteen billion more, and we'll be over the hump! No one will cancel the program then. My people tell me that your chief lobbyist, Louisa Turner, isn't into the effort 100%. If that's true, Zeke, that's a problem."

"Louisa into the effort 99% and that's fine. She feels that frankly, it's an extravagance right now; she's said it to my face that with her mother's social security and Medicare being cut, she finds it hard to justify the Liberty. And I kind of agree with her. But nevertheless, we are making a strong argument that the technology being developed for a rapidly reusable, light-weight spaceplane is extremely important for the future of space travel. I am not worried about the competition because it is becoming very clear that my gryphons and polarises are cheaper. What NASA is doing will enable the next generation of commercial spaceplanes to be cheaper than the gryphon."

"And we are pressing hard to keep the technology in the public domain and licensable for commercial use. DARPA is resisting; they want it classified, naturally. But they won't win. You and the other companies will have access to the Liberty's technology at a reasonable fee. That's my pledge."

"And it's my pledge that we will support the Liberty in Congress. That 15 billion may not be going to social security, but it is paying the salaries of a lot of engineers. My concern, Dorinda, is with Project Columbus. We've now landed a hippogryph on Mars and unloaded its cargo. Its solar panels are deployed; it's making methane and oxygen from internal hydrogen and Martian air. The technology for launching astronauts back to Mars orbit is now demonstrated. The hippogryph on Phobos has deployed its drill, and we're having a lot of trouble with it, but we'll certainly be able to manufacture some methane and oxygen propellant there. Even if we can't, in two years we'll send an extra hippogryph to Martian orbit with all the methane and oxygen propellant needed for sending a gryphon back to Earth. In two years, we'll land a fully loaded gryphon at Aurorae to give our astronauts a backup launch vehicle. There can be no doubt in anyone's minds that we will send a team of six astronauts to Mars in the summer of 2035; less than four years from now. Under those circumstances, Project Columbus is not tenable. Congress will never fund it because it will simply duplicate our efforts for ten times the cost, at least six years later. Do you want to see European, Russian, Canadian, Japanese, Brazilian, and Indian astronauts on Mars six years before any Americans land? It won't work, Dorinda. Congress will want an investigation, it will be a huge embarrassment, and NASA will come back to me and ask for a contract to include Americans in Project Redstar, its objectionable name notwithstanding."

Dorinda looked around the coffee shop to see who might be listening. She turned back to Zeke. "I have to confess, you are right about that. Your landing at Aurorae was a huge victory for Project Redstar and a huge blow for Project Columbus. I congratulate you, Zeke; I really do. But we can't drop Columbus. Even if Liberty gets canceled, we still want to pursue Columbus, and for many of the same reasons you have cited: we're developing key technology. You're going to

Mars with solar power; we can get you nukes. You're going on a six-month trajectory with chemical rockets; we can get you nuclear or solar electric and cut the transit time in half."

Zeke shook his head. "Nuclear reactors are a great supplement, but with the new 35% efficient solar cells, they aren't necessary. We're going with light-weight, highly efficient solar panels that cost a few percent as much as your nukes, which will require several billion dollars to develop. As for nuclear electric: it'll be a few decades before it's effective for human spacecraft, and it still won't be able to get people to Mars in three months. Meanwhile, chemical propellant is getting so cheap, we could get people there in three months with hydrogen and oxygen fuel! You're a great engineer, Dorinda, but don't get taken in by all these claims. Every NASA facility wants a piece of the Project Columbus pie. If you give them all a piece, you'll get a big, expensive pie no one will fund."

"Zeke, I can limit things only so much. The Congressmen lobby for all these supplementals and worm them into the NASA budget. Technological development makes commercial efforts like yours possible."

"In a way, yes, but very inefficiently." Zeke shrugged. "I know you're stuck in many ways. But Project Redstar is a way out. It gets Americans to Mars in the first wave and preserves national prestige. The supplementals can make it faster and cheaper in another decade. Do you really want to land Americans on Mars in 2040, Dorinda, when I'll be landing the rest of the world there in early 2036? Think about it very deeply. I suggest that the only way you'll get the development money for the nukes is to attach them to Project Redstar."

She stared at him, frustrated, then said, "This is not the time to debate the wisdom of Project Columbus. I want to protect Project Liberty and you've agreed to help. We'll throw a few small things your way, like leasing the Condors and a contract to take astronauts to ISS2 via the

gryphon. I'm sorry we can't promise anything bigger right now. But we're in a long-term relationship and I want to preserve as much cooperation and collaboration as possible. Work on Louisa Turner. She needs to turn up the heat on some Congressmen. We're about six votes short in the House and two in the Senate; it's quite close. We've gotten the vote postponed until January, so we have more time, but it can't wait any longer."

"Alright," agreed Zeke. "I'll talk to her. But we really are doing all we can. Believe me when I say that."

4.

Earthlight

Late December 2031

"I really appreciate you jogging with me," said Will, as they returned to Larisa Tatarinov's hotel. "These two weeks have been much more pleasant as a result."

"I like jogging, but I don't like jogging alone, and I don't know this area," replied Larisa. She sat on a chair in the lobby to catch her breath. "It helps a lot to jog with someone who knows the streets, and I feel safer with a man around. Thanks for inviting me."

"Glad to." Will sat on the chair next to her. "So, you're off to Canaveral tomorrow for the launch."

"Yes, all eight of us; the largest crew yet. Plus four tourists, of course. I'm so glad we have a plan for the first two weeks, too, thanks to our three-way video with Doug. Kwaku Sawyer is enthusiastic to share his geological knowledge."

"And he'll do fine, with Moises helping here and Pete Theodoulos and Angela Braun stepping in for a few weeks to recount their expeditions. We've got a good support system this time."

"Yes, and Doug wants a parallel expedition with joint engineering and construction tasks, but he doesn't want his people training us. Interesting, but it does give him more flexibility."

"I think he's right that the current organization has its drawbacks. He's not going to get the overlapping missions changed, not soon, anyway, so running parallel expeditions makes sense."

"I watched your tv interview last night. You were very gracious about the problems with the Crisium expedition."

“Well, watch it again, carefully. I never blamed Doug for anything, but I didn’t take the blame for anything that was his responsibility, either. The process was new and it had flaws. The way to find the flaws is to give the process a try. With proper feedback we could have found the flaws more quickly and adjusted. I think it’ll go better with the Marius expedition.”

“I liked your comment about his leadership abilities. It’ll warm his heart!”

“It was honest, but it wasn’t the entire story. ‘Not everything that a man knoweth can be disclosed,’ as it says in the Bahá'í writings.”

“That’s smart. You won’t make an enemy out of him. And if you want to go to Mars, I wouldn’t make him into an enemy.”

Will shrugged. “I’m not performing a calculus about allies and enemies, or that’s not my priority, anyway. As for Mars; I don’t know. But I can see you want to go.”

“Oh, yes! I want to be on Columbus 1! And I think I’ve got a good chance because currently, Russia has two slots. If the US gets on board, as it were, maybe not, but then I could make Columbus 2 or Columbus 3. Columbus 3 lands in 2040 and returns in 2042; I’d be 45. Plenty of time to retire, get married, and settle down.”

“But not start a family.”

“Probably not, especially with all the radiation damage. I suppose I could adopt.”

Will nodded. “You never know. I heard from Madhu Anderson the other day that she emailed Lurleen, my ex-wife. Lurleen just had a baby with her husband, Tad. And she’s staying at home with the baby! She had always made it clear to me that she didn’t want to do that. She married Tad partly because he had agreed to stay home with the baby, so she could continue her fancy, important job. The more I think about it, the more I realize that the problem between us was that she was competing with me and she didn’t feel she could. I wasn’t worried about it; I

wanted her to be successful, and her success didn't reflect on my success in any way. But my success diminished hers, somehow." He shrugged.

"Yes, some people are that way. Say, why don't you come up to my room to wash? There's plenty of space."

Will smiled. "Thanks, Larisa, but I've got to get home, wash up, and get to work."

She looked at him. "Can't blame me for trying."

"That's exactly what you said to me on Northstar 2, remember? And I said 'I don't blame you.' I don't blame you now, either."

"But last time, you referred to your 'covenantal commitment' with Lurleen, and you don't have that, now."

"True. But I believe in making a commitment to a woman first, then engaging in physical relations, not the other way around. Call me old fashioned."

"That is old fashioned. But I appreciate it." Larisa smiled. "Have a good day, Will. I may see you around Northstar Control."

"Perhaps. But if not, have a safe trip." He leaned over and gave her a kiss on the cheek.

"Thanks."

"Any time, we're good friends." Will rose, waved goodbye, and headed out to his car.

He took his time washing and getting ready for a long day in the office. Larisa was attractive, likeable, and potentially was a good helpmeet. But her goals and values were different from his, and that bothered him. Still, how picky could he be? How long should he be picky? And what to do about his loneliness? Seventy hours a week of work was not good, even if he enjoyed it. He went to Northstar Control with some ambivalence.

Lunar Surface Exploration was humming with activity. Kwaku Sawyer was preparing to take out an expedition of two rangers with two team members on a four-hundred kilometer expedition to a crater on the lunar far side. Will stopped at several TROV control stations to find out who was doing what; there were no scheduled stops until the afternoon and all the stops had been well planned. He went into his office and found that Douglas Morgan had called, so he called him back.

"Good morning, Doug, I see you called."

Morgan nodded; they had a video connection. "Yes, half an hour ago; you're later than usual. I've been thinking about the Marius-Flamsteed-Grimaldi-Orientale expedition and want your input about some changes. I was looking at the website yesterday and all the potential geology stops you've identified, and those are proposed just through the orbital reconnaissance. The lander goes down in a few days with TROVs and I can't imagine what else you'll have at that point."

"Most are in the Marius Hills, where the expedition starts. There are more volcanic domes, rilles, and cinder cones there than anywhere else on the moon. One could spend months there."

"I know; there are all sorts of speculations about its relationship to terrestrial plate tectonics. Right now we're talking about a landing on January 24, when the sun rises on the Marius Hills, and a southward and westward trek until February 12, when the sun sets on the outer ring of Mare Orientale. That's just 20 days."

"You'll have strong earthlight at that point for a week, though."

"True, but the Earth will be very low above the horizon and there will be huge areas of black shadow. Not optimal. What do you think of this instead: We fly to the Marius Hills on

January 9. That's three days before new moon, or full Earth, if you prefer. The Marius Hills will have brilliant Earthshine for about ten days; enough for a considerable amount of geology. From about January 19 to January 24 we'll have very limited Earthshine and won't be able to do very much, but the lander will still be there, so we'll have plenty of power. If we bring some extra geological equipment along—the mass spectrometer and X-ray fluorescence spectrometer, for example—we'll be able to do a lot of analysis while we wait. When the sun rises on January 24, we can do a day or two of wrap up and head for Flamsteed."

"So, we're talking about over a month of exploration. We could get in all the major geological objectives we have in mind for all four areas. The Marius Hills video won't be quite as good for the terrestrial audience, but I bet it'll be reasonably good; there's enough light."

"There isn't enough to see color, but the moon doesn't have much color anyway!"

"That's true." Will thought about the idea, and the first thing that occurred to him was that Douglas Morgan would set a record for the longest lunar expedition, and it would endure a long time. Furthermore, he would set it just two weeks before he returned to the Earth and announced he was running for Senate. "I can't think of a reason we can't land on January 9. There's no requirement for sunlight and with the TROVs already there to serve as beacons, a pinpoint landing is not a problem. The two rangers and the shelter will give you plenty of housing space for a month and their life support systems can handle the duration. A week of near-darkness is a pain, but it sounds like you can keep yourself busy."

"No worse than spending a week flying back to Earth. And my flight to Earth will take a week this time, you know! We have to stop at the Indian station being placed at Lagrange 1 for two days."

"Really? Why?"

"That's what I asked. I guess you could call it international cooperation, not that we'll cooperate on anything when we're there!"

"At least at Marius, you can go outside if you want, and you'll have plenty of lab work to do. We already have plenty of geology stops and no doubt we'll have more. It'll be a strain on my staff; that worries me more than anything else."

"They'll get a break between January 19 and 24 when it'll be too dark for us to do any significant outside work."

"Good point. As long as the lander stays at Marius Hills, it'll be able to provide you with plenty of fuel cell power; more than you could ever use. I think the plan will work quite well."

"So, will you help me present it to Redding?"

"Sure; when?"

"This afternoon? Let's go over the plan in more detail. I suggest January 9 because Northstar 9 lands January 2. That gives us a week to welcome them and brief them. Then I'll leave with Kwaku Sawyer and Shankar Patel for a month or so—if the earthlight is adequate, we may explore Orientale a bit longer—then we'll return in plenty of time to close out our time at Peary and turn everything over to Commander Tatarinov."

"Who will essentially be the Commander of Peary on January 9."

"Exactly, with her 8 and 3 of mine; she'll have 11 personnel including herself, but she'll be finishing up my engineering and construction goals, which will be nice. It's a good arrangement overall."

"I'll make sure we can provide good support, Doug, but I need to count on you to tell us whether to give you more daily objectives or fewer."

“This is my expedition, it’s the one I wanted to do all along, and I want it to be the best; it’s the culmination of my career, Will. I want to get as much done as possible, but yes, I will tell you when the objectives are too much. I plan to study the website very carefully; you can count on me to be an active participant in the process.”

“Good, that’s what I need to hear.”

“Thanks, Will. And thanks for your kind words in the interview last night. I really appreciate them, after that difficult conversation we had six weeks ago. I apologize if I was rough on you, but it a stressful time.”

“That’s okay, Doug. I didn’t take blame for anything I didn’t do and I didn’t say anything I didn’t mean. You can count on that.”

“Thanks, Will, I really appreciate that. A quarter million miles is a pretty big barrier to communication. We have to be honest with each other for it to work.”

“Exactly. Let me write down our conversation so that I can review it. I’ll send it to you; you check it out. Shall I start on a day by day itinerary?”

“Sure; you know everything on the expedition website better than anyone else. I’ll start on PowerPoints, okay?”

“Okay, good idea.”

“Then we have a plan.”

5.

Marius Hills

Early-mid January 2032

"So, was earthlight really enough?" asked Will.

There was a pause longer than the usual 3 second time delay. Then he heard, faintly in the background, Kwaku Sawyer said "Yes, it was fine," and Shankar Patel added, "Agreed."

"Yes, it was fine," replied Doug. "It was fifty times as bright as a full moon on Earth and tomorrow it'll be fifty-five times brighter. By the way, there's just audio and no video because we're keeping the light level as low as possible in the shelter, to sharpen our night vision. It worked for World War II pilots."

"We're also in our longjohns," added Kwaku in the background.

"That's the other reason I have the phone on speaker," said Doug.

"That's quite a picture," replied Will, wondering whether Doug would be able to speak to the plain folks in the Ohio Republican primary after spending a month in spacesuits and longjohns with an Indian and a Ghanaian. "So, wasn't the geology great?"

"Yes, really fantastic," replied Doug. "Your team chose a pretty good, basic example of a lava dome for the Earthlight. I can't wait to get to the better sites, close to us, in headlights and later in sunlight."

"We'll start with the simplest things that should be viewable in earthlight," said Will.

"I want to get to the bottom of the so-called skylight!" said Kwaku. "It's about 85 meters deep, but we don't even know for sure how deep it is. There aren't very many lava tubes on the moon with broken roofs, and none with a hole that big."

"The hole's 65 meters in diameter. We could fly to the bottom with a lander, if there's a flat floor to land on," said Shankar. "And we'll have five days when it's too dark to explore up here; might as well explore down there. The lava tube may be dozens of kilometers long!"

"I'm not sure it's safe, and NASA is VERY conservative," replied Doug. "Still, we can drop the lander within one meter of where it's supposed to go, if we have GPS. I don't know whether we'll have a GPS signal on the bottom."

"The bottom of the skylight is not mapped, so there are no coordinates for it, and it can't be put into a landing routine," said Will. "But if we map the bottom, it can be added to the lunar global GPS map and it could be a landing site. I don't know whether it'd be considered safe, but it'd be worth exploring."

"Definitely, it'd be worth it," said Doug. "We have one hundred meters of power cable, so the rangers can be plugged into the lander but not be too close. Maybe tomorrow we should drive over to the skylight and use the power cable to lower a light to the bottom. If we swing it around and photograph the walls and sides from several angles as the light descends, Northstar Control's computers can generate a three dimensional map of the skylight, and then we'll know whether it's plausible to fly to the bottom."

"I'm not sure why you're so much in favor of this effort," Redding Desmarais said to Will four days later. He repeatedly moved his head back and forth to enjoy and appreciate the holographic image of the skylight that NASA's computers had created.

"It's quite an image, isn't it," said Will, smiling at Redding's intrigue. "You can even see up the lava tube a little bit, thanks to the camera they lowered with the second light. If we could

get a TROV or two down there, they'd be able to go pretty far; the tube is pretty straight, according to the seismic data, anyway. We could be looking at the site of a future lunar city."

"City?" Redding laughed.

"You never know. If this tube is at least sixty meters in diameter, as it appears to be, and we know it's at least five kilometers long, that's 300,000 square meters, or 30 hectares, or 75 acres of land that could accommodate buildings up to twenty stories high. The rille is 40 kilometers long, and the skylight is near the far end; the lava tube could be intact all the way to the source. That's an enormous piece of real estate! And all in an environment of constant temperature, no extreme daily heat or extreme nightly cold, no micrometeoroids, no cosmic radiation, no radiation from solar storms, no ultraviolet light to degrade plastic. Inflatable bubbles could be emplaced, one by one, and ordinary construction could be erected in them. It's a fairly large space; it wouldn't feel claustrophobic."

"Still, you'd be a cave dweller, and you'd be two thousand kilometers from the nearest source of water. There are no resources in the Marius Hills."

"We don't know that yet. The volcanic deposits may have traces of water, possibly enough to extract profitably with advanced technology. And the volcanics are very diverse, mineralogically. There are high ilmenite lavas."

"Maybe. But like I said, why are you helping him?"

Will frowned. "What do you mean?"

Redding was startled. "Will, Douglas Morgan is a Republican. I thought you were more liberal than that! Exploring a cave on the moon; what a fantastic boost for his reputation!"

"That's true, it would be, but I'm not worrying about politics. The question is, is it safe? Is it timely, that is, do they have the equipment they need? The floor has some small, flat spots

on top of the collapse debris. The engine guys say the best landing spot is pretty small, but the lander could touch down on it. The engine blast is a problem, but they could send it primarily along the lava tube and away from the nearby walls. If the lander hovered for ten seconds before descending, they'd know whether anything was likely to break loose and fall. That's the biggest danger. If they can land safely, they can take off safely. If they brought the TROVs along, they could deploy one in the lava tube every 500 meters to serve as a communication relay and they could travel quite far without losing radio contact."

"And what are they looking for?"

"The main goal is to explore the lava tube; see where it goes, what it's like, whether it has trapped volatiles—the interior should be about minus 20 Celsius, cold enough to trap some adsorbed water, but probably not ice—and whether it's a potential resource for future use."

"I see. How would anyone get in and out?"

"If we ever planned to set up a base there, that's the first challenge the engineers would have to solve. I suppose eventually someone would install an elevator!"

Redding laughed at that. "Well, I'm glad we talked about this. You're right, politics is not relevant, but safety and timeliness are. They aren't equipped to spelunk in a lunar cavern, so timeliness is an issue. And if the rocket blast knocked a single rock down onto the lander, it might never be able to take off again, trapping them. Those are pretty tough criteria to meet, in my opinion."

Will nodded sadly, for it meant there would be no expedition to the bottom of the skylight. "I agree."

"Good; we are in agreement, then. Now, a different matter: can you call Larisa Tatarinov? You guys are friends, right? She and Doug are having problems. He's calling every evening and

asking for a detailed accounting of what's happening at Peary. As far as she's concerned, she's Commander there and she's not inclined to give him a report."

"Really? She knows he's in charge overall. I suspect there's a problem of personal chemistry."

"That sounds right to me. I can try to call her, but we have a very formal relationship. We barely know each other. I could call Moscow, but they don't know Doug or the situation, since all Mission Control operations are here. But you have the ears of both of them."

"Barely; Doug and I have had our tensions." He sighed. "Okay, I'll call her."

"Thanks. I'll talk to the engineers more about the potential issues of landing in the skylight. Maybe they have solutions we can try. But I doubt it."

Will nodded and stepped out of Redding's office. He had not seen Doug and Larisa interact, so he wondered about their relationship. But it occurred to him that Jerome Lamoreaux, the French cook in the Lunotel attached to Peary Station, might have some ideas. So once he entered his office in the Lunar Surface Exploration Support area, he closed his door and called Jerome.

"Hey, Will, haven't seen or heard from you for over half a year! What a surprise!" Jerome's jolly face looked rounder than usual on the screen; Will wondered whether the chef had been putting on weight.

"Yes, I wanted to say hello. So, you've been on the moon thirteen and a half months! In another two and half, you'll break my record!"

"Yes, and I've signed a contract to stay 2 years. I may extend it to three; certainly, I'll be back after six months or a year of vacation on the earth. Running a hotel on the moon is a dream job. Even when there are no tourists, there are astronauts to cook for."

"And I'm sure they're as grateful as we were. How are things up there?"

"Pretty good. I suppose you heard that Northstar 9 brought a dozen lab rats? So we now have animals to use to study the effect of lunar gravity. Perhaps that'll make it easier on us humans. I think they've shipped fifty kilos of blood and tissue samples back to Earth, just from me!"

"Yes, I heard. The Europeans have made a long-term commitment to the experiment. It'll be interesting to see how well the rats reproduce."

"I would have preferred if they had experimented on something edible, like chickens. But the Lunotel Company has agreed, believe it or not, to shipping me five hens and a rooster in April! NASA isn't amused by our unscientific experiment, but our goal isn't science; its gastronomy. I've already made them a chicken coop out of old plastic cartons. I should be able to cook with fresh eggs every day or two, they'll eat our table scraps and plant waste, and we will probably get a roasted chicken every few months. I'm looking forward to it."

"Where will you put them?"

"In the old greenhouse. The basement of shelter 3 belongs to NASA, but the old greenhouse belongs to the Lunotel."

"Sounds like you have a good plan, then. Say, I have a question for you. Do you have privacy to talk right now?"

"Sure; I'm in the galley and there's no one else up here in the atrium. Breakfast is over and everyone's at work. What is it?"

"Redding Desmarais, NASA's head of the Northstar Project, has asked me to talk to Larisa, because she and Doug apparently aren't communicating very well. Any suggestions?"

“Hum. Good luck! I saw two rather tense conversations between them over supper. Doug is overall commander and wants to know exactly what is going on here, almost hour by hour. Larisa even came to me and asked me what my schedule was, the other day, because apparently she thought Doug wanted to know. Of course, he has never wanted to know, and it isn’t his business; I’m not his employee! Larisa, on the other hand, is in charge of Peary and wants the independence to make all the decisions. Their personalities don’t seem to mesh well, either. She’s suspicious of him and he’s rather aloof to her.”

“That sounds right. He’d come off to her as distant, and she’s not one to push around.”

“I’m not sure there’s much you can do about it. He’s away for a month, when he gets back he’s here two weeks, then he leaves and she’s commander.”

“I know, but I’m friends with them both, so I’ve been asked to talk to them. Thanks for some background, Jerome. Pretty soon, you’ll be the person with the most longevity—actually you already are because I won’t be going back to the moon any time soon—so you’ll be a voice of continuity.”

“I already am, and because I feed everyone, I play a rather central role in this place! I love that role; it’s one reason I don’t want to leave!”

“You are in a unique position as a so-called lowly cook—in reality a master chef—who stays when everyone else comes and goes. I hope to see you at Peary again in a few years, Jerome. Thanks for your ideas.”

They exchanged a few more closing words and Will ended the call. He immediately punched in Larisa’s number and she answered promptly.

“Good morning, Will. I’m afraid I’m not yet ready to discuss our expeditions further; maybe when Northtstar 8 leaves.”

“That’s alright, Larissa. We’ve already discussed quite a variety of expeditions that are ready. Polishing, scheduling, and launching them won’t take long. No, I’m calling about Doug.”

She rolled her eyes. “Did they ask you to call me? That man is very difficult. He’s treating me like an incompetent female and asking for a report about everything; who did what, how well they did it, how long it took . . . and all these accomplishments go on his record, not mine. The process is misogynist and the results are ridiculous!”

“Do you want to talk to Redding about all this, or do you want me to convey the issues to him? Because the only way this will get resolved is if someone talks to both parties, unless they can talk to each other. Doug Morgan is Commander for another six weeks, not you.”

“I know. Will, part of it is his tone. It’s condescending; he questions my competence. Part of it is micromanagement; he wants to know everything. Yes, he’s responsible overall, but he isn’t here and he made me Commander of Peary in his absence. NASA has trusted me to be overall commander from the end of February until the end of June, so surely he can trust me, too!”

“That’s a fair argument, Larisa, except he does need some sort of daily report, don’t you think? He’s the overall commander of operations, after all. From the sound of things, and based on what I know of Doug, I bet he got daily feedback from everyone when he was at Peary.”

“Yes, at breakfast he reviewed assignments and at supper he got reports.”

“I wonder whether Mission Control can capture them live and run them through transcription software. Maybe an administrative assistant can type up summaries. That might solve that problem.”

“The problem then would be timing; the summaries probably wouldn’t be available until noon the next day.”

"I'll ask whether someone could listen live to the supper exchange, take notes, and email them to you and Doug. Even Mission Control could use that. Then the two of you could discuss the notes. Would that help?"

She considered. "I think it would. If he wanted additional details, he could attend the dinner exchange by video and ask his own questions or email the appropriate personnel. But he'll still bother me about a lot of details that, frankly, I don't care about."

"I understand. You have different management styles, and that's alright. As for Doug's tone, that's a bit harder to work on. We can't ask him to take a workshop. Maybe Redding can say something to him; maybe Doug's wife can say something. But I do have a slightly radical suggestion to you."

"Please don't ask me to be nice to him!"

"Well, let me tell you a story. As you know, I am African American. It isn't terribly obvious because I am light skinned, but it is obvious enough. I get stopped by the police occasionally as a result. Here at NASA, there's no shortage of people who treat me like a kid, or they did anyway, because I was young; or maybe partly because I am African American, I can never be sure. My father, who is darker than I and who has had much more trouble, once gave me a good piece of advice. He called it 'stooping to conquer.' It's not a matter of being nice to people who treat you badly. It's remembering that they are human beings too, just like you, and respecting them as people. That doesn't mean liking everyone; some people are inherently unlikable. But it is a kind of love for people simply because they are people. Martin Luther King himself said in his speeches that this is the way to heal divisions between people. It is difficult. But if we give it a try, we can sometimes close the gulf between us and another person."

"Well, you are certainly right about that, but you also have the personality to do it, Will!"

"We all can try it though."

"Alright, you have a good point. But Redding needs to talk to Doug about his attitude when he lays out this new way to handle daily reporting. I can't be the only one in the conversation trying to be nice."

"Okay, I'll talk to Redding about that, too. Because I don't know Doug well enough for that conversation."

"The Marius skylight and lava tube have really captured the popular imagination in France," Will's friend David Alaoui said to Will via video link, four days later.

"Same in the U.S.," agreed Will.

"It's been all over European television. And they definitely aren't going in?"

"No, it's not safe enough. There's no question the lander can set down safely in a safe spot, but there's no place for the rocket exhaust to go. The sides of the skylight will be blasted by steam moving at 4.5 kilometers per second, and that could cause rocks to fall on the lander and damage it. It may be possible to land a condor there, though; it has less than a tenth the mass and thus a much weaker rocket blast. We may try to land a TROV there in the next year or so."

"Good. Meanwhile, I got an email from a group of engineers at the Université de Strasbourg. They've proposed a 'tube elevator' to the European and French Space Agencies. It would be attached to something solid at the top of the skylight—a ranger initially—and would be lowered into the skylight. The ribs would be inflated, stiffening the tube. A wheeled car would ride up and down the tube on two pairs of cables attached to motors at the top and bottom of the tube. You'd open a door on top, climb in, ride it to the bottom, and open another door at the bottom to exit."

"Clever! How much?"

"They say it'd mass about a tonne and could be built in a year for a couple million euros."

"Not bad. A member of my surface exploration support team has been conducting a 'survey' of lava tubes. There are quite a few. Some are very easy to enter, too."

"Are you planning expeditions to any of them?"

"We're adding them to the database of expeditions and prioritizing them. I'm sure we'll schedule some of them in the next year."

"Keep me informed, alright? Because ESA is interested. We're looking for a place we can eventually set up a separate European station on the moon. The Marius Hills, with the Aristarchus Plateau 400 kilometers to the north, is a perfect base for volcanological research. Apollo 12 is 600 kilometers to the south, a short tourist flight away. And we could get water from Peary via the Aristarchus Highway."

"But shouldn't you be supporting Peary?"

"We'll continue to support Peary, which will remain the moon's 'McMurdo.' But McMurdo isn't the only station in Antarctica, and the moon's much bigger than Antarctica. We want a distinctly European contribution."

"I see." Will was distinctly concerned and disappointed. "Okay, I'll keep you updated. And I'll let Doug know that his work may stimulate the construction of a tube elevator. That's a really cool idea."

"I think so, too. How are you holding up?"

"Me? Fine. I love the job, David."

"Good, and you're perfect for it, Will. I'll probably see you next summer. I may be Commander of Northstar 12, which goes to the moon in December. I gather you're trying to get commanders and crew to Houston earlier."

"Advance planning; we'll accomplish more with the same or less resources."

"Makes sense. I hope to see you then. Bye."

"Bye." Will closed the connection and leaned back in his chair. A tube elevator: what a clever idea! But the bigger issue was a European station. He'd have to tell Redding about that one. He glanced at the chronometer on his desk; 9:15 a.m. Redding was finally going to have a talk to Doug that morning and it should be over by now. He punched in Douglas Morgan's number.

"Morning, Will. Please don't ask us to go out today, it's just too dark. We were stumbling around rather badly, yesterday."

"No, my crew is taking some days off; sunrise is a few days away and then everything will become rather intense. You all have a hundred samples to analyze anyway."

"We do, and it's keeping us busy. We're sad we can't go to the bottom of the skylight, too."

"You look too sad to be sad because of that!"

"Yeah, Redding and I just had a conversation." Morgan sighed. "We're making some administrative changes, but that should make the next month go more smoothly. What can I do for you?"

"Just wanted to let you know that the European Space Agency has become fascinated by the Marius Hills and the skylight and they're considering a proposal to build a 'tube elevator' to

the bottom. The tube's ribs would inflate and stiffen, and a wheeled car would ride up and down inside. They may have it ready in a year. So your effort has stimulated a lot of interest."

"Oh, good! So, if we don't get to the bottom, someone else will."

"It looks like it. We're cataloging known skylights and investigating expeditions to them. I suspect someone will be exploring a lava tube in the next year or two. Meanwhile, we'll be figuring out what equipment a team would need to stay in communication; probably a light-weight spool of wire."

"Yes, this has been a good development. The dark period is a bit of a pain, but we're getting a lot of analysis and testing done, and when the sun comes up, we'll be ready to finish off Marius Hills and head for Flamsteed P. Please give our thanks to your team, Will. They've been great."

"I'll do that, Doug. It looks like we finally have the support team and the surface team pretty well coordinated. I'm sure it'll get even better."

6.

Dvaravartman/Gateway

Early March 2032

Docking was a dance.

Doug Morgan watched the distance between Northstar 8's gryphon capsule and the Indian station steadily shrink as they approached. Directly behind the station was the Earth, noticeably larger than it was in the sky on the moon, though not that much larger; the station was located at "Lagrange 1," the gravitational balancing point between the moon and its mother planet. The station was nothing fancy; the Bigelow B-330 inflatable was ten years old and used, but it was 14 meters long and 6 meters in diameter, a substantial volume. Solar panels and an antenna festooned one end, where a Polaris capsule was also docked. They were heading for the opposite end.

Doug glanced at Shankar Patel; he was excited to meet his fellow Indians. Theo Brown, their pilot and engineer, was professionally overseeing the docking, but was rather irritated by the unnecessary stop on their flight back to Earth. Doug kept an ear on the television commentary and wondered how many Americans would appreciate the visit. It struck him as counter-productive; it would undermine Project Columbus and might even set back the launch of his Senatorial campaign. But the importance of the appearance of international cooperation had to be maintained, and not stopping would look like a snub.

They were now close enough to see the faces of some of the Indian crew, looking out the portholes at them and at the moon, so close, behind them. Theo focused on the instrumentation and rarely looked out the window; the computer was doing all the work. The docking was a boring 24-hour process; fortunately it was nearly finished. When they heard the clank of the

docking apparatus, they all applauded. In a few minutes they achieved a hard dock and the tunnel between the vehicles could be opened. Doug Morgan floated over to the tunnel to complete the opening himself.

"You are clear to enter Dvaravartman Station," said the commander, Kalidas Sharma, over the radio link.

"Thank you, Commander," replied Doug. He could actually hear the man's voice through the hatch as well. Doug turned the handle and opened the hatch. He floated through into a large common room.

"Welcome, welcome!" said Kalidas. He extended his hand and caught Doug's in the air. They shook hands.

"Thank you so much. Congratulations to you for your work and to India for this great advance in the human exploration of space."

"Thank you, Commander Morgan. You and your crew are warmly welcome. This station has so much potential for refueling vehicles heading to the moon or Mars, and maintaining and servicing telescopes and other instruments stationed at this and at other lagrange points. India is thrilled to make this contribution to the exploration of space."

"Gateway Station is indeed a great advance in the exploration of space. The U.S. will no doubt lease access to it from time to time, especially for asteroid rendezvous missions. We are thrilled to make the first deep-space rendezvous with it."

Doug Morgan moved aside to let Shankar Patel enter. He shook hands and exchanged greetings in Hindi, followed by the other four crew members. Down in Northstar Control, Will, Redding, and Moises were watching the entire arrival ceremony. Redding shook his head several times. "This is such bad timing for Project Columbus and the Liberty shuttle."

“I can’t believe the funding vote was postponed until after this ceremony,” said Will. “But the consensus is that the Speaker of the House is opposed to both.”

“Zeke Swift himself convinced India to do this so that Project Redstar vehicles would have a refueling depot, right?” asked Moises Arroyo.

Redding nodded. “I’m surprised he’s not here to watch the ceremony.”

“It’s amazing what he has accomplished,” said Will.

“Revolutionized space travel,” commented Redding.

They turned back to the screen. Doug and Kalidas had introduced both crews and everyone had shaken hands. Morgan gave Sharma a United Nations flag that had been hanging on the wall at Peary Station; they now kept a small supply of gifts for ceremonial occasions. Sharma gave Morgan an Indian flag in return. Shanker Patel presented his six fellow Indians with moon rocks as gifts. Then they all sipped hot Indian tea in bottles and had a big Indian meal. At that point Redding went back to his office, so Will and Moises headed down to Surface Exploration support. “What did they call Gateway Station?” asked Moises.

“ ‘Dvaravartman.’ I guess it just means ‘gateway’ in Sanskrit.”

“The station doesn’t amount to much. There’s no depot.”

“The Thunderbird-H stage that pushed them to L1 is a few kilometers away and has a tiny bit of leftover hydrogen and oxygen propellant. It has a cryogenic refrigerator and solar panels to keep propellant liquid, so it’s the depot. Lunar landers can fly up, transfer 14 tonnes of hydrogen and oxygen at a time, and return to the moon empty. Peary Resources plans to set up a solar array and electrolyzer in the next year or so. Then the landers can fly up water instead.”

“But Project Redstar needs methane, not hydrogen.”

“Peary is scheduled to get two new landers in the next year. The old landers will make their last flight to Gateway with methane and oxygen and will serve as storage depots. Gateway will also be used to refuel unmanned flights to other planets, like the upcoming Uranus probe, and most of them will stop for hydrogen. Escape velocity from low Earth orbit is 3.3 kilometers per second. A tiny bit more delta-v will get a vehicle to Gateway. Mars takes 3.7 to 4.3 kilometers per second, depending on how quickly you want to get there. If you refuel at Gateway, a small 0.3 kilometer per second delta-v will send you back to Earth, and when you pass it at 3.3 kilometers per second you fire your engine and acquire the remaining velocity you need to go to your target. You can afford to take on more fuel at Gateway, using a smaller stage or a bigger payload, and fly to your destination faster, especially to the outer planets where the total delta-v is higher.”

“So, it’s like flying a two-stage rocket to your destination when you only have a one-stage rocket.”

“Yes, exactly. And lunar hydrogen, methane, and oxygen will be cheaper at Gateway than in low Earth orbit because it’s easier to get it there. It saves money.”

“But you don’t need a crew to transfer fuel?”

Will smiled. “Yes, if there is a problem with the automated systems. Gateway Station itself will be inhabited only occasionally. Its main use will be serving optical and radio telescopes, asteroid missions, and it may provide a safe refuge for moon flights if they have trouble at the right point in their flight. The B-330 is a used module from Pax Hotel in low Earth orbit; it didn’t cost much. The small ion engine to provide station keeping cost just a few million bucks. The Indians have a station on the cheap.”

“Good for them! It’s too bad Bolivia doesn’t have the will to pursue projects like Gateway.”

“I guess Swift hasn’t visited La Paz yet,” said Will.

Moises laughed at that. He headed for his TROV control station; Will waved and headed for his office.

Will pulled up his messages, which were numerous. Larisa had emailed him about their early April trip to Mare Ingenii on the far side and its lava tubes; they were bringing seismic equipment to map the tube and detect any others that lacked skylights. He referred the question to one of the staff, who had overseen the plans for the expedition. Two university geologists had forwarded expedition proposals, which he reviewed quickly. With more eyes scanning photos and other data, valuable expeditions were being proposed weekly.

But he was distracted by Gateway. Kalidas was an old friend from Northstar 2. The formal festivities up there should be over by now, so he pulled up Kalidas’s email address from Northstar 2, which would probably work, even at Gateway. He punched it in and made a call to it.

Sure enough, Kalidas answered after three rings. “Hey Will, what a surprise! How are you!”

“I’m fine! I was watching the arrival ceremony for Northstar 8 and it brought back a lot of memories of our time on the moon together on Northstar 2. I thought I should call you and offer my personal congratulations. Gateway is quite an achievement, Kalidas.”

“Thanks, Will, I appreciate that. Yes, we’re proud of India today! We’ve been here two weeks and we’ve got another two weeks of set up to do, then we’ll head home. Another crew

will be here in eight months. It looks like the Russians will lease Gateway late this year, too, so we already have business."

"That's great news. Kalidas, I thought you were going into politics? I was surprised to hear you were chosen to be Commander."

Kalidas smiled. "Eventually, Will, but right now this is what my nation is calling me to do. We're making a big commitment to space; we're the world's fourth largest economy and we're moving up fast. We'll pass China in a few decades. I think we may make a bigger commitment to Peary and possibly get a Commandership there. We're also working closely with Swift Transportation. We may get a Thunderbird launch facility. If the United States doesn't join Project Columbus, India will probably get a seat on the first flight to Mars."

"Congratulations for that! So there are a lot of possibilities for you."

"Well, for India. I'm not sure I want to spend 30 months on a round trip to Mars! Say, is Larisa still at her Northstar 2 email address? Because I should give her a call some time. We're only 58,000 kilometers apart!"

"Yes, you can reach her the same way. Just think, the two of you are commanders of the only human communities beyond low Earth orbit."

"Who would have thought? It's good to hear from you, Will. Good luck with all your work, coordinating surface exploration. Who knows, maybe Gateway can be a platform for instrumentation and can collaborate with your efforts."

"Who knows. It's good to talk to you, Kalidas. Best wishes with everything."

"Thanks. Bye."

"Bye."

“I’m not one to gloat, Dorinda,” said Zeke Swift.

Dorinda Stetson spread her hands. “I appreciate that, Zeke, and I’m impressed that you came all the way to my office in Washington, rather than expecting me to go to yours in California.”

“I did my best to support the Liberty shuttle in Congress; it’s a good piece of technology, even if it won’t be cheap. But the vote to cancel was 399 to 125.”

“A rout. Gateway was the last nail in the coffin.”

“It was clever of the Speaker to schedule the vote for three days after Northstar visited it,” said Swift. “We didn’t anticipate that.”

“We won’t get the decision reversed in conference committee, either, assuming Liberty’s part of the budget gets approved in the Senate; and that’s pretty unlikely now.” Stetson sighed. “So, where do we stand? Congress is not likely to approve Project Columbus, either, but there’s no guarantee they’ll approve funding for the United States to join Project Redstar, either.”

“I know, but I have a proposition to you, where that’s concerned.” Zeke paused to consider his words. “It’s pretty generous, but I love America, maybe even more than if I was a native citizen. This country is the greatest in the world; it needs to be the greatest off this world as well. Let’s merge Project Redstar and Project Columbus. My equipment and timetable; your name.”

She was startled by that. “You’d basically give us your project?”

“Yes, basically. That’s the arrangement with Northstar; it’s a United States led project contracted out to Swift Space. Columbus would be run from Houston and would proceed on the existing timeline. It would be an international project, so treaties would protect it from cancelation. The cost would be pretty modest because we’ve developed most of the technology

already. NASA would be able to devote some of its many labs and research facilities to technological support, which I would welcome. And with the cancelation of Liberty, you'd have money left over to support lunar exploration more vigorously."

"With the transportation capacity raised to twelve, right now we can't easily send our reasonable share to Peary Station, which technically is ours. We also want to conduct more asteroid missions."

"We'd be glad to support asteroid missions. They'd be an excellent test of our system. The cost of getting to low Earth orbit is a tenth of what it was, twenty years ago. The cost to the moon is double that; a fifth the cost of sending things to low earth orbit twenty years ago. The cost of sending things to Mars will start out four or five times the cost of shipping things to low earth orbit and will slowly drop until it is comparable to shipping to the moon in about a decade. Mars will open up to settlement; and I mean settlement, Dorinda, not just visiting crews, like the moon. The United States has to be in charge of the settlement of Mars."

"That's hard to believe. It sounds like a pipe dream."

"It's not a pipe dream, it's a vision, and it's on the verge of becoming a ten or fifteen year plan. I have a hippogryph at Aurorae and a ranger clearing landing pads and opening supplemental solar arrays. In a little over a year, a spare Earth return gryphon goes to Aurorae; it's getting 'broken in' flying crew to Peary and back right now. When it arrives, there will already be enough fuel to fly a gryphon back to Earth, and the *Pavonis* will be able to refuel itself even faster because it'll bring even more solar arrays. In the summer of 2035, six crew will fly to Mars in two gryphons. I want that crew to include two Americans."

Dorinda leaned back in her chair, considering his proposition. "How much?"

"About half a billion per passenger."

She raised an eyebrow. It was a tiny sum compared to what NASA would spend; yet it was also a large sum, considering the mood Congress was in. “I think I can sell it to the White House,” she said. “I’ll need the proposal in writing, and I’ll need it fast, while Congress is still debating the budget.”

“I’ll have a write up to you this evening.”

“Good. That might work, Zeke. You’ll make me look like a very persuasive negotiator.”

He smiled. “Save your powers of persuasion for the President and Congress.”

7.

New Duties

March 2032

"In short, thanks to this great American here—" Dorinda Stetston put her hand on a smiling Zeke Swift's shoulder, "—America is going to Mars! We are going in American made hardware, using NASA technology, leading the rest of the world to the Red Planet. All of you are involved in the effort from nearly the very beginning. You will make this historic breakthrough in human exploration and the expansion of our species to happen! In a century we will be a two-planet civilization and this moment in history will be remembered in the textbooks. So bring us your best ideas and your clever insights. On behalf of the President and the American people, I thank you for your devoted service to this ideal." Dorinda nodded, as if to say "get to work" and headed off the stage. The staff in the Northstar and Redstar Building—now christened "Moon and Mars Command" rose from their chairs to applaud enthusiastically.

"Thank you again," replied Dorinda, pleased she had managed to inspire everyone. She led Zeke off the stage, to where Redding Desmarais was waiting.

"It was a good meeting," said Zeke. "I'm so glad this is going to work out. We have a good, experienced team here."

"And if we're going to learn how to manage a crew on Mars, with a communications delay of 6 to 45 minutes, a more autonomous station at Peary is a place to start," said Redding. "Shall I talk to Will Elliott about his new duties?"

"Let's all talk to him," replied Dorinda.

Redding nodded and walked to Will, who was talking to three other astronauts—all currently driving TROVs on the moon and providing support to the geology team there—and

interrupted the conversation to invite him to Redding's office immediately. Will nodded and followed the boss upstairs, where Swift and Stetson were waiting.

"It's a pleasure to see you again, Dr. Elliott." Dorinda extended her hand.

"Thank you, Madame Administrator, it's a pleasure to see you as well." Will offered his hand in return and they shook.

"It's good to see you again, Will," added Swift.

"Thank you, Dr. Swift."

"Call me Zeke."

"Alright." They shook hands as well, then Redding gestured to chairs around a table, so they all sat down.

"We're making some positive changes to the operation," Redding began. "Mission Control will be in charge of Project Columbus as well as Northstar because it will be using most of the same equipment. Mission Control will also continue to be charge of gryphon flights to low earth orbit and tourist flights to the moon. Eventually, Northstar's astronaut training will also be in charge of Project Columbus's astronaut training. Down in the basement, Redstar's control area for TROVs and rangers will continue to run Aurorae Outpost setup, clearing trails, running electrical lines, running the drill, and deploying solar panels and other equipment essential to base set up. It'll be renamed 'Aurorae Outpost Support.' We want to broaden the mandate of 'Lunar Surface Exploration Support' to include Mars and we think you can handle the added responsibility quite well."

Will was surprised. "I'd love it," he said. "A year and a half ago, before I started Northstar 5 training, I drove a Prospector 400 at Aurorae for several afternoons, so I'm familiar

with the equipment. I haven't published about Mars, but I have kept up with the research somewhat. Will we be driving the TROVs?"

"Some," replied Zeke. "We landed three TROVs on Mars in 2030. Two are still working. The one in Hellas is being run by a team at the Singapore Institute of Technology and the original one that landed at Aurorae is currently being run by a team at Moscow State University. Those contracts end in June and at that time we will return control of the TROV in Aurorae to the team here. It's twenty kilometers north of the outpost site, exploring the base of the escarpment. The three Prospectors we just landed at Aurorae back in October are still busy with base setup, but that phase will end in a few months. Even now, we can probably spare one of them for exploration of the mesas due north of the landing zone. Base setup remains the jurisdiction of Aurorae Outpost Support."

"So, our main responsibility, after local exploration, will be to plan longer expeditions?"

Zeke nodded. "There's one ranger there now. Hippogryph cargo landers will bring a portahab in 2034 and another ranger in 2036, so the Columbus 1 crew will have two rangers and a portahab, sufficient, based on our lunar experience, for expeditions of up to 700 kilometers from the outpost."

"But we'll have to start with small expeditions to verify the reliability of the equipment under Martian conditions," said Redding.

Will nodded. "Just like we did with Northstar 1 and 2. What about Phobos and Deimos?"

Zeke shook his head. "Exploration of them will be directed out of Moscow, for now."

"Will Columbus 2 land at Aurorae as well?"

"Yes," said Zeke. 'That's the current plan. We need a Martian McMurdo first, before we set up other outposts."

"What about longer expeditions from Aurorae?" persisted Will.

"You'll need to come up with reliable ways to get energy," replied Zeke. "The gryphon has enough propellant to fly from Aurorae to another spot within about a thousand kilometers of Aurorae, then back to Aurorae, but not farther. Mars's gravity is much stronger than the moon's. That means expeditions will need to haul along extra fuel and oxidizer; or haul along methane or hydrogen and extract the oxygen they need from the Martian regolith; or set up solar panels and create refueling depots along their route."

Will nodded. "So, we should start on a database of potential expeditions we need to study."

"There currently are a dozen reconnaissance, communications, and GPS satellites in Martian orbit," noted Redding. "The data we already have is absolutely staggering; we may have Mars photographed in more long-term detail than the Earth. There's plenty of time to ask for specific areas to be imaged and sensed in great detail."

"Your budget will increase by fifty percent," said Dorinda. "Some of that needs to go to hiring three or four Martian geologists who will do nothing but proposing and detailing surface expeditions."

"A database, like we have for the moon," agreed Will. "The system we have for lunar exploration, with some important modifications, can serve as a model. How many geologists will be sent?"

"Project Columbus is designed to fly six to Mars the first time," replied Zeke. "The plan when it was Redstar was to fly at least two professional geologists, at least two professional engineers/mechanics, one physician, one horticulturalist to run the greenhouse, and two pilots. Everyone will have to have multiple competencies, of course."

"That's probably what we'll do," confirmed Dorinda.

"What about travel?" asked Will. "The Director's job will be enhanced by visits to universities and agencies. I've started doing that in the United States. If we want the TROV in Hellas to do investigations cooperatively with TROVs elsewhere on the Martian surface, we need to go talk to the people operating it face to face, and offer them incentives, such as opportunities to work on the moon."

Dorinda nodded. "Sure, we can give you a travel budget. But don't commit any additional NASA funds."

"No, all I would do is commit resources under my control, in order to make our operation more efficient."

"So you'll take the new responsibilities?" asked Redding.

"Yes, of course," said Will.

"Excellent!" Redding offered his hand; Will shook it with a smile. "Can you give me a memo summarizing our conversation and offer your further thoughts about implementation?"

"Of course."

"Excellent." Redding looked at Dorinda and Zeke, who nodded.

"Thank you so much, Dr. Elliott," said Dorinda Stetson, by way of a goodbye.

"Thank you for this opportunity; I'm pleased to be of service."

"Thank you for coming," added Zeke. "I look forward to working with you."

Will rose and left the office. He walked down the hallway calmly, but when he got to the elevator he walked past it to the stairs and practically ran down them to burn off his excitement. Mars! He was playing a central role in Project Columbus! Even better, Northstar and Columbus

were integrated together, so they reinforced and strengthened each other! The war between the moon folks and the Mars folks was over, or at least temporarily suspended!

He hurried into Lunar Surface Exploration Support. “Ladies and gentlemen, I have an announcement!” he exclaimed. He paused for people to come out of their offices around the edge of their central space or look up from their cubicles in the middle. ‘Ladies and gentlemen, from this day forward we are now ‘Martian and Lunar Surface Exploration Support.’ Our responsibilities remain the same, but are now extended to two worlds. We will gradually acquire responsibility for Prospector-400 TROVs on the Martian surface, just as we now have responsibility for Prospector-350s and Prospector-300s on the moon. One of our main responsibilities, between now and early 2036 when humans land at Aurorae, will be to create a database of expeditions, short ones, long ones, and ones that start from other spots on the Martian surface. We will also have responsibility for training astronauts in Martian surface geology, when the time comes, just as we train them in lunar geology now. What do you say?”

There was a pause, then several people cheered and others began to applaud, so everyone applauded. “On Friday we’ll take a long lunch break and celebrate together,” Will continued. “It’ll be a little while before we can start because the TROVs are all being used in base setup. We’ll also have to develop relationships with the various Mars programs at universities and other institutions around the world. So, how many of you want to go to Mars eventually?” He smiled as he looked around the room. Of the fifteen people there, three raised their hands. “I hope you make it,” he concluded. “Because humanity is going to Mars to stay, not just to visit.”

“Will, what did you think of the staff meeting?” asked Silvia Ferreira, a Portuguese engineer who had gone to the moon with him on Northstar 2. She was in Houston for a few months to strengthen her lunar geology skills.

“I was very encouraged. The President and Congress have made a financial commitment to Swift’s transportation system and Swift has essentially given it to NASA. It’s being tested almost weekly through tourist flights or flights to the moon, which makes it the most reliable and capable system ever built. The cost to orbit has never been lower and the volume of traffic is growing. We’re riding on the crest of a revolution, and it will take us to Mars in less than four years. What about ESA, Silvia? What do you know of their reaction?”

“I think what you say is correct,” she replied. “The European Space Agency made a lukewarm commitment to one seat on Project Redstar’s first flight to Mars. It was worried that American commitment and leadership was lacking. I don’t think Europe felt ready to take leadership. But now, that one seat is a solid commitment and I am pretty sure they’ll commit to a second.”

“So, two Americans and two Europeans,” said Moises Arroyo. “Who will get the other two?”

“The Russians will get one,” said Will. “They’ve committed to the exploration of Phobos, they’ve developed a drill for the use on Phobos and on the Martian surface that has been tested at Peary, they’ve already sent out one mission to a near-Earth asteroid, and they plan to send out another one in about a year. I suspect the sixth slot will go to the highest bidder, because there will be competition for it.”

“Then it won’t be Bolivia!” said Moises.

“No, and you can be sure the US will not allow it to be China or an Arab country, either,” said Will. “We’ll find out soon enough. Meanwhile, thank you, all of you, for your efforts. We’ll have quite an adventure together over the next four years.”

Will headed into his office while everyone went back to work. He sat at his desk but was too distracted to get work done. Possibilities seethed in his mind. And in the back of his mind was the nagging thought: should he apply for Columbus 1? He'd be a very strong candidate: he was young, very experienced, and knew lunar and Martian geology better than almost anyone else.

He turned to his computer screen, called up his mother's email, and called her.

"Good morning, dear," she replied when her face popped onto his face. "This is an unusual time for a call. Aren't you at work?"

"I am, and I have news. 'Northstar Control' has been renamed and redirected; it's now 'Moon and Mars Command' and is the control center for Project Columbus, Project Northstar, and all flights of Gryphon and Polaris capsules."

"Wow!"

"And 'Lunar Surface Exploration Support' is now "Martian and Lunar Surface Exploration Support' and I am the Director of the newly expanded department."

"Fantastic! Congratulations, Will! Your father and I are very proud of you!"

"Thanks, mom. It's very exciting. They're also going to give me a travel budget. I've been traveling to universities using my own money—I have plenty, since I'm single—but now I can keep it, let it accumulate, and travel on NASA's dime. I need to go to the Far East at some point to talk to universities in Singapore and Malaysia about their research on lunar and Martian geology and see whether I can bring about a bit more coordination of effort."

"That'll take some time. And Will, right now you're working 60 or 70 hours a week."

"No, not that much, mom."

“No, I disagree! Every time I call you, you’re either doing office work or writing up your research. How many paper have you authored in the last six months?”

“Four, but—”

“No, please don’t say ‘but.’ I’m just asking you to acknowledge that you’re working way too many hours as it is.”

“But I love what I do!”

“Good, I’m glad you do! All I am saying is that we weren’t put here on Earth just to contribute to humanity’s understanding of lunar and Martian craters and volcanoes. Those are not trivial subjects, but they aren’t the central purpose of life on this plane of existence. We exist to learn how to love, to be compassionate, to be patient, to listen, to exercise a mature sense of justice, to serve others . . . and while you can develop some of those capacities through your job, your job can’t help you with all those and other spiritual qualities. Please keep that in mind, Will.”

For a moment, Will wasn’t sure what to say; he felt stung by a sense of failure. “You’re right, mom,” he finally said. “I accept you point. But I have plenty of time. Some of what you are talking about develops in the context of marriage and family, and haven’t given up on them. But I think it’ll be in phase 2 of my life. Right now, being an astronaut is phase 1.”

“And why can’t they mix better?”

“Well, for one thing, I’ll probably apply for Columbus 1, and if I get selected I’ll be away 30 months!”

“I see what you are saying. They can’t make Mars expeditions shorter?”

Will shook his head. “You can make the trip between the planets only once every 26 months, and right now we don’t have the fuel to go out, visit Mars, and fly back on one pass of the two planets. You have to return at the next encounter 26 months later.”

“Hum.” Catherine considered what her son said. “Well, even so, I wouldn’t eliminate the possibility of marriage. Don’t be burned by your experience with Lurleen! There are women out there who will marry a man who plans to be away two and a half years.”

“That’s true.” Will decided he had better not argue with his mother; she brought up the topic once a month. “Look, mom, I’ll try to relax more, alright?”

“And go to Bahá'í meetings. Houston has a lot of young people.”

“I know; I was there last month. You’re right, work isn’t everything. But please, at least appreciate this development in my life!”

“I do, very much, and I have already said so. Congratulations again, Will. You are an amazing and unique individual, and I am sure you will accomplish an extraordinary amount in your life. I just want the accomplishments to be spiritual as well as material.”

8.

Storm

May 2032

"So, do you like the moon?" Will asked Moises Arroyo.

"I do!" replied Moises. Will could see him smiling broadly on the small image; Moises was talking to him over his smart phone. "I can't tell you what a relief it is to have gravity, first of all! I was space sick three days out of the four it takes to get here. I threw up several times. Next time, I'll take the Dramamine before launch."

"That was a crazy launch, too, with two of the nine engines of the Thunderbird first stage shutting down early."

"They'll be investigating that problem for some time, but we got to orbit fine on the other seven. Now that I'm here, I'm gradually getting moon reflexes; I haven't run into any walls! I'll be ready to go outside tomorrow."

"Good. They recommend that astronauts wait 24 hours before making their first EVA. How was the welcoming dinner last night?"

"Magnificent; Jerome is an amazing cook. My appetite came back as soon as I had gravity."

Will could hear other people talking in the background, so he said, "Say, is Larisa Tatarinov there? I'd like to talk to her quickly."

"Yes, she's still at breakfast." He turned. "Larisa, Will wants to talk to you."

There was a pause, then Moises handed his smart phone to her and her face appeared on the screen. "Good morning, Will! How are you today!"

"Quite well. I miss having a jogging partner. I'm getting up really early now, though, because it has gotten hot and humid in Houston."

"It's that time of year. Sorry I won't be around any time soon."

"So, quite an arrival: two engineers to test plastic manufacturing, our first Chinese astronaut, and chickens as well."

Larisa laughed. "That's one way to put it. I'm glad Moises is here; his lunar geology is excellent. We're looking forward to the field trip in two weeks. The plastic manufacturing engineers are going to be draining a lot of power with their prototypes, but the result could be quite significant, if they are able to make plastic and extrude it into useful things. And I gather you already know Dr. Sun."

"Yes, Sun Shilin; he was at Shackleton when I visited. I'm so glad—and a little surprised—that NASA agreed to a Chinese astronaut at Peary."

"So am I! The Chinese are leasing out their facility, though. The first Iranian astronaut is at Shackleton right now."

So I understand. Here's my question, Larisa: I understand the condor that landed at the North Pole is functioning well, now that you've replaced some parts and updated its software."

"It is, indeed. It's ready for its maiden voyage."

"Why not send it to the South Pole with a tank of methane, so the Chinese can fuel up the condor there? Shackleton has plenty of liquid oxygen. With Dr. Sun at Peary, this is a perfect time to arrange it. It'd take them less than two hours to transfer the methane and fill the oxygen tank. It uses the same refueling equipment as the lunar landers and the gryphons."

"I bet we could do that. The condor there needs some repair, also, but it appears to be flight worthy. I'll talk to Shilin. Have you mentioned this to Redding?"

"Yes. He said we shouldn't ask NASA for permission, just arrange it quietly through Dr. Sun. We can easily give Dr. Sun some tasks or opportunities he wants in exchange. By the way, we've been trying to arrange another joint expedition for the south polar area. So far, the Chinese are saying they'd prefer to explore the cold traps there by themselves, but they will share all the data."

"Sounds like they're claiming half the moon's water and volatiles!"

"It sure does. Of course, right now the moon doesn't belong to anyone, but proximity means they can lease out half the deposits or exploit them themselves."

"It does. I'll talk to Shilin."

"Thanks, Larisa. I'm anxious to start using the condors to move TROVs around. It'll make lunar exploration much more effective."

"If they want anything in return, I'll offer them eggs! The four hens are already recovered from the flight and are laying eggs for us. Jerome's in heaven."

"He must be. How are the lab rats doing?"

"Alright. The first litter of babies was mostly normal. We'll see how the chickens do. NASA's not happy with Jerome's unscientific experiment, but they have assigned an intern to collect data on the chickens daily, so they'll be a scientific experiment as well."

Will laughed. "That's good. I'm with Jerome; study lunar gravity on useful animals rather than lab rats! Thanks, Larisa. We're all ready for your field trip to Rupes Altai. It should prove quite useful."

"It'll be our first excursion into the Central Highlands. I'm looking forward to it."

Since the Chinese team was leaving Shackleton in a mere three weeks, the informal negotiations were quick and Condor 1 flew down to the South Pole six days later with a tank of methane on its cargo platform sufficient to fuel Condor 2. The Chinese provided a video feed of their work to Houston, so Will, Redding, and several engineers sat in a conference room to watch them move the methane tank from Condor 1 to Condor 2 and attach the transfer hose.

"They seem to know what they're doing," exclaimed Penny Waterhouse, the chief engineer familiar with Condors. She had flown in from Swift Space's California headquarters that afternoon to watch.

"It's pretty basic," observed Redding. "The cargo platform has standard clamps to which the tank was attached to Condor 1, and the methane transfer hose works the same as the landers' hydrogen transfer hoses."

"Except for the diameter; the methane hoses are slightly larger around than the oxygen transfer hoses, and much smaller around than the hydrogen transfer hoses. The diameter is roughly scaled to the density; liquid oxygen is the densest and liquid hydrogen, the least dense."

Will listened to the Chinese discussion. Two astronauts were working as a team to attach the methane tank to Condor 2. After each one spoke, a second or so later an artificial voice provided a computer translation into English. "The translation is pretty clear."

"Good software," replied Redding. "The voices sound a bit mechanical, though."

"They still don't have the tone and rhythm of the English quite right," said Penny. "That's yet another layer of meaning to infer in the translation."

"Good point." Will watched and listened, and suddenly realized that one of the two Chinese voices also sounded mechanical. "Say, both of those guys aren't speaking Chinese," he

said. “One is speaking something else and we’re hearing a mechanical translation of his speech into Chinese, then mechanical voices translating both into English!”

“Hum . . . I think you’re right!” agreed Redding.

“I agree,” said Penny a moment later.

Will looked at the image very closely. Both men had their names on their space suits in Chinese; he could see the characters. One also had his name on his suit in the Roman alphabet; he could read Li Baozhi with some difficulty. The other man’s name was also written under the Chinese version, but he couldn’t see what the alphabet was.

The man turned to help with the clamps on the right side of the lander’s platform, and Will got a clearer view. He was startled: it looked Arabic. He could clearly read “allah” at the end of the man’s first name! He was sure because the prophet founder of the Bahá'í Faith—his own religion—was named Baha’ullah, and that name also ended in “allah.”

“Oh, my,” he said. He turned to his tablet. “What’s the name of the Iranian astronaut at Shackleton Station on the moon right now?”

It paused for a split second. “His name is Ruhullah Islami.”

Will pointed to the screen. ‘That’s him.”

“What? An Iranian? Are you sure?” Redding said, very alarmed.

“I’m sure. Look at his chest where it says his name in Chinese. Right underneath is his name in Persian.”

“And you can read it?”

“A little tiny bit. I recognize the “ullah” part of his first name, Ruhullah because it’s the same spelling as “Allah, the Arabic and Persian word for ‘God.’”

“That’s a BIG problem,” said Redding. “If it gets out that the Chinese invited their Iranian guest astronaut to help them, and of course the whole operation is being videoed so there’s a Mission Control in Tehran who’s watching the whole thing . . . that’s a big, big problem!”

“Some of this technology is considered strategic,” noted Penny. “Of course, NASA knows the Chinese will see it; they’ve used the refueling system before. But the Iranians; that’s not okay.”

“It’s a diplomatic incident, then,” said Will. “It’s their fault; they violated our trust by inviting him to help.”

“Yes, but we didn’t warn them not to. I didn’t know there was an Iranian up there; but I gather you did, Will?”

“I read it in a standard memo we all got when the Chinese crew arrived,” said Will, deciding not to point out to Redding that he received the memo as well.

“Shit,” said Redding. “This was run past the White House, too.”

“So it was their mistake,” said Will.

Redding laughed and shook his head. “Are you kidding? They’ll deny having any knowledge of the whole thing! It’s going to go down the chain of command to the lowest man, and that’s you!”

Will’s eyes bulged in shock. “You’re kidding, right?”

“Hell, no! So be prepared for a storm, Will! There were be heavy media attention if this gets out, and be damn careful what you say!”

“I guess so,” said Will.

They lapsed into silence. Ruhullah: *The Spirit of God*, Will reflected. The Muslim title for Jesus, ironically enough, and the first name of Ayatollah Khomeini. Islami: a very Islamic name, no doubt! He was a geochemist and geophysicist who had published a few articles Will had read. They were pretty good.

"The methane transfer hose is attached, Peary," announced Li. "You may begin methane refueling."

"Thank you, Shackleton," replied Larisa Tatarinov. A moment later she confirmed, "Methane transfer has begun."

The Chinese retreated back to their lunar rover to wait in case there was further need for their help. The video ended, so Redding, Will, and Penny sat patiently. Finally after 45 minutes, Larisa reported, "The methane transfer is complete. Thanks, Shackleton. You did a great job."

"We're glad to help, Peary. Best wishes with the launch."

That's it," said Redding. "We now have two condors, assuming they both take off and return safely to Peary."

"Condor 2 won't be available right away because the Mustang-1 engines are scheduled to be replaced," said Penny. "It'll be 4 to 6 weeks before it can fly."

"Here they come," said Will, pointing to the screen. The entire Lunar Surface Exploration Support team was sitting in their central common area, watching a lander bring Larisa Tatarinov, Moises Arroyo, and Muhammad Zekeria to Rupes Altai.

"It's nice to have a Prospector-350 and a Condor there to broadcast the landing," said Silvia Ferreira.

“I was impressed that Larisa was able to refuel Condor-1, check it out, load a TROV on board, and fly it to Nectaris in less than 24 hours,” added Will. “We only lost a day of sunlight and it gave us a week of advance exploration. How many samples have we accumulated?”

“Four kilos,” replied Francisco Almeida, a Brazilian astronaut who was in Houston for training for the next six months. “Checking out the various routes up the escarpment, however, probably has saved them several hours of scouting.”

Will nodded. “Yes, that’s true.” The Rupes Altai was a 400-kilometer-long escarpment—a cliff—several hundred kilometers west of Mare Nectaris. It was over a kilometer high in places; a spectacular exposure of highland crust, formed when an asteroid blasted the Nectaris Basin out of the young moon. It was the largest lunar escarpment and a fascinating geological feature to study.

A cloud of dust blasted into the sky as the lander settled onto the ground. “Houston, we have landed,” said Larisa. “Everything is nominal. Propulsion system shutdown has commenced.” A pause. “Surface Exploration Support, thanks for your advance preparation! This is a great spot; no boulders and a good, clear view of the escarpment just two kilometers away!”

Will activated the audio. “Give us a panorama, lander 1. We’d love to see the escarpment, too.”

“Copy.” Larisa pushed some buttons and a live video stream began from a camera mounted on the roof of the ranger, which was clamped on top of the lander’s cargo platform. They stared at the spectacular image of Altai.

“Just imagine, the escarpment edges of Valles Marineris on Mars are several times higher,” noted Will.

“This is Peary Control,” exclaimed another voice. “Lander 2 has blasted off and is on its way. ETA, 45 minutes.”

“Thank you, Peary,” replied Larisa. “Let’s get outside and get the ranger down to the ground. Surface Exploration Support, the route part way up the escarpment is 650 meters to the southwest, correct?”

“Correct, lander 1,” replied Will. “There’s a 500 meter crater there that blasted a nick into the escarpment and built up a pile of debris. The TROV went down and back up; just follow its tracks.” Will turned to Silvia. “Move the Prospector closer and give them a salute, okay?”

She laughed. “Okay.” She went to a nearby TROV control station and moved the Prospector-350 off the crater rim where it had videoed the landing, about 100 meters from the landing site. She moved the right manipulator into a salute and started moving it in so they could retrieve the rock samples it had accumulated.

“So, Larisa, a good flight?” asked Will.

She laughed. ‘The usual! I wish we had been able to make at least one more expedition! This was a pretty quiet Northstar, geologically speaking.”

“That’s alright.” Neither of them was going to comment about the lack of highly skilled geologists; Dr. Zekeria had not proved sufficient, and he had been the only geologist until Northstar 10 arrived with Moises. “You’ve got a pretty good expedition over the next seven days, though. You probably haven’t heard the latest in the last eight hours, while you were preparing for the flight. The TROV we landed northeast of Pons J has started to climb the scarp at that point. The latest data suggest there is indeed a viable route to the top. We’ve also verified a route through the Fermat ZZ Boulder Nest.”

"Good, that will shorten our route by five kilometers. Once we get past the Fermat section of the escarpment, getting to the top becomes possible. It's too bad we can't get all the way south to the Piccolomini section."

"That's another expedition. If we leave one TROV at Pons and move the other one to Piccolomini, another expedition could pick up where yours left off."

"Yes, that was a good suggestion you had. I had better stop chatting and get my suit on. We've got a long, busy day ahead of us."

"We're heading to the hotel now, Will," exclaimed Silvia. Will looked up from his computer screen. Francisco Almeida was with her.

"Have a good night," Will replied.

"It's almost 11 p.m.; how much longer are you staying?"

"Not much longer. Two hours ago I switched to writing a paper on south polar volatiles that I need to finish, and I have another page to go."

Silvia shook her head. "So, you relax from your job as Director of Lunar Surface Exploration by writing up lunar research? That's not good, Will. You need a hobby!"

"I suppose I do. Give me another year and the job will fall into a routine and I'll have more time. See you at 10 a.m. for the EVA?"

"Yes, we'll be here," agreed Francisco. "We reviewed the proposed stops; they look good. Dr. Zecharia should be able to handle it!"

"Good. We're providing him pretty solid, collegial support. Thanks again."

“Good night,” they both said. They waved and headed out of the area. Will looked around; he was the last one in the area again. He did need to go to bed, too. He turned back to his paper, reread the last few paragraphs, completed the thought., and saved the file.

But rather than closing down the computer, he went to a space news website. There was still no mention of the Iranian who had helped set up Condor 2 at Shackleton. That had happened almost two weeks earlier; the chance of it coming out was much less, now, and if it did, there was no urgency left to the news. Seven days earlier—a day before the Altai Rupes expedition began—he had received an email from one journalist asking whether he had known about the Iranian’s participation and he had given a careful answer, which apparently had been sufficient. Then the Altai expedition, with its spectacular views of the 1,000 to 2,000 meter escarpment, became the focus of moon news. He skimmed through the latest articles about the expedition, all positive.

Will put his tablet in his little briefcase and headed out of his office. But before he crossed the central area, his tablet and smart phone beeped simultaneously. Someone was trying hard to reach him. He saw that it was someone in Mission Control.

“Hello?”

“Dr. Elliott, this is Greg Sandusky in Mission Control. I’m the night director up here. We just got a notice of a proton storm heading towards the Earth-moon system. I can’t get ahold of Dr. Desmarais; he’s on a weekend trip to Colorado and has his phone shut off.”

“Well, I’m not in the command hierarchy. Where’s Wendy?”

“She had a baby two days ago; that’s why I’m interim director of the night shift.”

“Oh, that’s right. I’d keep trying to get ahold of Redding, but you’re in charge of Northstar, Greg.” He paused to try to remember who the fellow was, but the night shift was

usually a skeleton shift and he didn't go upstairs much in the evenings. "The standard procedure is to scramble a lander and fly down to pick them up, if there's at least 24 hours warning. Otherwise they have to shelter in place."

"There's an estimated 75-minute warning."

"*What?*" That shocked Will.

"That's what the space weather guys say. The sunspot was quite ordinary and small, two days ago, but it has suddenly expanded. It just released a coronal mass ejection. It happens to be right at the spot where the magnetic field lines connect it to the Earth-moon system, so the resulting proton storm is being accelerated toward us very rapidly."

"Incredible. They have to be warned immediately. They need to shelter in place. I'll be right up." Will closed the telephone line and dashed up the stairs to Mission Control.

Greg was his age—a kid, Will reflected, for so much responsibility—and looked very nervous. "Tatarinov's not answering."

"They've all gone to sleep." Will looked at the wall covered with dozens of screens; it was actually one huge screen, divided electronically. One of them showed the vital signs of the three astronauts, but only one showed heart rate and respiration.

"Whose chart is this?" Will pointed to the one with vital signs.

"Arroyo."

"He still has his ear piece in, so call him."

"Tatarinov shouldn't take her ear piece out."

"Never mind that. It's uncomfortable to sleep with." Will also knew Larisa's proclivities and suspected she was not sleeping alone.

Greg called Moises Arroyo. "A proton storm?" he said, surprised.

“Yes, and you now have a bit over an hour before it hits. You need to shelter in place.”

“Moises, this is Will. I’m in the Control Room, too. I’m checking the local geography to see if there’s a good spot against a cliff or crater rim.”

“Thanks, Will, I’ll wake up the others.”

Will pulled out his tablet. “Can I have a big screen? I need to project a map.”

“Sure. Sit here.” Greg pointed him to a work station nearby. Will sat and plugged his tablet into the work station and a square on the wall screen cleared. While Will clicked on icons to find the map he needed, Greg made the square bigger and bigger until it occupied half the wall. In a matter of seconds, a map popped onto the wall showing the two docked rangers, the escarpment, and the cratered, rolling surface. Will added contour lines; he needed a spot with closely packed lines next to a flat spot with no lines.

Nothing.

“This is a pretty flat, boring area,” growled Will. He put his finger on the screen of his tablet and expanded the view. One of Greg’s team members, Jane, came over to look with Will.

“How about here?”

“It may be hard to reach; see all the boulders?” Will pointed to purple dots.

“Oh, that’s what those are. That’s a mess.”

“The base of the escarpment has a lot of boulders and debris.” Will shook his head.

“We should move into one ranger, right?” asked Larisa.

“What a relief to hear your voice, Larisa!” exclaimed Will. “You guys have maybe an hour. It’s a very fast proton storm; one in 2005 hit the Earth in just 20 minutes. The fast ones are intense. I’m looking for a spot to park the ranger with as much rock around you as possible.”

“We’ll start moving everything into ranger 1. Are you in charge, Will?”

"No, Greg Sandusky's here; I just happened to answer. Sorry about that."

"That's alright. This is Greg. I'm sending you an audio file of preparations so you can listen while you prepare."

"Thanks, Greg, that's great."

Jane tapped Will on the shoulder. "What if we can find a spot where there are boulders on several sides?"

He nodded. "That may be best. The moon has no real cliffs; they always have a pile of debris and rocks at their base, so you can't get very close. Proton storms are anisotropic, meaning that the protons come from all directions. The more rock around them, the better."

"Got it."

Will pointed to a big boulder field about a kilometer from the rangers. "Let's look here. They can get here in five minutes."

Jane nodded and Will moved the map to the boulder field. They split it between two screens so they both could search; they projected an icon of the ranger onto each map and tried moving it around with their fingers. The computer would simulate the movement and determine whether it would fit. "The computer doesn't have the small rocks and pits, so a route may not work in practice," said Will. "We need to find a parking space near the edge of a boulder field, not deep inside it."

"I understand," said Jane. She tried adjusting the map to provide a photo view; that way, the rocks appeared as the gray shapes they really were, with red meter contours projected on them. Will tried a series of colors for the contour lines and looked at places the colors were on top of each other; he was used to that convention.

"It's a needle in a haystack," said Jane.

“Hey, we’ve tossed most of the food, clothes and equipment into ranger 1,” said Larisa, a note or urgency in her voice. “You guys got a place for us to go?”

“We’re looking at the boulder field 1100 meters northwest of you,” replied Will. “There are no cliffs or steep-rimmed craters that will help, but there are some house-sized boulders you can nestle against.”

“I know that boulder field; we drove by it last night. We’re heading over.”

“Acknowledged. It’ll save you time.”

“How about here?” asked Jane. She pointed to a spot where a chunk of the escarpment had slid down the lower slope and had broken into a dozen house-sized fragments.

“It has potential, but the spaces between the fragments are also filled with rocks and boulders. They could easily get stuck.”

“This is an almost impossible task!”

“We don’t have the fine-grained information,” agreed Will. He turned back to the communications line and gave Larisa the coordinates of the area they were looking at.

“I see the area you are suggesting,” she said. “God, that’s a dense maze of debris!”

“We can’t see anything smaller than about half a meter, Larisa, so we really can’t refine your route,” said Will. We can see several possible spots where you can park, but if you go into them carelessly, you could get hung up on a rock. By the time you free yourself, the proton storm will have hit.”

“That has occurred to me!” Larisa replied. “Send us a map with possible parking spots highlighted.”

“We can do that,” said Will, looking at Jane.

Greg looked at Will. “What about ranger 2?”

“Set it to autodrive to follow ranger 1’s tracks,” replied Will. “It can park against ranger 1 to provide some additional shielding, and it might have to pull them out.”

He turned to the screen in front of him. Another of the Mission Control staff, Jim, was helping Jane as well. Will glanced at the area they were checking and moved to a different point along the edge of the boulder field. He magnified the image and moved his finger into a spot between two boulders. The computer refused to move the ranger icon in; the passage was too narrow or the data suggested it was too rocky. He tried another spot. The computer set the icon there; it was a possibility. He saved that spot and the ranger icon there turned green. He created another red ranger icon and tried moving it into another parking spot. The computer said no.

He hoped the computer’s programming was as good as it was supposed to be.

“Hey, how about this?” asked Jim. “The two boulders on the sides are four and five meters high, respectively, the space between them is four meters wide, and there’s another boulder in front that’s just two meters high.”

And they have to wind around this boulder, which will be behind them,” said Jane. “Even it will provide a little protection.”

“Mark it as number 1,” replied Will. “This spot I found is number 2. Let’s send these and keep looking.”

Jane and Jim nodded. They moved red ranger icons into the boulder field at other spots; nothing else worked. In a few minutes, Larisa drove up to the field and flicked on the cameras. Screens on Mission Control’s walls lit up with images of boulders, none of which were recognizable as ones on the map.

“Is that the right spot?” asked Jane.

“According to GPS, it is,” replied Larisa. “Here we go.” She began to move the ranger forward slowly, past a boulder on the left, around a big rock on the right, then a twist around to the back of the rock on the right, then forward. The ground was covered with big rocks; the ranger rolled up over one, jolted when it rolled off the other side of it, and they heard a loud crunch of metal. Larisa increased the power going to the ranger’s six wheels and turned to the left so the middle and back wheels avoided the rock. But they dropped a wheel on the left side into a small crater.

There was a grinding and whirring sound.

“We’re stuck,” reported Larisa.

“Where are you?” asked Will. He turned back to the screen and projected the GPS of the ranger onto his map. “You’re in a pretty good spot, though. We wanted you to move another three meters forward. You have rocks on both sides and behind you.”

“This will have to do, but I have no idea how we’ll ever get the ranger out of here!” said Larisa. “We’re going to hunker down.”

Greg pointed to a screen with data from a solar observatory at the Earth-Sun L1 point, a million miles from Earth. Its proton detector had suddenly jumped upward. “The proton storm will reach you in just a minute or two, so hurry,” he said to Larisa.

She switched on a camera inside the ranger. Across the middle of the cabin was a long seat able to accommodate three. They had raised the seat up a meter and laid the back down to form a platform, on top of which they were piling everything they could. They would sit on the floor underneath, shielded by everything they had above them and the moon itself underneath and around them.

“Here it comes,” said Larisa, and just as she spoke, the radiation sensors in the ranger began to jump. The three of them crawled into their makeshift shelter.

“It reminds me of the blanket house my mother used to make for us,” Larisa commented.

“I hope this doesn’t last too long, because I’ll need to use the bathroom in a few hours,” commented Muhammad.

“And we’ll want to cook some food,” added Moises.

“We can dash out for a minute or two periodically,” replied Larisa. “Mission Control, any idea how long this will last?”

“They estimate about six hours,” replied Greg. “But there will be a ‘tail’ of less severe radiation lasting several days.”

“So much for the Altai Escarpment,” said Larisa, disgusted.

9.

Surprise Commitments

July 2032

"Larisa! It's so good to see you again." Will waved and shouted as Larisa Tatarinov came out of Houston Airport's arrival concourse and into the luggage pickup area.

"Will, it's so good to see you, too! I couldn't believe it when you said you'd meet me at the airport."

"Glad to." She walked up to him and he gave her a hug. "It's the least I could do. You're a good friend. And I still feel bad about the confusion, right before the solar storm hit the moon."

"It's not your fault. If you hadn't been working late, it could have been much worse." She pointed toward the luggage carrousel and they started walking toward it.

"They've tightened up procedures, as you know. They've made my status as backup emergency coordinator official; I now have to keep them informed of my whereabouts. I'm usually only a ten minute drive away and I have no family to be disturbed by an emergency, so I'm a logical person to be involved. But they're also increasing the night staffing by one position and tightening up training requirements."

"Still, everyone will now know to dash to the nearest boulder nest. Our lunar surface data isn't good enough to find parking places reliably and quickly and it never will be. We'd need to have the lunar surface mapped better than the decimeter level." They stopped at the carousel; luggage was already coming out. "There's my bag. Sorry it took me so long to get here, I walked pretty slowly."

Will picked it up. "Let me carry it. Are you tired, or are you still adjusting to terrestrial gravity?"

"A bit of both; jet lag and the gee." She turned and walked with him toward the parking garage.

"So, you've been back ten days. What did the doctors say about the radiation exposure?"

She sighed. "Oh, Will, it's so sad." She looked down at the floor for several seconds while she summoned the strength to go on. "Even with all the stuff piled on top of us and the moon all around us, we got quite a dose; a tenth of a Sievert or 10 rems, if you prefer that measurement."

"Wow, that's hefty. A fifth of the recommended lifetime max."

"And all at once. I have to take it easy for at least a year and they want to check me regularly. And the Cosmonaut Corps has said absolutely not for Columbus 1, even though that's still three years away. As for Columbus 2 . . . who knows, it's possible."

"That's good. So, Mars is still a possibility."

"But not until 2037-40, which means I come home at age 43 and with a total dosage of about 0.75 Sieverts, fifty percent more than recommended. That precludes a family, as far as I'm concerned; I'd be just about too old anyway, but with a radiation dosage of 0.75 Sieverts, I don't think it'd be wise anyway."

Will pointed to his car and they headed across the garage toward it. "So, what are you going to do?"

She sighed. "It's too soon to be sure. The moon has forced me to reassess my life anyway, and the storm has made it even more urgent. But I think my next priority is to settle down, find a husband—another husband—and start a family while I still can. I can work in Star City for either the Russian lunar or Mars programs; that's guaranteed. Do you want to learn Russian?" She said that in jest, but he could hear a note of interest in her voice.

Will shook his head. “Sorry, I’m not that good with languages; besides, I plan to put in for Columbus 1.”

“You do? The Moonman?”

“Why not? Can’t I be the ‘Mars man’ too?”

She laughed. “I suppose.”

Will opened the trunk of his car and put the suitcase in. They climbed into the front seats and he drove off, down the ramps and through the garage’s exit. “Take us to Northstar Mission Control,” he said to the car.

“Northstar Mission Control it is,” replied the auto.

“You have autodrive?” she said, impressed.

“Yes, and it is quite nice. There are autodrive lanes on the freeway, now. They look very dangerous because the cars are so close together, but statistically, they’re much safer.”

“So I’ve heard.” She watched the car change lanes and zip up to the speed limit, but not a bit faster. Will had his hands off the steering wheel; it looked very odd. “So, are you enjoying your job?”

“Of course, I love it! And with the merger of Northstar and Columbus, my budget has grown by fifty percent, so I have the resources to support lunar exploration better. We’re also getting astronauts here sooner, so there’s more training time for geology, and they provide additional support and TROV driving. I’m heading out of Houston for four weeks, once this big meeting is over. Rick Page will be Interim Director while I’m out.”

“Vacation?”

“Some. I’m visiting universities in New Zealand, Australia, Malaysia, Singapore, South Africa, and Zambia to talk about their lunar and planetary science programs. Most likely, we’ll

get some astronauts from those countries in a few years, and they'll come through those universities. But I'll also do some sightseeing as I go; NASA is paying for the plane tickets and I'm paying for the extra hotel days and a few excursions."

"That sounds nice."

"It'll be full, but it'll be really different, and I need the break." He looked at her. "I still can't imagine you as a mother, Larisa."

"Why not?" she said, affronted. "I've always wanted to have a family. But being a cosmonaut is very demanding and very stressful. It can lead to a certain . . . lifestyle. But that doesn't mean I can't settle down."

"That's true. Good point. I didn't mean to offend you."

"No, that's alright. I'm mentally adjusting, too. So, what do you know about this meeting?"

"Just what they advertised it as: a chance for agency heads to get together and reevaluate their participation in Northstar and Columbus. Northstar 11 goes to the moon in less than two months. Northstar 12 is the official end of the program, but obviously they can't really end it; it's got too many assets on the moon now, too many people are part of the support system on Earth, and the public is supportive. On the other hand, there are only so many resources for space travel, and the moon takes resources from Mars."

"That's what would worry me; balancing the two."

Will nodded. "Unfortunately, space flight falls more in the realm of politics than science, and politics rarely is balanced."

Two days later, the large conference room at the hotel near Northstar Mission Control began to fill up with national space agency representatives. Dr. Dorinda Stetson arrived early to make sure everything was getting set up properly; she was the hostess. Her administrative assistant, Mickey, sat at the big oval table next to her; Redding Desmarais and Will Elliott sat behind them. Will was still surprised he had been invited, but his role was to whisper advice to Stetson on science matters and nothing more.

To Dorinda's right was Zeke Swift and his son, Asaph, with two secretaries seated behind them. To the left of Mickey was Dr. Helene Colmar, the representative of the European Space Agency, and her team. The other agencies, represented by between one and four people, were from Russia, Japan, China, France, Germany, Britain, Canada, India, Brazil, Israel, Korea, Pakistan, Qatar, South Africa, Australia, Mexico, Kazakhstan, Ghana, and Argentina. Altogether, the large table and the space around it accommodated 66. The 32 seated at the table itself had large name tags on the table in front of them. Will was pleased to see Larisa Tatarinov seated in the rear of the Russian delegation; Francisco Almeida behind the Brazilian representative; Kalidas Sharma sitting at the table next to the Indian representative; and Silvia Ferreira one seat from him, behind Helene Colmar.

At 9:15, everyone having arrived and gotten their coffee, Dorinda rose from her seat. "I want to welcome everyone to Houston," she began. "Thank you for bringing cool weather; today it'll only be 88 degrees, or 31 Celsius! In mid July we can often get 35 Celsius here.

"I am immensely pleased to see such a wide range of representatives of space agencies. It's the largest assembly since 2025, when it became clear Northstar was launching in 2028. Here we are, 4 years later, devising a plan for continuing Northstar beyond its 12th flight, which occurs this December. It's also now definite that Columbus 1 will launch to Mars in the summer of

2035, just three years from now, and it's time to finalize commitments to it. Columbus will fly once every 26 months, and we're looking at a commitment to the first four missions, launching in 2035, 2037, 2040, and 2042.

"Currently, Northstar 10 is operating on the moon with ten astronauts. To date, the program has flown 89 astronauts to the moon, with stays ranging up to sixteen months. Peary Station has expanded from six to its current maximum of 33, though it has never had more than twenty-five at any one time. I don't even know if we have an official count for the number of expeditions that have been mounted; it's close to one hundred. In short, we can be immensely proud of what we have accomplished in the last four years.

"Now, allow me to turn the floor over to Dr. Zeke Swift, who has a proposal for everyone."

There was polite applause as Dorinda sat. Swift rose from his seat. "Good morning, everyone. I am delighted to see all of you together in the same place, because I have met many of you, but in your respective offices in your capital cities. This meeting bodes well for international cooperation. It has been a great honor to help bring all of you together and to play a role in birthing the Northstar Project, even though I had never planned to be part of an effort to return humans to the moon.

"As you know, a year ago Project Northstar underwent a shift in transportation vehicles, from the Polaris to the Gryphon. The Polaris was designed to transport up to twelve to low Earth orbit and was capable of transporting six comfortably to the moon. The Gryphon is designed to transport up to six to Mars and is twice as large as the Polaris; it can transport twelve or more to the moon and twenty-four to low Earth orbit. It is reusable; so far, three of the five trips to the

moon have been made by the same craft, which will be heading to Mars next year to serve as a backup return vehicle for Columbus 1.

"The lunar transportation system has served as a testing program for the Gryphon, and admirably well. But the current system is inefficient in one respect: the crew at Peary fluctuates in size because each crew remains six months, but there are three flights a year. This means there are two teams at Peary for four months out of six. Someone arrives as future commander, but is subordinate to the outgoing commander for two months; then has two months with just her or his team; then a new team arrives and he or she has to merge the two teams together in order to complete his or her mission's objectives. This has not worked very efficiently.

"A second problem has also arisen: crew members have not always proved to be a good fit. Some have not fit in with their team members well; others were not well prepared to go to the moon. An opportunity to swap members of the team in or out would potentially improve a team's effectiveness.

"Therefore, I propose a different arrangement for the lunar transportation system. There will be two astronaut transports per year, in late December and late June, rather than three. Each team will remain six months and have one commander throughout. Each team will have twelve or possibly a few more; the Gryphon has 44 cubic meters of volume and the Apollo astronauts had only two cubic meters each. The Gryphon Block 2 that is under development will have over 80 cubic meters of volume and could easily accommodate 20 to 24. Two shifts per year, therefore, will provide a stable and growing system for developing Peary Station.

"There will be two tourist flights per year as well, in late March and late September, half way through each crew cycle. It will have a crew of two and ten tourists. The crew will also serve as 'tour guides' on the moon, minimizing the disruption to Peary's operations. Nations that

want to send an astronaut to the moon for a brief time will be able to send them up on either a tourist flight or an astronaut flight and return them on the other, which will allow three-month stays on the moon. This will also allow rotation out of crew members if they prove unable to work well on the moon, or if they have health problems. Teams will have minimal disruption from sudden influxes or departures of personnel. Commanders will have six months to complete their objectives, and more time to make the team gel. The Gryphons will be set up to accommodate up to fourteen but will normally have twelve, allowing for some emergency or last-minute transportation in either direction.

"In addition, we anticipate charter flights for tourists wanting more exclusive accommodations and for special scientific expeditions. There's talk of building a large radio telescope in Rozhdestvenskiy Crater on the far side, near Peary, and that may require twelve crew members for a year or longer to complete the task. We hope to see the average of four Gryphon flights to the moon every year grow to eight in eight years and to ten in ten. Questions?"

"How much?" asked Dr. Rajesh Chakravarti, the Indian representative.

"We're going to change the way we calculate pricing," replied Zeke. "There will be a base price and contingencies. The latter will be based on whether there's a rush on the seat, whether extra accommodation is needed, and whether the base price needs adjusting because of circumstances.

"We can send you the details of the base price calculation, but here's the short version. Gryphon development has cost 1 billion so far and we anticipate spending another 500 million on the Bloc 2 and various upgrades. We have assigned a third of the $1.5 billion development cost each to the low Earth orbit, lunar, and Martian programs.

“The lunar gryphons cost $100 million each and we anticipate building 7 of them. Thus, each one must cover a $70 million share of the half billion dollars of development costs we are assigning to that program. If each one flies ten times with ten paying customers each, that’s 100 paying customers; dividing the 170 by 100 yields $1.7 million per passenger.

“Each flight requires about $5 million in refurbishment, maintenance, and consumables, or half a million bucks more per passenger.

“The Thunderbird launch to orbit costs $12 million, which includes the fuel, direct launch costs, part of the vehicle manufacturing cost, and refurbishment of the first stage, which is a reused vehicle. That adds $1.2 million per passenger.

“The gryphon is refueled in low earth orbit, in lunar orbit or at L1, and on the lunar surface, and the refueling adds $25 million in costs, or $2.5 million per passenger.

“Adding all that up, the total is $5.9 million per passenger. Add 30% for insurance, interest payments, and profit, and the total is $7.5 million per passenger. That will be the base price for the next five years. After that, depending on demand, the base price may go up or down slightly. Of course, you have to add about $5.5 million to cover the cost of flying 1.5 tonnes of consumables per astronaut to the moon. We currently anticipate a contingency of $2 million because the moon’s methane production is inadequate. So the total is $15 million.”

There was surprise around the room, even a gasp or two. Swift smiled. “Northstars 1 through 12 plus the tourist flights are averaging $30 million per passenger and will carry 120 passengers to the moon; that’s $3.6 billion, which has covered the costs of developing Polaris, upgrading the Thunderbird to use hydrogen, and developing and building the lunar landers, rangers, portahabs, Conestogas, and the shelters. I should add that starting next year, Gryphons and Polarises will be available for lease to qualified partners for similar prices per passenger.”

"For flights to Gateway?" asked Chakravarti.

"Yes. A Polaris flight to Gateway will cost about $40 million."

"What about asteroid missions?" asked Dr. Sobolev, the Russian representative.

"The same, with a contingency cost depending on propellant needs."

"But we will have to check with the White House about whether Russia can lease one," interrupted Dorinda. "There is strategic technology on board."

"But none of it is visible from the capsule or on the outside," replied Zeke, looking at her. "If an American astronaut were included on the mission, there would be an independent witness that the strategic technology was not studied."

"We'd have to check with the White House," repeated Dorinda.

"What about a charter flight to lunar orbit?" asked Dr. Song, the Chinese representative. "If we sent taikonauts up with tourists or with a scientific expedition, could they get a separate lander flight to Shackleton?"

Zeke nodded; Dorinda said, "We'd have to check with the White House."

Will looked at Silvia at that point. He had swapped chairs with Redding so that he was sitting next to her. "Think how much money that'd save the Chinese," he whispered to her. "I bet their flights to Shackleton cost well over a hundred million per taikonaut."

She nodded and whispered back, "They can send six at a time instead of three and man it full time. I bet that'll be the reason the U.S. will say no."

"I'm puzzled about something," said Helene Colmar, the European representative. "Why have you been charging us $30 million for the gryphon flights if the costs are half that?"

"The gryphons are substitute vehicles for the Polaris and the extra income is covering the development of the Polaris, the lander, and the surface facilities," replied Zeke. "Their

development is now paid for. I should add that the surface habs, the rangers, portahabs, and Conestogas that will be used on Mars have benefitted from the lunar development and their reduced costs will reduce the cost of a seat to Mars."

"Which is how much?" asked Dr. Araujo, the Brazilian representative.

Swift paused and pulled up some data on his tablet. "We're assuming the development costs are covered over the first four Columbus missions, or nine years, and that only Columbus 4 will be reusing equipment. That means we need to manufacture seven gryphons, at $100 million each, and each needs to cover $70 million in development costs, just like the seven lunar gryphons, but each will fly only 3 to Mars, so that's $170 million divided by 3 or $57 million per ticket, right there. We also need to manufacture and fly fifteen hippogryph automated cargo vehicles at $35 million each; they may prove reusable, but we are assuming they aren't. That's another $505 million; divided among the 24 passengers who will fly to Mars over four oppositions, at six per opposition, that's $22 million more each. We're also assuming that for the first two flights, we will need to fly two hippogryphs to Martian orbit with methane and oxygen for the trans-Earth injection, since the gryphons are designed to manufacture enough fuel to get them to high Mars orbit, NOT to get them all the way back to Earth; but those hippogryphs will fly back to Earth orbit and are reusable, so they are included among the cargo landers for Columbus 3 and 4. Propellant costs add about $45 million per passenger. We're spending a billion on infrastructure; TROVs, drills, a Phobos propellant manufacturing facility etc., and they add $50 million more per passenger. So that's $174 million per passenger. Add 35% for insurance, interest payments, and profit and the total rises to $235 million. We're currently adding a 35% contingency to the base price to cover uncertainties, raising the total for Columbus

1 to $300 million per passenger." He paused and looked around the room. Everyone was pondering.

"And Columbus 2 will be more like $250 million per person?" asked Dr. Hayashi, the Japanese representative.

"Probably, all the way through Columbus 4, which may cost as little as $200 million per person. With Columbus 5, if development and infrastructure costs are covered and the vehicles are being reused, a 'ticket' could decline to the $50 to $100 million range. In another decade, if the prices fall by half again, we could be looking at a revolutionary situation."

"Surely, you don't think that's possible?" asked Dorinda.

Zeke paused to consider his words. "Dr. Stetson, if each gryphon is used ten times, just like they are used to fly passengers to the moon, the costs will decline similarly. I see no reason to assume that tickets to Mars, including consumables, will exceed $10 million per passenger at some point in the next 20 or 30 years."

"That's incredible," replied Dorinda.

"But it isn't settlement, Dr. Swift," noted Colmar.

"It's the start of settlement, Dr. Colmar, but real settlement requires an economic base and lower transportation costs. And I assure you I'm working on the transportation aspect. The key is the continued decline of costs to low Earth orbit. Cargo can now get to LEO for $1,000 per kilo; people, for a bit less than $2 million. Currently, the lunar transportation system involves a 4 to 1 multiplier and the Mars transportation system, a 150 to 1 multiplier. Those multipliers will decline to about 2 or 3 to 1, and the cost to LEO will halve."

"Two or three million to Mars," said Will aloud, which he wasn't supposed to do, but several nodded.

“Alright,” said Dorinda. “Back to business. The United States will commit to 8 astronauts per year to the moon; 4 per flight. We’ll also commit to 2 to Mars on Columbus 1.”

“Europe is prepared to commit to at least 6 per year to the moon, and 2 to Mars on Columbus 1,” exclaimed Colmar immediately.

That was followed by silence. “Russia will fly 3 per year to the moon and 1 on Columbus 1,” exclaimed Dr. Sobolev.

“Brazil commits 1 to Columbus 1 and 2 per year to the moon,” added Araujo.

“Japan commits 3 to the moon and 1 to Columbus 1,” said Hayashi. That gave Columbus 1 seven, which was beyond its capacity.

“India the same, plus 1 flight a year to Gateway,” said Chakravarti.

“We now have 8 for Columbus 1, so it sounds like there will need to be some additional negotiating,” exclaimed Dorinda. “But it does mean Columbus 1 will fly in the summer of 2035.”

“And we have 24 of 24 seats to the moon committed,” said Mickey. “Who else wants to make a commitment to the moon?”

“Canada; one every year.”

“Australia, one every other year.”

“Korea, one every other year.”

“Argentina, one in the next two years.”

“Mexico, one in the next three years.”

“Qatar, one in the next two years, and I have been asked to commit Saudi Arabia to the same.”

“Pakistan, one in the next two years.”

"Israel, one every other year."

"Kazakhstan, one in the next two years."

There was a pause in the discussion. "That's about 31 commitments per year for the next two years," said Mickey.

"Some negotiations will be necessary, then," said Dorinda.

"Of course, China would like to participate in Columbus, and we have already flown one taikonaut to Peary," said Dr. Song. "We'd like to continue flying at least one taikonaut to Peary every year. In turn, we will include astronauts and cosmonauts at Shackleton, where we plan to maintain 3 to 6 people continuously."

"The White House has said that it will not agree to Chinese participation in Columbus yet; not in Columbus 1 or 2, maybe not through Columbus 4," replied Dorinda. "You'll have to take that matter up with the White House."

"I'll need to fly some Swift Space people to Peary as well," said Zeke. "But I can use the tourist flights. So can some of the astronauts; they could fly up on a tourist flight and return three to six months later. So there are ways to accommodate more than 24 per year."

"How many tourists are you expecting?" asked Sobolev.

"The tourist base price will be $10 million, including two weeks of preflight training and ten days at the Lunotel," replied Zeke. We'll announce the price next week. As soon as 42 sign up and pay a deposit, we will schedule a third annual flight. Our goal will always be to have an 18-month waiting list. Marketing research suggests that at least 150 people will pay $10 million to go to Peary."

"So, you have six years of demand," said Sobolev.

"Probably more."

“Some of us have been devoting our own research and development money to aspects of the Mars transportation system,” said Sobolev. “I refer specifically to Russia’s commitment to Phobos exploration and our Phobos drilling project.”

“Russia’s research and development counts partially toward the cost of a seat and guarantees a seat on Columbus 1,” said Zeke. “So does Europe’s research on three-d printing using lunar plastic and manufacturing with carbonyls made from meteoritic nickel iron. So will the United States’s provision of a nuclear reactor for Martian surface power, if they come through. We will be glad to include essential technology development in the overall budget and seat price. What we won’t do is count research a government or company has done because they happen to think it’ll be useful, unless we really want to buy it.” Zeke looked around the room but seemed to look at Dorinda the longest.

“India is considering a major expansion of its space program,” said Chakravarti. “We already have a commitment of three astronauts at ISS2 and one at the International Orbital Manufacturing Facility. Our commitment of three per year to the moon is solid. We may even consider our own lunar surface station in the next decade; we have been very pleased by how well Gateway has worked out. You may need to increase the number at Peary.”

“Japan, also, may wish to increase its commitment,” agreed Hayashi. “The financial commitment I was authorized to make would equal 5 or 6 astronauts to the moon every year.”

“Brazil, also,” said Araujo. “None of us expected the gryphons to be as inexpensive.”

“We can look into ways of flying more to Peary,” said Zeke. “For example, if a flight with six tourists and six astronauts went to Peary in early January and early July, Peary could have a permanent crew of eighteen.”

“You may need to consider that,” said Dorinda.

“If the moon is going to have more astronauts all the time—at least eighteen, including Shackleton, but probably closer to twenty-four—the plans for lunar science and development need considerable revision,” exclaimed Sobolev. “May I propose a conference on that subject this fall in Moscow?”

“Yes, definitely,” agreed Colmar.

“We’ll come,” said Chakravarti.

“We’ll support it,” committed Dorinda.

A chorus of voices went up in support of the idea. “We’ll schedule it for October,” suggested Sobolev. “Before it gets too cold in Moscow!”

“Let’s take a fifteen minute break,” suggested Dorinda. “When we resume, Dr. Redding Desmarais will give us a presentation about the results of Northstars 1 through 10, and we’ll discuss the sorts of commitments all of us can make. We need a balance of scientific, engineering, mechanical, and medical expertise. Thank you, everyone.” She turned to Mickey. “Can you check on the refreshments?”

“Sure.”

Zeke Swift leaned over. “This is going very well, Madame Administrator. If we really can commit to close to 36 astronauts per year—that’d be eighteen twice a year—can the United States raise its annual commitment from eight to ten?”

She thought a moment. “Based on your prices, yes, but that will have to be cleared with the White House.”

“Of course. If we do get 36 astronauts, the prices will decline slightly.”

Dorinda nodded. She turned to Will and Redding and pointed to the door. “Gentlemen, let’s talk.” They rose and followed her out into the hallway.

She looked around to make sure no one was nearby. “Those damn Russians, proposing the lunar science and development conference. That’s something we should be hosting.”

“We can host the next one,” suggested Will.

“Oh, I’ll be sure that we do,” she replied. “If Peary is expanding to a permanent 12 or even a permanent 18, we’ll need a detailed plan to propose. I don’t want the Russians setting the tone for lunar research for the next half decade!”

“Of course,” said Redding.

“We really need a director of lunar science,” said Will. “He or she would look at more than just lunar surface exploration; there would be lunar atmosphere, dust elevation, lunar core and mantle research, interaction with the terrestrial and solar magnetospheres, solar wind effects, the use of the moon as a platform for astronomy, medical and biological research—”

“You’ve got the job,” said Dorinda.

Will looked at her. “I don’t want that job. I’m already overworked handling lunar surface exploration.”

“Well, you have it anyway, until we can define a position, advertise it, and interview for it. That’ll take months; we need a lunar science plan in three months.”

“That’s a committee.”

“Fine; you’re chair and convener. I need a list of people to invite, a timetable, and a budget in five days.” She turned to Redding. “And I need you to convene the same for technological and engineering work. The Swift people can help; they know what they want, and this is the crowd to give it to them.”

“Every NASA facility wants a piece of the pie, too.”

"This is their chance to contribute in immediately useful ways," said Dorinda. "Make it happen. But their projects have to have relevance. The days of NASA benefitting from pork barrel spending are at an end. That's what the Liberty shuttle taught us."

10.

Moscow

October 2032

Will pulled his coat tightly around him. “When Sobolev said the conference should be held in late October because that’s before winter starts, I thought it’d be warmer than this!”

“I’ve been in Moscow in October before. It can be very nice; or really cold!” replied David. “Are you sure you want to go out?”

“Yes. They told us to be very careful about talking in the halls because of listening devices.”

“Listening devices!” David laughed. “That’s rather paranoid!”

“I suppose.”

“On the other hand, we Europeans would just talk in the halls, not worry about it, and discover later that the Russians have stolen some of our ideas. Maybe that is a good precaution.”

“Four days ago I was packing to come here and I was presented with a brand new tablet and cell phone by a security official. He said I couldn’t take my tablet or cell phone and should load into the new ones only the things I’ll need in Moscow, and the next day he’d want to check them. It took me all night to set them up, he never looked, and then I had to add more things because I forgot some of the programs I needed.”

“I suppose that’s why I called you and got voice mail.”

“Yes, I have a new number for the trip; I’ll give it to you. At least NASA will pick up the entire phone bill.”

“I wish I could say the same about ESA.”

“Hey Will and David!” Will and David turned around and saw Larisa Tatarinov and a man walking toward them from the sidewalk. They waved.

“Good afternoon, Larisa!” said Will.

“Thank you. Welcome to Moscow. I’m sorry it’s so cold!”

”We’re ready for it!” replied David.

Larisa pointed to the man with her. “This is my fiancé, Valery Ivanov. He’s an engineer here in Star City.”

“Very pleased to meet you!” said Will, warmly.

“Thank you, Dr. Elliott,” replied Valery, shaking Will’s hand. Then he introduced himself to David Alaoui.

“I hope we can get together for lunch and catch up; maybe tomorrow?” suggested Larisa to Will.

“Yes, that should be good,” replied Will. “Right now, David and I are going out for a quick supper and a talk.”

“Very good; good to see both of you,” she replied. “I’ll look for you right after the session ends.”

“Great,” said Will, nodding.

Larisa and Valery continued into the building; David and Will headed to the street. “She’s getting married! I’m surprised,” said David.

“We talked in Houston, after she returned from the moon. The radiation exposure was serious; they don’t want her flying to the moon again for several years. By the time she can fly again, she’ll be 40 or so, and if she can go to Mars, she’d be back when she is over 43, so she’s

decided to get married and have a family. Looks like her plans are working out! I'm glad. She's a good friend, but not a good enough friend to marry!"

"I know what you mean." David pointed to the right and they turned east on the sidewalk. "By the way, your presentation this morning was absolutely brilliant and very well received."

"I'm very grateful for that; I was very nervous! I haven't slept adequately for most of the last two months, to get the report about lunar science together. It was an exhausting effort."

"NASA needs a Director of Lunar Science."

"I know, and I said that to Dorinda Stetson! She said until we can hire one, you're it! And they still haven't started creating the position, either."

"This is the place," said David, pointing to an old looking storefront that had the faded word "Gastronom" written in Cyrillic letters above the door. "This is an old Soviet-era food store. They've converted it into a café."

"So people can reminisce about the bad old days?"

"I guess so; they're so old now, people can reminisce. Of course, this place serves an abundance of coffees and pastries that would not have existed in the Soviet Union!"

They walked in, ordered coffees and sandwiches, and sat at a corner table far from anyone else. "Tomorrow we'll finish the discussion about engineering and technical developments," said Will.

"I feel really bad for Desmarais," replied David. "His report was absolutely ripped apart."

"I know, and it wasn't his fault. Right after the space summit, Dorinda met with us and told us 'I want an American moon plan; something with our stamp on it. The commissions should be of US citizens; no foreigners."

"So short sighted!"

"I was amazed! Redding asked whether he should call around and talk to people in Paris, Moscow, etc., and she said no. She told me not to make calls, either. But I was about to leave for a three-week trip to Australia, New Zealand, Malaysia, and South Africa, and to those stops I added two days in Darmstadt on my way home; I had to fly through Europe anyway. I asked some questions for him, too, knowing what he needed to know about. Redding has no contacts overseas and no need to travel. I have a travel budget and I know the people doing lunar geology anyway. The scientists publish their research; engineers usually keep it secret until it's finished. So when I convened a lunar science commission, the Americans present knew the research their overseas colleagues were doing. The engineers from Langley, Johnson Spaceflight Center, Armstrong, Goddard, Ames, Langley, etc., knew relatively little about the work being done overseas. So Redding's report was created in a vacuum."

"An unnecessary vacuum."

"An embarrassing one, for him especially, since Stetson won't take the blame."

"That's politics." David shrugged. "But you know, I still can't believe that in a matter of months, Peary will have *eighteen* personnel. When I take command on January 3rd, it'll have thirteen or fourteen; we might still add someone, even though the launch is less than two months away!"

"Congratulations on the command, again," said Will. "I'm really envious!"

"Don't be; you're Director of Lunar Surface Exploration! That's a pretty exalted position. We'll have five geologists. And I have to tell you the definite number one priority of Northstar 12: the Marius Skylight."

"Really? Is the tube elevator ready?"

“It will be in March. You see, Swift came through in September and talked to Ibis; the hotel chain, that is. They want to open a hotel in Low Earth orbit next to the Orbital Manufacturing Facility, which has a steady flow of technicians and engineers, some of whom will appreciate nicer accommodations. Tourists can go there as easily as anywhere else, some will be interested in the manufacturing work, and some investors may want to visit the facility before investing, so it’s a good location for another hotel. He was interested and willing to provide transportation to the hotel. Then they asked about a hotel on the moon, and Swift said ‘Where? I have an exclusive contract for a hotel at Peary, and I don’t think we can support one at Shackleton.’”

“Exclusive? I doubt that.”

“Well, that’s what he said. So the President of Ibis said, ‘Well, what about the Marius Skylight? The tourists could tour the volcanic features, explore the lava tube, and visit Apollo 12.’ That surprised Swift and the more they talked, the more he liked the idea; tourists would land at Marius, visit the area and fly to the spectacular Schroeder’s Valley for a visit, then fly to Apollo 12 quickly, then to Peary for the last half of their visit. Two hotels are twice as good as one and there’d be a lot more moon to see.”

“But where would the lander get the fuel to fly to Peary? There’s an insignificant amount of water at Marius. Would you truck it down the Aristarchus Highway?”

“Yes. A robotic truck carrying ten tonnes of cargo would need four solar-powered refueling stations between Peary and Marius. The trip would take about two and a half days; two trucks could make three trips per month each. That’s a lot of water and cargo, and the price wouldn’t be too bad.”

“But a hotel, all by itself, out on the middle of nowhere?”

"There's more to the story. The President of Ibis came to Paris to talk to Helene Colmar. She mentioned the tube elevator and called me to join them in her office. Ibis agreed to give a million euros to speed up the development of the tube elevator and add it to Northstar 12. Helene came back from the Space Summit wondering how she could protect ESA's moon budget; even raising our contribution to Peary to eight per year isn't enough to spend the budget allocation! But add a shelter, two rangers, a portahab, maybe a Conestoga and a lander, and Europe has its own lunar base, and for a few hundred million euros."

"I remember when we talked last spring, you said Europe was thinking about a separate moon base. So, you won't send Europeans to Peary anymore?"

"No, we'll do that, too, but maybe two or three a year to Peary and twelve a year to Marius. In other words, we'd be sending fifteen per year to the moon; more than the US. Europe feels it made a big mistake by ignoring Swift's suggestion that we establish Gateway Station. Then he went to India and the Indians agreed to do it instead, and at the space summit their commitment was to send six astronauts beyond Earth orbit every year, which was equal to ours!"

"And if you do that, the U.S. will feel it needs to commit more astronauts to Peary."

"Probably. But if Peary has fifteen or sixteen continuously instead of eighteen, it'll still be the biggest station by far. Marius and Shackleton would have six each. If someone needs to have their appendix removed, they'll have to be flown to Peary."

"It'll have to maintain the emergency facilities," agreed Will. "This is fascinating."

"And confidential; you can't share it with NASA officials. They'll freak out."

"Okay, I understand. Your secret is safe with me."

“I want you to know because some of our research questions, when we go to Marius, will not be strictly scientific. They’ll be oriented around the possibility of establishing a station there.”

“As they should be; Marius has remarkable potential for the future. There’s one other thing to remember about NASA’s possible reaction: four days from now, on Tuesday, November 2, is the Presidential election. Vice President Quaid is going to lose; the polls favor Nordstrom 57 to 43.”

“That’s true, and Nordstrom is no friend of NASA.”

“That’s for sure. He wants to strengthen the social safety net, and it badly needs strengthening, but the money has to come from somewhere. Raising taxes is virtually impossible and government debt has risen to crushing levels. NASA’s budget has already been cut to about two thirds of what it used to be, and it’s not going to be restored. If anything, it’ll drop to half its old level.”

“You’re right, so they won’t increase their commitment to Peary.” He shrugged. “That’s not bad for our commitment, though, unless it causes ESA’s budget to be cut more.”

“Your commitment to the moon may also strengthen NASA’s commitment to the moon. The various Research Centers are in trouble. Unless they can justify themselves, some of them may close.”

“Who are you going to vote for?”

“Me? I’m not affiliated with either political party. I’m torn between my social concerns, which will be addressed by Nordstrom, and my job, which is probably safer under Quaid. We’ll see.”

“Good luck with that!”

"Well, what did we get out of all of this?" asked Dorinda. She had brought the entire American delegation to the embassy on Sunday night, after the conference was over, for a frank after-dinner discussion.

No one spoke up at first. Then Will said, "I think we have a very good idea about science priorities over the next few years, even the next decade. Twelve million for six months of astronaut time on the moon and two million for a tonne of cargo have a lot of people thinking."

"But many of those experiments also require better orbital data, which means a new generation of satellites," said Rick Page. "And that two-million dollar tonne of scientific equipment might cost five million to develop and produce!"

"And a lot of these projects are not American projects," said Dorinda. "That concerns me. American leadership can easily be lost. We were outnumbered here."

"Well, we knew we would be; we're one delegation out of twenty," said Will.

"Your science plan was well received, but that's also because it included everyone else's research plans," said Dorinda. "I wish you had focused more on American contributions, Will."

"I emphasized them as much as I felt I could, Dorinda, but in science, one needs to use scientific criteria to determine priorities as much as possible. Our American research plans had some blind spots that European, Russian, and Chinese researchers, in particular, were filling. If the blind spots aren't filled, our research suffers as well, because it doesn't reflect the big picture."

"I suppose," she reluctantly conceded.

"The way to increase our role in the process is to be sure we have enough money," said Redding. "There are some important engineering projects underway. The Japanese project to

build a solar thermal rocket is potentially quite important for lowering the cost of transportation to low lunar orbit. The European effort to make metal carbonyls from nickel-iron meteorites could lead to extraction of platinum group metals, a resource potentially worth billions. The Chinese pledge to build a nuclear thermal rocket: if they do that, everyone will want to partner with them."

"We've got to get a space nuclear reactor into our development plans," said Dorinda. "I'm concerned that the number of personnel that nations want to send to Peary keeps growing."

"I wouldn't worry about that," said Will. "If anything, it is an argument that our contingent needs to remain large, and shouldn't be cut. And that may be an important argument, after Tuesday."

Dorinda scowled at him. "Why, do you really think Nordstrom will win?"

"That's what the polls say."

"Damn polls! They're skewed by the liberal press. Fox News has Quaid on top."

Will shrugged. 'They're not known to be impartial, either. All I'm saying is that if Nordstrom wins, efforts to cut the moon and Mars budgets will be hampered by the realization that we'll lose our central role."

She shook her head. "If Nordstrom wins, nothing can save Northstar and Columbus; he'll slash them in order to provide a few more poor people medical insurance. That's the end of everything."

There was silence for a moment. Will was tempted to point out that people said the same thing when the other side won, but knew it would do no good. Besides, if Nordstrom won, NASA would have a new Administrator, and Dorinda no doubt was reflecting on that.

Finally, Redding spoke up. “Either way, Mission Control’s going to be busy. There will be six gryphon flights to the moon in 2033 and at least twelve to low Earth orbit. Then there’s one to Mars and at least one to Gateway.”

“And it might even take off from Sriharikota. I can’t believe the White House has approved of the launching of Thunderbirds from India.”

“And Kourou,” added Redding. “At least it’s American technology.”

“American technology,” said Dorinda. “That’s one thing we still have; commercial dominance of the space market. I guess we can be thankful for that.”

11.

New Directions

Early January 2033

"Welcome to Houston, Claude," said Will, shaking Claude Duval's hand. He was surprised by how young the visitor looked; early twenties. "You've arrived just in time to avoid Paris's big blizzard and enjoy our heat wave."

"It is beautiful here," replied Claude, slowly, with a considerable accent. "I apologize for my English; it is not good!"

"No, it is fine," replied Will. "So, you got the tube elevator to Swift Space's Colorado Spaceport?"

"Yes; it is there and will be loaded into the cargo hold for launch in three weeks; January 31, to be exact."

"Excellent. And you're here for how long; a month?"

"No; two and a half months! I'm going to the moon on the tourist flight that launches March 30 and I'll return to Earth on the tourist flight that lands July 3. I'll be going to the Marius Skylight with that expedition on April 11."

"That's very exciting; are you the main engineer who designed and built the tube elevator?"

"No. It was a team. But the two lead engineers didn't want to go to the moon; they were frightened by the idea. I was willing, so here I am! A graduate student and a temporary, one-time astronaut!" He smiled broadly.

"Maybe not; space gets into your blood, if you know what I mean. So, you're here to learn lunar geology for two months?"

"Yes, and how to use a space suit, prepare for launch, etc. But I'll be here in Lunar Surface Exploration most of the time."

"Excellent! We'll add you to the lunar geology class—a new one starts in two weeks—and teach you how to drive TROVs, and you can read all the articles about lunar lava tubes we have. Are you settled into the hotel?"

"Yes, I arrived yesterday afternoon, went there, and rested. It's very comfortable."

"Two of us go jogging at 7 a.m. five days a week; would you like to join us? You'll see the neighborhood, get exercise, and have some conversation."

"I'd love that! How far do you go?"

"About five miles; eight kilometers."

"I can jog that far, excellent."

"Meet us in the hotel lobby tomorrow morning, then. Come into my office; let's call Dr. Alaoui."

Claude nodded and followed Will into his office. Will brought his tablet over to a table and beckoned Claude to sit close enough so the camera could pick up both of them, which Claude did reluctantly. Then he called David. It took a few minutes for the signal to reach Peary Station.

"Hello, Will! Oh, and I see Claude has arrived!"

"Yes, I thought you'd like know, he's here in Houston, safe and sound. He's the fourteenth member of your team, right?"

"Fifteenth! The first twelve arrived on January 3 and the remaining two came on the tourist flight on January 4. It was quite crowded here because Northstar 11 was still here, but they returned home on our gryphon on the 6th."

“They had the privilege or penalty of staying on the moon only four months. So, are you settled in?”

“Pretty much. We’ll stay around here with the tourists, getting used to the gravity and moon suits until early February. Then we make our first trip to the Marius Hills, and we can’t wait! Claude, learn your geology well, so you’ll be ready for the excursion in April!”

“Oh, I promise I will, Dr. Alaoui!”

“And Will, take care of Claude. He’s going to break your record for the youngest man on the moon!”

“I suspected. I was 28.”

Claude smiled. “I’ll have just 24 years.”

“That’s a record that will stand for a while,” said Will. “He’s joining the jogging group, David, and I’ll show him around.”

“Great. Everything up here is excellent, Will. It’s exciting to have such a large multinational team all working together for six months. We have some important work to do, too. The two Russians working on fusing basalt into building materials have already gotten started; I know, our power supply is struggling to give them the heat they need. The portable microwave heater will be tried next week on Whipple Trail; we’ll see whether we can heat the regolith enough to make a hard road surface.”

“If nothing else, it should reduce the dust that the wheels kick up.”

“We hope so; the astronomers can’t have dust interfering with their observations. No one wants the telescope built a hundred kilometers away. It’ll probably become an entire telescope complex, eventually. I have to run. Good to talk! Bye!”

"Bye," replied Will and Claude simultaneously. Will closed the line. "Let's get you a work station." He led Claude back to the central common area, which had a series of work stations against one long wall and a series of offices along the other wall. "I think this one is empty; it can be yours. You will note the TROV controls; all these work stations can serve as TROV control stations. So can all the offices. Let me introduce you to Tony, our administrative assistant. He's the guy who maintains the TROV control schedule and the work schedules. He also can verify that this work station is unoccupied at the moment." Will led Claude into an office next to his and introduced the two men.

As he was coming back out, he saw several men entered the Lunar and Martian Surface Exploration Center. In the lead was Zeke Swift, but right behind him was a man about 45 with a familiar face: the Vice President elect, Matthew Coombs. Swift saw Will and beckoned him over. Will smiled and approached.

"Welcome to the Lunar and Martian Surface Exploration Center, Mr. Vice President Elect." He extended his hand.

"Thank you very much; you're Dr. Will Elliott? I recognize you from television."

"Thank you, I recognize you from television, also." They shook hands. "How may I be of assistance to you, sir?"

"I'm giving the Vice President elect a tour of Northstar and Columbus Control," explained Swift. "President elect Nordstrom has asked him to maintain the space portfolio for the administration."

"Excellent. You're taking over at a remarkable, historic, time, Mr. Vice President Elect. Exploration of the moon is expanding and becoming routine and we'll have the first humans—the first Americans—on Mars in exactly three years."

"I quite agree, Dr. Elliott, but we have the problem of justifying the enormous expenditure to the American people."

"Of course, and pointing out to them that they spend more on pizza—not to mention alcohol and tobacco products—than on space exploration doesn't seem to matter. But the moon is telling us how the Earth formed, Mars is telling us how life started here, and Venus is telling us what Earth's fate in the future may be. The moon has the potential to supply us with platinum and related rare metals, essential for cell phones and electric cars—"

"Really?"

"Yes indeed. There are nickel-iron meteorites on the moon that are enriched in platinum, and we can find them. The platinum we mine here on Earth mostly comes from nickel-iron meteorites; no doubt we can find them in space as well as on the moon. Low Earth orbit has begun to be the center of manufacturing of some pharmaceuticals. New applications for zero gravity are being found every day. The moon and Mars are potential sources of materials for low Earth orbit manufacturing—"

"The moon? The surface of the Earth is much closer!"

"In distance, yes, but not in energy. It takes about 22,000 miles per hour to get something 200 miles up into orbit, but you can get something to the same place from the moon for only 6,000 miles per hour and from Mars for only 14,000 miles per hour. There's even the possibility of beaming solar energy to the United States from orbit or from the moon, providing us with a new source of renewable energy. The moon is the size of Africa and its natural resources are very poorly known, so this department is coordinating the systematic exploration of its surface. Mars is the size of all the dry land surface of the Earth, and while it won't have petroleum and resources of that sort, it probably has gold and platinum."

"But how could we get it here cheaply enough?"

Will turned to Swift. "This man. Between 1969 and 1972, the United States landed twelve men on the moon. The cost in today's dollars was about a billion dollars each. Because of Dr. Swift, in 2033 we will be sending Americans to the moon for 12 million each, and in another decade that may decline to half as much. We'll be putting astronauts on Mars for $300 million each; less than a third the cost of Apollo. Eventually Mars will be as cheap as the moon is now, then cheaper."

"We'll be putting American civilization on Mars," added Swift, obviously pleased by Will's argument.

Coombs nodded, appreciatively. "Of course, people have been promising that space will pay off for over 75 years."

"And it already has; weather satellites alone have paid for the entire space program in terms of property saved from hurricanes, not to mention the lives saved," replied Will. "Don't forget communications satellites and GPS. As for people in space, I go to meet with kids down in Brownsville every few months. I talk to them about science; I go to their schools sometimes, too. I've given their schools moon rocks. Brownsville's school system has a technical and engineering program and kids are enthusiastic to get involved. Manned spaceflight can inspire, too."

Coombs smiled very broadly. "You are very persuasive, Dr. Elliott. And I'm impressed you are providing this service to the kids in Brownsville. I wish more astronauts were doing that."

"Many are. We're also weaving some important international bonds here, and strengthening international relations. And frankly, space exploration is becoming a bargain, with

cheap access to space and the development of a transportation system to the moon, Mars, and other objects as far out as Jupiter."

"A bargain! I wouldn't go that far. But you're right, we're doing a lot more with the money than buying pizza."

"Exactly."

"Thank you." Coombs shook Will's hand, then went around and shook hands with everyone else in Lunar and Martian Surface Exploration. He and Swift headed down the hall.

"Very impressive," said Coombs to Swift.

"We have a pretty efficient and effective headquarters, here, and as Dr. Elliott said, we're revolutionizing the costs. That's the key. And NASA is learning from us."

"We need to steer more of the funding through commercial operations."

"But not all of it. NASA has an important role to play in technological development. I'm very grateful for all the technology they've developed that we are using. The problem is focus; a commercial operation can provide that."

"The United States government is grateful to you, Dr. Swift, for your focus," replied Coombs.

11.

Marius Skylight

April, 2033

Two landers, bearing rangers and a crew of two, descended on the meteor-battered cinder cones, lava domes, and rilles of the Marius Hills, hydrogen-oxygen engines blazing. One by one they touched down about one hundred meters from the gaping black hole, 65 meters across, that was the Marius skylight. Out came the crew—David Alaoui and Claude Duval from ranger 1 and Bonita Jackson and Chen Wei from ranger 2. In an hour they had lowered the ramps, snapped them in place, released the clamps on the rangers' wheels, and rolled them to the ground. They drove the rangers into the crater that punctured a hole in the roof of the underground lava tube, stopping just a meter back from the edge of the Marius Skylight. They climbed out.

David got as close to the edge as he dared and stared down into the inky blackness. "Nothing to see."

"The sun's been up just a few hours; none of it penetrates down into the hole," noted Bonita, who was an American geologist.

"Then let's deploy the light," said David.

Claude walked to the back of ranger 1, pulled out the electrical box, and deployed the tripod while David went inside the ranger to run its crane. He moved the crane down low over the side of the ranger so that Claude could attach the electrical box to it and verify the connection. Once he confirmed the setup, David raised the tripod and light, attached to the crane via an electric cable, and swung it out over the hole. He pushed a button and the light came on; with the controls, he swiveled the spotlight around to test their ability to move it. Satisfied, he began to lower the light into the skylight.

It was a long way down; 85 meters or 280 feet. Bonita, Claude, and Wei leaned over the edge to watch the light descend while David watched it via a camera mounted on the crane. Finally, after five minutes of careful descent, the tripod touched down. They now had a circle of light illuminating part of the bottom.

"It's so far away, we can't see much," said Bonita.

"That's alright," replied David. "We didn't expect the light to help very much. But it might help us to place the tube elevator. That's the next task."

"Let's get started," said Claude. He walked to ranger 2, which had already been backed up within three meters of the edge of the skylight at a pre-planned spot. The tube elevator was a cylinder two meters in diameter, accordioned into a tight bundle, with an elevator car inside, firmly attached to a special trailer. Claude checked the connection to the nitrogen bottle, warmed up the controls, then began to send nitrogen gas into the tube's inflatable ribs. The cylinder began to accordion outward. The far end had a rigid metal collar to which four cables were attached on the outside. Claude had to play out the cables as the gas pushed the tube outward. He kept an eye on a screen, which had a television image from the camera on top of ranger 1's crane. He had done this a dozen times at a quarry in France; they had even run the elevator car up and down the inflated tube. But he had never done it in lunar gravity and a vacuum.

The tube began to bend under the effect of gravity and enter the hole. Lights on the end of the tube made it easier to watch its progress, but the GPS data was the key; that told them how far above the floor the end was. Too much inflation and the ribs would be too rigid and the tube wouldn't bend enough to reach the floor; too little and the tube would just droop straight down. The key was playing out the cables and adding air to the ribs at the right rate.

David and Wei came over to watch anxiously; Bonita stood at the edge and watched from there. The tube was 110 meters long; the skylight was 85 meters deep and 65 meters wide. Claude played out the cables two meters and the tube extended and drooped lower; he added air until it stiffened the ribs and the tube straightened, rose, and approached the far wall; then he played out the cables two more meters and the tube extended and drooped again. A landing spot had been carefully selected on the side of the pile of collapse debris because it was clear of rocks, but several large, low rocks would help to anchor the tube once the elevator began to ride down it.

The extending process was slow, careful, and took two hours. Maneuvering the tube to the landing spot was tricky because it had to be done blind, using GPS. Finally the end ring of the tube—which was studded with metal spikes on the bottom—touched down in the landing area. The spikes sank into the mix of rocks and fine material that blanketed the floor of the skylight.

"Congratulations, Claude!" said David, slapping the engineer on the back. Wei shook hands with both of them; Bonita came over to join them and celebrate. The sounds of applause could be heard over the audio feed from Mission Control.

"Congratulations, Marius!" exclaimed Will. "We're thrilled up here. You've done it!"

"Now we have to run the elevator car down and back up," said Claude. "We'll see whether that works!"

"Let's give it a try," said David, waving at the controls.

"Alright." Claude turned to the controls of the elevator car. It was a cylinder of light-weight but tough plastics two meters in diameter and two meters long, with doors at each end. Tiny wheels on the bottom and sides guided the car as it moved; four cables inside the tube,

connected to pulleys at the far end, pulled it up and down the tube. Claude checked the tension on the pull cables and the condition of the motors, then he sent it down the tube. It began to move horizontally along the tube, rolling on its wheels as well, then it dipped downward and headed down. The far end of the tube felt the pull on its cables and sank deeper into the regolith.

"The position is good," said Claude. If the far end of the tube shifted toward the near end, it would kink the tube and make the car's ascent difficult or impossible.

In two minutes, the car reached the far end of the tube and stopped. It had worked! Claude called the car back up and they held their breath as it struggled over the lip on its wheels, then came to rest at the top end.

"I'm going down to anchor the far end," said Claude. "I have the training. It's not hard to run the controls at this end."

"Alright," said David, who wanted to do it himself, but he relented. "Let's change your life support backpack first."

Claude and David stepped back into the ranger, which was wide open, removed Claude's life support pack and put a new one on his back; his suit could run without it safely for several minutes. Once it was checked out, Claude came back out of the ranger, stepped into the elevator car, closed the doors, and sat on a seat facing uphill. He put the seatbelt around himself and reached over to push the "down" button. The car started down.

He was startled when the car tipped steeply downward. The silence was a surprise as well; in a vacuum there was no humming of motors or clunk of cables. But the car moved steadily downward and in two minutes it slowed, then stopped. Claude removed the seatbelt, rose, and opened the exit doors.

Blackness.

He flipped on the exterior lights and stepped out. He looked down; the weight of the car had caused the end of the tube to move by about a meter, which was worrisome. He stepped out onto the floor of the skylight. The tube had come to rest about half way down the far side of the pile of collapse debris; the heap extended another twenty five meters horizontally and ten meters vertically to the far wall. He grabbed an anchor cable spooled against the side of the tube's end collar and extended it to its full five-meter length. He did the same with an anchor cable on the other side, then came back to the tube to grab long metals stakes and a hammer. With the hammer, he pounded the stakes into the debris pile.

"Call the car back up," he said.

"Acknowledged," said David. Claude watched while the car silently moved back up the tube, out of sight. He waited anxiously to hear whether it got stuck, looking around at the debris pile with his headlamp. He didn't want to contemplate what it would be like to climb the tube in a spacesuit; he had practiced that, too.

"It has arrived," reported David, finally. "No problem."

"Excellent. Let me finish the work down here." Claude took the claw of his hammer and used it to pull the spikes studding the bottom of the end collar out of the regolith. It was difficult to do and took half an hour, but eventually he managed to work them free of the rocks and debris. Using a lever arm, he winched the cables in, stretching the tube another meter and a half. That finished, he locked the anchor cables and drove new, longer spikes in the collar back into the regolith.

"Okay, the bottom of the tube is now safely anchored in place, Commander. You can come down."

“Thanks, Claude. We’ve set up the elevator’s solar panels and power storage system, and installed the trailer’s anchor cables up here. The elevator is now ready for use.”

“Not bad; it took six hours!”

“Rather than me going down, why don’t you come up,” said David. “We need to go inside, have something to eat, and rest a bit.”

“Alright.”

They waited until the next morning to descend into the lava tube; Lunar Surface Exploration’s crew had to go home for the day anyway. David and his crew went outside briefly in the evening to detach the ranger from the tube elevator and drive it away. The next morning they were rested, the life support backpacks were fully charged, and support was ready to help.

David went down first, stepped out, and sent the car back up for Claude, then for Bonita. The car could easily hold all four of them, but for now they planned to ride it one at a time. Wei, their Taiwanese engineer, stayed on top; someone had to for emergencies, and his geological training was limited. When Bonita exited the elevator car, she saw David and Claude walking around the debris pile, their head lamps blazing.

“What do you see?” she asked.

“Nothing out of the ordinary,” replied David. “I suspect we’ll find a lot of the impactor here, if we bother to look. There are a few scattered chunks of nickel-iron, so I suspect it was a nickel-iron body.”

“That would explain why it had the strength to punch through.” Bonita looked around. “The lava tube’s 80 meters in diameter; wider than the skylight. And the roof is at least 50 meters thick, except where the impact punched through and dug a crater 35 meters deep.”

"It looks like at least three lava flows buried this tube," agreed David. He pointed uphill. "Let's go this way, toward the lava source. Bonita, can you bring the line?"

"Sure, I'll get it." She reached inside the elevator car and picked up a big spool of wire—two kilometers of it, altogether—and a bag of cellular communications nodes. She plugged the end of the spool into an outlet in the tube's end collar and screwed the connection into place so that it couldn't pull free. Then she walked down off the debris pile, unspooling the line as she went.

"Let me take the nodes," said Claude, taking the bag from her.

"Let's go, said David. "Mission Control, we are entering the lava tube."

"Watch out for the bats," replied Will.

David laughed, though a bit nervously. Once they were off the debris pile and under intact roof, David looked around with his headlamp. The tub was eighty meters wide and fifty meters high in the center; the roof formed a natural arch. The floor was covered with small rocks and dust from the collapse, which would have occurred millions or even billions of years ago. As they walked up the tube, there was less and less debris on the floor, and what was there had fallen from the roof. "The tube appears to be remarkably intact," he said. "There are no huge debris piles to step over; not yet. The walls are rough and show signs of deposition of lava on them, three and a half billion years ago."

"We've got video from all three of your helmet cameras," replied Will. "It's hard for us to recognize features, however. You've got a much better view than we do."

"Sorry about that, but there's not a lot we can do. Our headlamps are only so bright."

"Hey, look at this," said Bonita. She was walking along the other side of the tube, so David walked over and shined his headlamp on the part of the wall where she was shining hers.

Some hummocky minerals filled a crack in the wall. She broke some off with her rock hammer and brought them to her eye. “Greenish-yellow, botryoidal in shape. I’d say it’s Prehnite.”

“A calcium aluminum silicate,” added Will a moment later, someone having looked it up on the web. “Hydrated, I should add. You’ve got a bit of water there.”

“Good,” said David.

“It’s commonly associated with basalt,” noted Bonita. “We almost never see real rock outcrops on the moon, because of the pounding the surface has taken.”

Sifting through the basalt regolith, we sometimes do find broken bits of minerals,” said David. “This confirms the situation. This tube may give us access to small quantities of resources.”

They continued up the tube. Three hundred meters along, they stopped to report a pile of boulders; sometimes stuff did fall from the roof. They noted the position and Will reported that there was a crater nearby, so the impact had probably shaken the rock loose. “More mineralization over here,” said David, who was walking along the northern wall of the tube, just as Bonita was walking along the southern wall. “I think we have calcite here, and maybe a bit of fluorite.”

“They’re often associated with each other, and with basalt,” said Bonita. “Calcite is $CaCO_3$, so we have carbon dioxide here as well.”

“I wonder whether we can find enough to make mining worthwhile,” said David.

“On the other hand, importing stuff from the Earth to the moon costs two million dollars a tonne,” noted Will. “And if they need calcium in low Earth orbit, you can send it there for half the cost of Earth.”

“If we can spend a hundred million to build and import the necessary equipment.”

Say, you guys are so busy looking at the walls, you haven't noticed these." Claude pointed his headlamp upward at the ceiling, revealing a series of small stalactites sticking downward.

"Wow!" said David. "But I suppose it makes sense. When a lava flow spread over this area, it would have had water and carbon dioxide gas in it; not a lot, but we know it had some. The water and gas would have leaked downward as well as upward and this tube would have had a temporary atmosphere."

"You're right," said Bonita. "Look on the floor for broken pieces."

"If I can't find any, I can try knocking pieces off," suggested Claude. "I'm sure I can throw rocks that high."

"Let's not risk creating a rock fall; not yet," said David.

They began to look at the debris on the floor, rather than at the walls. About two minutes later, Bonita reached down and picked up a fragment. "Here. It looks like calcite to me."

"That makes sense," said David. "Something else for the tourists to look at."

"Some of them are a meter long!" exclaimed Bonita.

They stopped when a bright red band appeared on the wire they were spooling out. They had reached the 500 meter point. Claude pulled out a communications node and plugged it into the wire; a tiny green light came on, showing that it was working. He put it on the floor and they continued down the tube, assured that they'd have reliable communications, as well as power.

They passed another pile of ceiling debris and stopped for fifteen minutes to pick through it. It had mineralization as well; calcite and a bit of prehnite. "We need to pay attention to the debris," said David.

They continued up the tunnel. The ceiling was now sixty meters above them, rather than fifty. At the one-kilometer point they stopped to install another communications node, which left another faint green light on the floor of the lava tube.

"Say, what's this?" asked Bonita. David and Claude came over to see a whitish patch on the floor and lower wall. David scanned the light around the tunnel.

"You know, the entire floor is covered with small, faint, whitish speckles," he said, pointing.

Bonita scraped some up and brought it to her helmet. "It looks like a deposit; maybe a precipitation."

"Sulfur?" suggested David. "Any volcanic gases that leak into this tube have to pass along it to the skylight."

"Sulfur would be a good guess, then. Where's the portable analyzer?"

"I've got it." David pulled from his belt a device the size of a pack of cigarettes. He pointed it at the deposit and pushed a button. They saw a bright laser flash; it seemed blindingly bright in the cave's blackness. About a minute later, the screen lit up. "Looks like a mix of sulfur compounds," said Bonita. "It has hydrated calcium sulfate; that's gypsum. But it has some iron in it as well."

"A bit of pyrite," said David. "Let's keep going."

They continued up the tube. The light deposit on the floor and walls became more widespread and soon it was a sort of crust. In one area there was a bit of bluish tint, so they stopped to zap it. "Copper sulfate mixed in," said Bonita, looking at the screen. "But only trace amounts."

"This whole deposit is a trace amount," said David.

“We’ve been doing a little calculating down here,” said Will. “Assuming the deposit is 1 millimeter thick and covers the entire floor, every kilometer of floor has 8 cubic meters of crust, with a mass of about 16 tonnes. So whatever the stuff is, it adds up to a substantial deposit, if we can design something to scrape it off the floor.”

“That makes the significance clear,” said David. “We’ll zap it more often so we have a better idea of the composition.”

“And take samples,” added Bonita. She stooped down and whacked an irregular spot on the floor, breaking it off. She dictated a description of the sample and put it in her sample pouch.

They continued up the tube, which was taller than ever; the last flow of lava had partially filled in the tube, and the filling was greater as one went downhill. David stopped to look at a thin vein of calcite in the wall, zapped it, and took samples. Claude picked up an intact piece of stalactite that was twenty centimeters long; it was also calcite. Bonita recognized several tiny stalagmites growing upward from the floor, showing that water must have actually dripped from the ceiling, uncounted billions of years earlier. It was a sobering thought that they were walking where nothing had ever gone before, exploring a sort of time machine into the lunar past.

They reached the 1.5 kilometer point and installed another node. The crust on the floor was now a bit thicker and was powdery on top; David, Bonita, and Claude spent a few minutes and excitedly scraped up a vial full of sample. They reached a spot where a calcite deposit oozed from the northern wall and flowed twenty meters to the floor, leaving a sheet of gray-white that gleamed in their headlamps. They stopped to examine a huge rock fall that partially blocked the tunnel, but eventually they climbed over it and continued up the tunnel. The crust was even thicker now, and their footprints formed distinct shallow depressions in it. It became difficult to see anything of interest on the walls because of the deposit covering them.

They stopped to examine another small rock fall, then continued to the 2 kilometer mark. At that point their power and communications cable ended.

"Let's rest," said David. He pointed to a shelf-like spot on the wall where they could sit, so they went over and sat down.

"Hard to believe we've been in here almost three hours, and we've come only 2 kilometers," said Bonita. "But there's so much here to examine."

"Yes, this is a treasure trove," said David. "I suppose the deposit on the floor is getting thicker because we are getting closer to the source."

"How far to the end of the lava tube?" asked Claude.

"The Morgan expedition walked along the surface with ground penetrating radar for five kilometers and followed the tunnel the entire way. At that point, they stopped. But the rille this tube is underneath extends uphill 35 kilometers from the skylight and 15 kilometers downhill from it. There's no reason to assume the tube doesn't go all the way up to the source crater. Of course, it may be blocked; there are some good sized craters in the rille."

"But none of them punched through and created a skylight," noted Bonita.

"Correct, so there's no evidence the tunnel is completely collapsed. Downhill, it looks likely that the tube gets filled in with more and more lava, but it must go quite a distance as well."

"Eighty meters wide; that's 80,000 square meters per kilometer, and if we have 40 kilometers of tunnel, that's 320,000 square meters or 3.2 square kilometers; over a square mile of land with no cosmic rays, no micrometeoroids, no extreme temperature swings."

“Do you think we could build two airtight walls across the tunnel, spray the basalt surface with plastic, and pressurize the section?” asked Claude. “Fifty meters of rock overhead is plenty to hold in the air.”

“You’re the engineer,” replied David. “I suppose it would be possible. No one will do it any time soon, however.”

“You’d have problems with chemical weathering of the basalt floor,” noted Bonita. “Water and air would leak out through cracks in the rock. But since the rock down here is minus 20 Celsius, the water in the cracks would freeze them shut.”

“ESA definitely needs to consider establishing a station here,” said David. “Assuming we can anchor the tube elevator solidly in place and it is reliable—we probably should install a second, larger one for moving cargo in and out and for a backup—we will have fully reliable access to the lava tube. We can get a buggy down here using the existing elevator to speed up exploration. With a bigger crane we could move large equipment up and down; that should be the next infrastructure improvement. Shelters and greenhouses are very easy to install down here because they can much thinner and lighter in weight than anything inflated on the surface. And there’s immense mineral potential down here!”

“Water?” asked Claude.

“We can truck it down the Aristarchus Highway from Peary; a robotic truck would need three or four automated refueling stops where it would drop off its water and take on new hydrogen and oxygen supplies. But it looks like we can extract a fair amount of water from the minerals here, too. And there’s another rille ten kilometers north of here that is about the same size as this one, but no skylight.”

"We need to use the ground penetrating radar to see whether it has a tube," agreed Bonita. "Because if it does, it'll have held in a transient atmosphere much better than this tube, so it may have more minerals."

"And volatiles," said David. "It could have ice because the vapor pressure of ice is pretty low at minus 20, and the escaping vapor would freeze up cracks."

"The Marius Hills and Aristarchus Plateau have dozens of rilles and several known lava tubes," said Bonita. "There's enough geological work here for decades."

"Absolutely," agreed David. "And since this has some of the last volcanic activity on the moon, the lavas may have the highest concentrations in rare elements. Certainly, the titanium levels are the highest. The moon has minerals after all."

"And the potential for significant mining," said Bonita.

"So, what's all this talk about a European station at Marius?" exclaimed Redding, as he walked into Will's office two evenings later.

"What? What talk?" asked Will.

"Every time they go up that lava tube—or down the other half, like today—they keep bringing it up," said Redding. "This expedition is not good for Peary!"

"They're speculating," replied Will. "But can you blame them? They found a calcite vein half a meter wide today! It could have tonnes of carbon dioxide—calcite is calcium oxide and carbon dioxide chemically bonded together—and we need carbon dioxide to make methane for the gryphons. Yesterday's expedition penetrated five kilometers up the lava tube and showed that the crust on the floor and walls gets steadily thicker as you move toward the lava source. The crust is ten percent CO_2 and five percent water; that's 1.6 tonnes of the first and 0.8 tonnes of the

latter per kilometer, laying on the floor waiting to be swept up and processed. It may very well be that robotic trucks will haul water from Perry to Marius and carbon dioxide from Marius to Perry, in a few years."

"What about the other minerals?"

Will shrugged. "Marius clearly has lots of calcium and sulfur. But right now there are no industrial processes on the moon or in low Earth orbit that need either one. Marius is also well located for extracting titanium; there are titanium rich basalts that are 12% ilmenite. Oxygen is an important waste product of the process, too. But titanium on Earth costs something like $6 per kilo or $6,000 per tonne. Exporting it to Earth costs $2 million per tonne."

"No market for lunar titanium, then."

"Definitely not. There may be some for lunar platinum; it's worth 40 to 60 million per tonne. But right now the cost of extracting it from lunar nickel-iron is much higher than that."

"So, it has a ways to go. Then why the excitement? ESA must have plans."

"You're probably right. The Marius lava tube is a fascinating tourist destination and the area has years' worth of geological exploration to do. Mining companies, thinking long term, might even be willing to subsidize the work. Marius and Aristarchus, together, form possibly the most interesting area on the moon. It's the area that's still outgassing, too. The trace gas sampler on the tripod they lowered into the skylight shows a transient atmosphere of argon, radon, helium, water vapor, and sulfur dioxide in the lava tube a hundred times denser than on the lunar surface. It's still a vacuum, but the tube is a conduit for gas escaping from the lunar interior."

"Radon? That's dangerous."

"It's in too low of a concentration, and it'll never be able to enter any habitats they build in the tunnel."

Redding shook his head. “This is very worrisome. We can’t afford to split our resources between two stations! We need the Europeans at Perry! We already have the Chinese at Shackleton and we can’t coordinate with them very effectively!”

“I agree, but it only costs 12 million to send someone to the moon, now, so we can expect the number to go up. We may end up with a European Station *and* more Europeans at Perry.”

“Possibly. I had better talk to the Administrator. I think he needs to talk to Helene Colmar.”

12.

Politics

Mid May 2033

David and Bonita rolled quickly down the tunnel on the buggy, its powerful headlights casting bright circles in the void space in front of them. For simplicity, they always followed in their previous tracks. It was a pain to report in every two hours, but there was no radio contact deep in the tunnel; they had brought only six kilometers of wire with them. The next expedition to come had to bring 40 or 50 kilometers of wire instead, as well as a second, larger tube elevator.

Suddenly David's communicator lit up; they were within a kilometer of the last communications relay and the signal was restored. Emails and voice mails began to pour in, but there was no time to attend to them while driving the last seven kilometers of the tunnel. David kept his focus on the tire tracks in front of him. If there was an obstacle, such as a ceiling collapse, they had placed a piece of paper on the floor with a caution triangle drawn on it; seeing that, he would slow down.

They were done for the day, this time, for they had pushed as far uphill as was practical for this expedition. The tunnel was actually becoming familiar to him, for he had driven back and forth for almost two weeks.

In a few more minutes they saw the heap of collapse debris ahead of them; they had reached the skylight. David stopped the buggy and he and Bonita transferred to the elevator car. Two minutes later they were on the lunar surface, looking up at the waning Earth. They walked to the two rangers and the portahab, which were docked together, and headed for ranger 1's airlock. It was a tight squeeze, but they both fit inside. David walked into the ranger's cabin to

take off his suit while Bonita changed in the airlock itself. They both entered the portahab at about the same time.

"We're reviewing your video right now," said Wei, pointed at the screen in front of him. David's space suit was still downloading the video of the last sortie; it was coming in at a high speed.

"Good. We got to a large cavern, a sort of lava reservoir; it was 150 meters across and seventy meters high. But the tunnel continued on, and according to our calculations, we were still five kilometers from the source. We can't get to the end and return to make contact every two hours. When we got to the big cave, we only had ten minutes to explore."

"The crust on the floor is two centimeters thick, there," added Bonita. "It's really incredible. And there's a lot of calcite and other minerals. There must have been a lot of water and gas up there for a long time."

"Definitely," agreed David.

"That fits our exploration downhill as well," said Claude. "There was a lot less water and gas down there."

David sat at the table; Wei had already microwaved four dinners, so they ate. "So, everyone's willing to stay another two weeks and explore the surface?" he asked at one point.

Everyone nodded. "The volcanic features here are incredible," said Claude. "And we never finished tracing the buried lava tube under the other rille with our ground penetrating radar."

"We need to finish characterizing that lava tube," agreed Wei. "We should be able to get a drill here in a year or two and drill into it."

"It may have some gas in it," agreed David. "What a discovery that would be!"

“Do we have permission for a third lander flight?” asked Wei.

David shook his head. “Pierre and Anita are anxious to come down, and Peary’s third ranger isn’t needed urgently over the next two weeks. I know, I still approve the work schedule! They want to utilize their geology skills here, too. I’ll call after dinner and find out what’s up at Mission Control.” He didn’t mention the resistance he was getting from Redding and even from Will.

“We have to have a flight; we don’t have enough food for fourteen more days, if we stay the entire dayspan, unless we ration it,” said Wei, who watched their inventories.

“I know, and so does Mission Control. Peary’s been packing up a supply. How much longer do you want to stay? Sunrise is tomorrow. If we stayed two weeks, we could complete a pretty thorough exploration of the area. Then two or three more days underground to wrap up the work there, after the sun has set, then we can fly back to Peary about May 27 or 28.”

“That’d make the expedition six and a half weeks long,” said Bonita. “That’s a new record.”

“I’m not interested in making a new record, as much as getting the exploration of this area started in a solid fashion.”

“Does Lunar Surface Exploration Support have enough field trips ready for us?” asked Claude.

David shook his head. “They have maybe eight or nine days planned out, not fourteen, but it doesn’t really matter. Will Elliott and I know this area better than anyone else. We can be spontaneous and it’ll work out fine. We don’t have to have every stop fully scripted.”

“That’d actually be counterproductive anyway, because orbital data is never good enough to predict where everything interested is located,” said Bonita.

"Then let's definitely plan to stay," said Wei, and Claude nodded eagerly.

"Alright, I'll make the formal request."

David finished his dinner, then retreated into the cab of ranger 1—which served as his office and sleeping cabin—to review his messages and make calls. As expected, he had a message from Will—to call him—and one from Helene Colmar, the Administrator of the European Space Agency. Since Helene probably had good news, he played her video message first.

"Good afternoon, David," she said in French. Since they were both French, there was no reason to speak in English. "I have had several very positive conversations with relevant government ministers today. The Germans can probably commit eighty million euros for the first two years and twenty-five million per year afterwards to a Marius Station. The minister told me that the German public was fascinated by the lava tube and all the minerals in it; he said it was as if we had discovered gold on the moon! Critics are already pointing out that the minerals are probably of no economic value and he said they have issued statements to correct that. Their pledge anchors our plans for the station.

"I then emailed the French minister, who wanted to be sure to pledge a bit more than the Germans. France will commit one hundred million for the first two years and thirty million per year afterward. As I expected, the Italians and British wanted to know the German and French pledges, so I emailed them. I haven't heard back from them, but as you know, the new British Prime Minister is very keen on space exploration. The U.K. may very well match the French pledge. I suspect the Italians will come in at about half the German level.

"Once I have those pledges, I'll email the Spanish, the Poles, the Dutch, the Swedes, the Czechs, and the Irish. They'll all come up with something. So it's beginning to look like we'll

have in the vicinity of 400 to 500 million euros to get Marius Station started. That's enough for a robust solar array and energy storage system for nightspan, two shelters, a greenhouse, several landing pads, two or three rangers, and associated scientific equipment. A lot of the really powerful scientific instruments that will be useful on the moon will have to go to Peary; we need to keep NASA happy. Some equipment we simply won't purchase and ship because it'd be easier to truck or fly samples to Peary for analysis on the equipment they already have. Peary will also need enhanced medical facilities and we'll include that in our budget. It'll be a tight budget, but once we get something established, it should get more supplemental money later. The Ibis people will be pleased; they're willing to invest 100 million euros. They just got a Swiss government interest-free loan for their low Earth orbit Ibis Hotel, by the way. Who would have thought the Swiss would support space flight!

"So, in sum, keep sending us good video of the lava tube and keep finding interesting minerals. It's working! Europe is on the verge of having its own lunar station. Bye."

David sat back in his chair, pleased. As much as he admired the United States, he wished that France could compete with her, and the European Union had often served as France's instrument for doing so. It appeared that it would happen again. It was even possible that the moon would soon have more European astronauts on it than American!

But that reminded him of Will's laconic "call me" email. He punched in Will's email address.

Will answered quickly; his face looked tired. "Good evening, David. I was just looking at the video of the lava chamber; what a huge space! Really amazing! And we have evidence of even larger lava tubes on the moon."

"I know. It's just below the exit of the source crater, but the source crater goes on for several more kilometers, and so does the lava tube. Maybe another time, someone can penetrate all the way to the end. The crust is almost two centimeters thick in places; that's a lot of sulfur, calcium, hydrogen, and oxygen."

"You even found copper sulfate the other day; enough to make at least a few tonnes of copper. This has been an incredible expedition; quite historic."

"That's why we want to extend it and get Pierre and Anita and ranger 3 down here. Peary doesn't need it for the next two weeks. With six of us and three rangers, we can really explore the Marius Hills thoroughly. We'd then stay two to four days after sunset to wrap up our work underground and fly back to Peary."

"Yes, it's a robust plan, no doubt about that. But let's be sure to keep our priorities scientific. If we stray from them and politics enters, we'll get all sorts of conflicts. Our usual approach is to send out a two to four week expedition, then return to Peary, process the samples, complete a preliminary evaluation of the results, and finalize plans for the next expedition in no less than a month's time. The astronaut team needs a rest and a time in radiation shelters; they need a rhythm to their activity to remain fresh. The support team down here needs some sleep! And the support team needs time to finalize the next expedition. If you return to Peary now, there's time to plan one more two to three week expedition before your departure in late June. If you stay two more weeks, there isn't. You've made two expeditions to the Marius Hills. We need to make a trip to the Serenitatis lava tubes as well. They'll give us comparison."

"You make a good case," agreed David. "But consider that Doug Morgan's expedition, which was the first to visit the skylight, went six weeks as well. They didn't have a radiation shelter for that whole time; we've been underground and gotten no radiation exposure down

there at all. For most of the last two weeks, the support team on earth has had some rest because we have been out of radio contact completely for two hours at a time. With Morgan's expedition, they had to sit in their rangers for five days when there was too little light to explore; we didn't have that, but we didn't need a rest and Morgan's team was pretty bored. As for Serenitatis, that can be done by the next crew; there's even a skylight there, and some lava tubes that should be accessible without a tube elevator. More data here will produce a richer comparison."

"But David, we've never sent out three rangers before. Are you all going out in one expedition, or will you do two parallel expeditions a few kilometers apart? How will the support team support two parallel expeditions?"

"How much support do we really need, Will? You and I have poured over the images and chemical analysis data for the Marius Hills for days; for months. We know where every lava dome and rille is located, where there are exposures, where craters have punched through and given us strata to examine. We'll just go from volcanic feature to volcanic feature and your team can pull up the relevant data as we go."

"David, we've created dozens of geology stops. I'm sure you plan to do them first, but let's face it: we do the advance preparation for a reason. There's a support team because we have all agreed it's useful. But we can't run them ragged trying to support exploration spontaneously. The science will be sloppier and less useful, also. We know that."

"You have a good point, Will." David leaned back. "You mentioned politics."

"Yes, and I think you know what I mean. Clearly, ESA is interested in establishing a Marius Station. By 'clearly' I refer to your comments during your EVAs and the increased level of speculation in the media, not to mention the articles by European space journalists that NASA is reading very closely."

“So, you’re hearing from them.”

“I think that is a very safe assumption.”

“Which puts you in a difficult position.”

“That’s safe to assume as well.”

David pondered a moment. “But speaking of politics; Doug Morgan was about to run for Senate—he’s now the junior Senator from Ohio—and he got his six weeks, which got his team all the way from Marius to the outer ring of Orientale! I hope no one is pressuring you to make sure his record stands.”

“No, no one has brought that up. Records are made to be broken.”

“I agree. So, no lander 3, ranger 3, and two additional personnel.”

“No.”

“What if the four of us stay here and run through the geology stops that are already planned? The database is rich in Marius stops, as you know.”

“It is. That’ll keep you busy for about nine days.”

“I bet we could stretch them out to last fourteen days. That’s not too much spontaneous exploration, is it?”

“No, we could handle that. But you don’t have the food for fourteen days. How long will your food last? Six days?”

“Seven if we empty the refrigerator of leftovers. But there’s a solution to that, too. Fly us more consumables via a Condor.”

“A Condor?” Will pondered that. “I don’t know how we’d anchor the supplies to the cargo deck.”

“The engineers at Peary are clever. They can rig up something. The acceleration is only one gee, so even bungee cords would do it!”

Will laughed at that. “Bungee cords and duct tape. I bet they could do better than that. You’d need less than a hundred kilos.”

“It isn’t much. If we could have more electrical line, that’d be great, too; we could extend our underground system. But Peary doesn’t have much in stock.”

“Okay, I think I can sell a Condor flight. But if not, you’ve got seven days of food and can certainly stay another week. You’re right, we bent the rules with Morgan, so we can bend the rules for you as well. Technically, this is not as difficult an expedition as Morgan’s; we had to fly the landers back here, refuel them, and send them to his departure point. You stayed put. And you brought a tube elevator; this was a special expedition from the beginning. I’ll see what I can do.”

“Thanks, Will. We’re not out to break Morgan’s record, but we do want to explore Marius as much as we can. There’s no question that expeditions will be back here often.”

“That argument cuts both ways, but never mind. I’ll go talk to Redding right now. Good luck with your plans tomorrow. Bye.”

“Bye.”

Will closed the connection and stood up. Redding was still in his office, even though it was 7 p.m., but he wouldn’t be there much longer. No reason to wait; he’d just fret about the conversation too much. Will headed up the stairs.

Redding saw him coming. “So, what’s the plan?”

Will came in, sat, and faced Redding. “A compromise. Doug Morgan got six weeks for his expedition, and it was logistically much more complicated than this one; it covered hundreds

of kilometers and involved two flights of two landers. Marius Hills have more proposed geology stops than almost any other area of the moon; it's a rich study area. But we can't support a third lander and third ranger easily, and the requisite six personnel. The support team would have to handle the questions and do research for six geologists at once; we'd get worn out. We wouldn't be able to support an emergency adequately, either."

"So: they'll stay a few more days?"

"They want to stay sixteen or seventeen days; complete a dayspan above ground, then a few more days underground to wrap up their work there. A team at Darmstadt is pouring over the scientific results of the underground phase and they need a few days of wrap up."

Redding laughed. "And they plan to go on half rations?"

"They've requested a Condor flight with a few hundred kilos of consumables and equipment. I support their request. They're there; they've got a crack geology team, with Bonita and David; Claude is a pretty good geologist and Wei is a fantastic engineer and mechanic; their equipment is in fine shape; their geology objectives for dayspan are well developed and we can support them adequately; their additional geology objectives underground will be well defined by the time the sun sets; their hydrogen and oxygen reserves are sufficient for the rangers' fuel cells and for their flight home, thanks to the additional power from the tube elevator's solar array. Safety is fine."

"Will, I told you quite explicitly that I wanted them back to Peary in the next three or four days."

"I've got a one word response to that, Redding: science."

"And I have a one word response to your response: politics!"

"And I have a two word response to that: Doug Morgan."

Redding stared at Will, then leaned back in his chair. “Damn it!”

“We can only bend from scientific criteria so much, and this is less of a bend than for Doug. In July, we’ll have an American commander at Peary and he can lead expeditions to all sorts of lava tubes, if we want to make them a priority, which we probably should. Give this one to the Europeans, Redding.”

“Alright. The Vice President will not be happy; the new Administrator will be livid! He can’t look ineffective. But the diplomats will agree with you.”

“Good. Stick to science, and we’ll be able to forge a consensus among partners. Without science, we’ll have conflicts and mistrust.”

“I’ll use that argument, but I want you here at 9 tomorrow morning when I talk to Coombs!”

“You can count on me.”

14.

Planning Northstar 14

Mid July, 2033

The image was sharp, but it seemed to be in black and white; asteroids were just as gray as the moon, and 2028 BT12 was no different. Half of Mission Control watched the cosmonauts on their exploration of the 200-meter nickel-iron body, while the other half focused on their other responsibilities, monitoring the gryphon *Pavonis* or the automated cargo Hippogryph-2 on their flights to Mars, or watching the progress of the tourist gryphon on its way to the Pax Hotel in low Earth orbit, or occasionally checking the systems on board the Gryphon *Copernicus,* sitting at Peary waiting for the tourists to complete their 7-day visit.

Sitting near the large screen with the feed from Russian Mission Control were Redding Desmarais and Will Elliott, and they had two special guests that day: the new Administrator of NASA, Fredrick Ross, and Vice President Matthew Coombs.

"Their movements look so effortless," said Coombs at one point.

"It's nearly weightless up there, isn't it?" said Ross.

Redding nodded. "What's the gee, Will?"

Will Elliott frowned. "Less than a ten thousandth of a gravity. They weigh less half an ounce; so little, I doubt they'd notice it."

"Amazing," said Coombs. "And what's the value of this mission?"

"First of all, national pride," said Redding. "No one has sent a mission out so far. This asteroid's orbit never crosses the Earth's; at one point it had a near encounter with Venus and now it stays within the Earth's orbit. So they are sending a mission into 'deep' interplanetary space and not to something that comes past Earth periodically. They're using their own

equipment, too, even though the mission cost ten times as much. They're gaining experience with exploration of an asteroid, which can be difficult in zero-gee."

"And it's nickel-iron," added Will. "It masses maybe 20 million tonnes, so no one is going to move it to lunar orbit. But it has several thousand tonnes of platinum and related metals, which are worth more per ounce than gold. If they could be extracted, they'd be worth billions."

"But no one knows how to do that?" asked the Vice President.

"Small-scale experimental equipment has been tested on meteoritic nickel-iron on the moon," replied Will. "Nothing profitable has been developed yet." He pointed. "That cosmonaut there, on the right? That's my friend Sergei Alievitch Landsberg. We were on Northstar 5 together. He was also on Northstar 1. He ran the nickel-iron experiments at Peary when I was there."

"It sounds like we should be encouraging American mining companies to go to asteroids, rather than sending astronauts on an *international* mission to Mars." The Vice President emphasized the word negatively

"Well, we're committed now," replied Ross.

"We couldn't postpone Columbus 1 by a year and squeeze in an asteroid mission?"

Ross tried not to look worried. "A year wouldn't be possible because you can launch to Mars only once every 26 months. The *Pavonis* is three months along and will arrive there in six months. We can't leave it on the surface by itself too long. We need to launch the crew during the mid 2035 launch window."

"But an additional asteroid mission would cost only about a hundred million, including everything," said Redding. "It could be planned for 2036."

“But where would we get 100 million?” mused Coombs. That startled Will, because multi-billion dollar missions used to be standard. He saw Will’s surprise and shrugged. “Social services and the Department of Defense need more money than our total tax revenue. There’s no money for anything else.”

“I know,” said Will, with a nod.

The three cosmonauts began to approach the camera, which was on their capsule. “Are they finished?” asked Ross.

“Yes; they’ve been outside seven hours,” replied Will. “That was enough time to float all the way around the asteroid several times and examine the entire surface once; its surface area is 5 hectares or about 12 acres. They’ll be there for ten days. They plan to set up a scientific package, take extensive samples, experiment drilling into the asteroid, ‘thump’ it seismically, study its interior with ground penetrating radar, etc. By the time they’re finished, we’ll know 2028 BT12 in great detail.”

“Fascinating,” said Vice President Coombs, though he didn’t sound fascinated. “I need to get to my next appointment, I’m afraid. But before I leave: Dr. Elliott, how are the plans for Northstar 13’s science going?”

“Quite well,” replied Will, wondering whether Northstar 14 would come up; he hoped not. “They’re installing a new, larger, carbonaceous chondrite ‘cooker’ to extract carbon and make methane in order to use up more of the excess oxygen production. As a result, one major scientific objective is to visit every potential source of carbonaceous chondrite within sixty kilometers of Peary—we have pretty good orbital spectrometry—to assess their potential, and to haul fifty to one hundred tonnes of carbonaceous chondrite to the station for processing into about ten tonnes of methane. They are also planning three long distance expeditions to areas

known to have many rilles, in an attempt to find and even enter some other lava tubes, especially at the Rimae Printz region."

"Fascinating. I hope we find additional sites of potential mineral extraction. What about Northstars 14 and 15?"

"As we have been requested, we have begun to prepare geological objectives for the next two missions, one connected with Marius and one independent of it. One can justify either scientifically; the moon still has over 75 sites of 'high interest' and they're all potentially significant. What one cannot do—from a strictly scientific point of view—is to argue against a geological expedition to the Marius Hills if a Northstar project partner has equipment they wish to set up there. If they are going there, what would be the scientific logic of refusing them surface exploration support? Also, if a partner insists on including a certain expedition in a certain mission, I can't think of a scientific reason to object, unless they were proposing to go to a site of no known geological interest. Does that make sense, sir?"

Coombs nodded. "Yes, it does. I appreciate the clarity of your argument, Dr. Elliott, and your insistence on separating science and politics. And in this case, the European Space Agency has already made a strong political and diplomatic argument for Northstar 14 to return to Marius, and the Administration has accepted it."

"So, Northstar 14 will indeed return to Marius?"

"Yes, it will. The non-Marius expeditions can be assigned to Northstar 15."

"Excellent, Mr. Vice President, that is a great relief."

"It shouldn't be such a relief! You're doing your job, and apparently pretty well." He looked at Redding and Ross. "Thank you, gentlemen, for the tour of Lunar and Mars Command. It's very impressive. Best wishes for your continued success. The President himself has asked me

to thank you for all your services to the country." The Vice President rose, so they all stood as well. They shook hands with him and Ross escorted him out of Mission Control.

"What a relief!" Will said to Redding, as they both headed back to their offices.

"Yes, and he's right; you shouldn't have said so! The Europeans are determined and there's no reason for us to oppose; just remind them to keep their commitments to Peary."

"Antarctica is covered with several dozen stations, not one. The same will happen to the moon, eventually."

"The Vice President knows that. He took our justification of the extension of the Marius Mission pretty well, too."

"That was two months ago. He didn't bring it up at all; it was as if he had forgotten."

"I think he said why: the Europeans leaned on NASA, and we don't have the money to ignore them. Right now, the Russians and the Indians have the most flexibility in space exploration. Everyone else is struggling with high social safety net costs." Redding waved. "Have a good remainder of the day."

Will nodded and went downstairs to the Mars and Lunar Surface Exploration Department. Everyone had gone back to work; they had been watching the EVA as well. "Do we have the Mons Rümker stops ready?" he asked Bonita Jackson, who had joined the team as a "senior scientist" now that she was back from Northstar 12.

"Five out of six. We'll have the sixth one ready for the website tomorrow."

"Good, because it looks like we'll need it. We have clearance to focus Northstar 14 on Marius. Vice President Coombs himself just told us."

"Great! I'd stay to finish it up now, but I have to get to day care in 45 minutes to pick up Zak."

"I bet he's glad to have mom back."

"You know it! I can't go away for six months again for a *long* time. Mike has made that very clear; he's done with being Mr. Mom. But he did a good job."

"I'm glad. I'm impressed that you made the commitment and I'm glad it worked out. And I'm really glad you're on board here, Bonita."

"Thanks, Will, this looks like a great opportunity to keep my hand in while my son grows older."

"Good. Have a good evening. We'll need the sixth stop ready tomorrow, since the Northstar 14 crew stops by the day after, but don't force yourself to finish it tonight."

"Alright. Thanks." She nodded and Will headed into his office. There was a lot to do, to get ready for the visit of the Northstar 14 crew, but first he wanted to email Sergei Landsberg. He pulled up his email account and dictated a message:

Congratulations, Sergei, on a very successful EVA! And congratulations to the rest of the crew as well, from me and from all of us in Mars and Lunar Surface Exploration. We devoted the entire day to watching very closely, in case we need to provide support for a mission to an asteroid someday. You obviously trained extensively; your maneuverings around 2028 BT12 looked effortless. The amount of non-metallic regolith on the body is surprising and good news for missions to similar bodies that might need hydrogen and oxygen. The mission is also further proof that interplanetary missions can be conducted safely and effectively. It's a great day for space exploration. Will.

He hit send, wondering how long it would take for the message to get to Sergei, who was one light minute away from Earth. He turned back to his messages and was surprised when Sergei responded in less than five minutes.

Thanks, Will. We are thrilled up here. I'm glad it looked effortless, because it wasn't! The magnetic boots were not very helpful; we had to rub our boots back and forth to clear a spot where the magnets could get a grip, and when we turned them off, magnetic bits of regolith clung to them anyway and got in the way later. The regolith isn't really deep enough to be useful. Someone calculated that 2028 BT12 has a thousand tonnes of stony and chondritic debris draping its surface, but it's never more than a centimeter thick. It's not like we can scoop it up with a shovel and drop it into an oven to cook out the volatiles! In the next few days, we'll try various systems for obtaining them. Maybe one of them will be reasonably effective. We were hoping this would help us prepare for Phobos and Deimos, but the analog has proved inexact, shall we say. Keep in touch. Bye.

"It's very good to meet you, Dr. Rodchenko," said Will, shaking Halyna Rodchenko's hand. "I'm sorry I never met you last year in Moscow."

"I'm a Ukrainian cosmonaut, not Russian," she replied, a note of offense in her voice.

"Yes, I know that, but the conference in Star City last year included about a hundred astronauts, including almost everyone who had gone to the moon or who planned to do so soon."

"Correct, Dr. Elliott, but I didn't attend. Ukrainian-Russian relations go up and down; at that time they were frosty."

"I'm sorry that was the case; it was a very important and useful gathering. And now you are to be the first Ukrainian commander of Peary."

"I will be the first Ukrainian on the moon." She smiled at that. "Allow me to introduce my colleagues. This is just the geology team of Northstar 14; there will be 18 of us, as I am sure you know, but six of will be the core of the geology team. Certainly, you know Teresa Dos

Santos, who was on Northstar 5 with you, and Dharmapala Peres, who is part of the NASA Astronaut Corps." Will smiled and nodded to both; Dharmapala, of Sri Lankan background, had just completed a Ph.D. in lunar geology and had joined the corps a year earlier. "This is Emily Scoville, a British lunar geologist. Paul Renfrew's from Canada and is ranger and life support systems specialist, but has also studied lunar geology. And Hiroko Sato, from Japan, is a volcanologist."

Will shook hands with all of them. "I'm very pleased to meet all of you. I've seen Dr. Sato's work on lunar volcanic domes, but I've never met him, so that's a distinct pleasure. I am pleased to see such a diverse team, and such a young team; I judge half of you are close to thirty, perhaps less. This new frontier is attracting a new generation of astronauts; that's a delight to see. Allow me to introduce Bonita Jackson, who was a member of Northstar 12 and is now working here on lunar surface geology. She was at Marius."

"Pleased to meet all of you," said Bonita.

"Yes, I remember hearing your voice," said Rodchenko, shaking Bonita's hand. Bonita went around the circle, shaking hands with everyone.

"I'm glad you were at Marius; you understand its importance," added Emily Scoville.

"Yes, we are very concerned that the exploration plans for Northstar 14 focus on the Marius Hills," exclaimed Rodchenko. "We fear politics will interfere with science and development of the moon."

"I assure you that those are my fears as well," said Will. He pointed to the chairs around the conference table. "Please, sit down." He sat and the others did the same, nervously. "I have been a strong advocate of the development of the human presence in the Marius region. Northstar 12's expedition not only explored Skylight Tunnel, but located two other buried lava

tubes via ground penetrating radar. Drilling into them and gaining eventual access to any lava tubes with volatiles and minerals is a high priority for lunar exploration and development. I have said that repeatedly and forcefully to people as high up as the Vice President himself. I suspect my comments were partially ineffective. However, ESA's representatives have more clout than I. The Vice President was here two days ago and said that Marius Hills could be the priority for Northstar 14."

"Really?" exclaimed Rodchenko. "We had no idea."

"Perhaps NASA hasn't communicated the concession to ESA. But we assume you prefer to plan a series of missions around the 'theme' of volcanology and the Marius Hills in particular, right? Because the other 'theme,' which will be the focus of Northstar 15, is impact melts."

"No, Northstar 14 wants volcanology," replied Hiroko Sato.

"Good," said Will. "So does Lunar Surface Exploration. We want to propose four expeditions to you. Bonita has helped complete the work on them, so I'll turn the floor over to her."

"Thanks, Will." She turned on a Powerpoint. "This plan is based partly on the cargo flights scheduled for September and March. The September cargo manifest includes two automated propellant making units and a truck; March has another propellant making unit and ten tonnes destined for Marius, which will include an inflatable shelter and related life support equipment. We are proposing a total of four expeditions.

"The first one is the only one that has to come first; the others can be in any order. It sets out on January 31 with the truck, ten tonnes of hydrogen and oxygen, and the two propellant manufacturing units. It heads down the Aristarchus Trail, setting up the propellant manufacturing units at 70 and 50 north; roughly 700 kilometers apart. It would stop at Harpalus—a fresh

crater—then continue on south to Mons Rümker, a very important volcanic complex another 300 kilometers to the south. We'd recommend a five to seven-day stop at Rümker; there has already been one stop there, but it was quite brief. The expedition would then continue south to Gruithuisen, which has not been visited at all. It is a complex of three volcanic domes, most likely of felsic magmas, perhaps some of the most felsic magmas the moon has produced. It would get another five days, and then the expedition would turn around and drive back to Peary, leaving behind every bit of water and propellant possible at the two propellant manufacturing units."

"Why would we go to Gruithuizen, instead of pressing on to Marius?" asked Rodchenko, suspiciously.

"Because you would need at least two days to get to Marius, when you got there you'd have only a few days of daylight left, and then you'd have to turn around and drive all the way back to Peary. It's not scientifically efficient," replied Bonita.

"Gruithuizen's very important," agreed Sato. "It would be good to sample it."

"Rümker, Guithuizen, Aristarchus, and Marius are all roughly on a north-south line," added Will. "It's almost as if the moon had a tectonic spreading axis for a while; indeed, that has been proposed as an explanation for them. They need to be studied together."

"Anyway, that's the first expedition," said Bonita. "And will keep you occupied until late February. Then the second cargo flight arrives. It may be easiest to land it at Marius to unload the large items and drive the consumables to Peary later by truck, or land at Peary, unload the consumables, and fly them to Marius. A flight to Marius is the second expedition and will take at least a month. The third expedition would be Marius-based and would go north to Aristarchus and Gruithuizen with the third propellant manufacturing unit. It would probably meet an

automated truck coming south with water. It would be a two-week mission. The fourth mission would be another expedition to the Marius Hills, probably to explore lava tubes and rilles."

"Four personnel or six?" asked Rodchenko.

"Two rangers and a portahab," replied Will. "We can't spare Peary's third ranger. You could go with five, though."

"I see."

"So, the engineering objectives of Northstar 14 would be two: setting up Marius and the Aristarchus Trail," summarized Paul Renfrew. "And the scientific objectives would also be two: exploring the volcanic features of northern Oceanus Procellarum and the Marius Hills."

"Sounds like a way to reduce America's embarrassment!" objected Rodchenko. "And why do we need three propellant manufacturing units? Didn't you use just two, when Northstar 2 cleared the Aristarchus trail?"

"We have to maximize scientific rationales for exploring the moon; otherwise nationalistic and political rationales will dominate and cooperation will collapse," replied Will. "There are three propellant manufacturing systems because the ESA decided to deploy three, not two. We deployed two when we cleared the Aristarchus Trail because we were present to repair the units if we had to, or manually refuel if the automated systems failed. ESA wants three because if one of them fails, an automated truck can drive to the next one; most vehicles have a 1,500 kilometer range and the refueling stations will average 700 kilometers apart. So that explains the two engineering objectives. As for the two scientific objectives, there's no reason to focus solely on Marius. There will be a station at Marius, after all; they'll be focusing on Marius plenty. If you're going to work all along the Aristarchus Trail, do science all along it as well while you go."

“I particularly like the idea of going to Gruithuisen,” said Dharmapala Peres. “But it strikes me as rather far to the east for the Aristarchus Trail.”

That caused Rodchenko to frown. “It is too far east,” agreed Will. “The Aristarchus Trail passes almost 200 kilometers west of Gruithuisen. But it is one of the most important geological stops on the moon that is still unvisited and it needs to be visited. We want it included in Northstar 14.”

“It would be an important addition,” agreed Hiroko Sato. He looked at Dharmapala Peres, who nodded as well. Rodchenko didn’t seem impressed by Peres’s endorsement; he was an American.

So, Northstar 14 will be the Northern Oceanus Procellarum/Marius Hills mission,” summarized Paul Renfrew.

“No. it’s the Marius Hills mission!” replied Rodchenko.

Will raised his finger. “I think Paul’s right. That’s true scientifically and from the point of view of engineering. And there’s one other rationale to consider, along with the scientific: it’s the principle of unity and collaboration. Calling it the Procellarum-Marius mission will reduce America’s embarrassment. I’ve argued that the proper role of America should be to support ESA’s plans, as long as ESA continues to meet its obligations to Peary. That way, everyone wins. ESA is continuing its support of Peary and America is supporting Marius. Let’s encourage and strengthen that collaboration with the name of the mission.”

“Yes,” agreed Paul. Hiroko nodded.

“I suppose,” said Halyna Rodchenko. “At any rate, you make a good point about science. We’ll make expeditions to Gruithuizen and Rümker. Once there’s a Marius Station, a mission to

Marius won't be special or noteworthy. We're better off broadening our mission and serving as the foundation of a broader effort."

Will nodded. "Enlightened self-interest; that's not a bad principle, too."

"It's America's self-interest, too!" Rodchenko responded.

"It is. So, when shall we schedule a review of the four expeditions?"

Rodchenko pulled out her smart phone and opened her calendar. "I think we can devote all day Thursday to the review."

Will looked at Bonita, who nodded. "Good; Thursday it is. You may want to come back on Friday. Northstar 13's team arrives at Rimae Printz that day, and on Saturday they plan to attempt an entry into the 'High Meadows' lava tube. We're pretty sure they can walk right in because it's a much smaller lava tube than the Marius Skylight Tube, and it isn't buried very deeply."

"We're free on Saturday," replied Rodchenko. "So I am sure some of us would enjoy that. "Right now, we need to go up to the conference room in the Training Department to meet with several staffers."

"Then thanks for coming. We'll see you Thursday."

"Thank you, Dr. Elliott. I think this visit worked out well for everyone."

Will smiled at that. He walked with the Northstar 14 geologists to the door out of the Mars and Lunar Surface Exploration Department, then headed back in.

"She's tough," said Bonita. "But I'm surprised you mollified her, and even engineered that compromise over the name of the mission."

“That was fortunate,” replied Will. “When Rodchenko said they hadn’t been told that NASA had approved a Marius-focused mission, that got me worried; that possibly Vice President Coombs had been overridden, or that the matter was being reconsidered.”

“You were the one who told me to include Gruithuizen, even though it’s 200 kilometers out of the way. Weren’t you already thinking in terms of a Procellarum-Marius mission?”

“I suppose I was, but it wasn’t organized that way in my mind. Paul Renfrew’s the one who came up with the term, and Rodchenko’s the one who realized it was a better choice for Northstar 14 than a solitary focus on Marius.”

“But Renfrew wouldn’t have come up with the term if the Powerpoint hadn’t been set up that way, and that was your idea, too.”

Will chuckled. “That’s true. Perhaps I was looking instinctively for a compromise. Like I said, after science, the principle of unity and collaboration needs to be uppermost.”

15.

Tranquility Tube 3

December 2033

It was indeed seven minutes of terror.

As the *Pavonis* hit the outer wisps of Martian atmosphere, Will glanced at the time: 04:21:10 Universal Time. In seven minutes they'd know whether it landed safely or not. But that night Mars was ten light minutes away. The *Pavonis* was already safely on the Martian surface or was a heap of smoking debris.

The vehicle was streaking through the Martian sky at five kilometers per second, but was a mere 120 kilometers above the surface. Will could do the math: 120/5 = 24 seconds. Of course, the calculation was misleading; the *Pavonis* was mostly moving horizontally, not vertically. But the calculation was disconcerting anyway.

The calculation remained disconcerting for three minutes, as the *Pavonis* lost altitude and velocity, but always seemed to remain seconds from the surface. Then the vehicle's altitude began to rise; as it approached the surface at 3 kilometers per second, the greater lift in the thicker air actually increased its altitude. It essentially bounced off the Martian atmosphere, rose back to sixty kilometers, then headed back down, and this time it *was* falling almost vertically, and accelerating.

"This is part of the flight profile," Will mumbled to the other members in the Martian and Lunar Surface Exploration Department. They were all seated in their central area, watching the video feed from Mission Control upstairs.

"When do the retros come on?" asked Charlie Vickers, nervously. He had come down from Brown University, where he was now a first year graduate student, to watch the landing.

"Any minute, I think," replied Will.

Almost on cue, the Gryphon's eight powerful Mustang-2 sidewall engines came on, blasting out flames fifty meters long downward and slightly to the side, so that the *Pavonis* wouldn't fly into its own exhaust at supersonic speeds. The velocity dropped fast as the vehicle slowed at three gees, but the altitude dropped fast as well; the gryphon was now falling like a rock in Martian gravity, the atmosphere too thin to rub off much more speed. Its five landing legs extended and locked into place and the *Pavonis* hovered briefly above the surface, then settled onto the ground, in the very center of the landing circle cleared for it.

The ranger, a hundred meters away, trained its cameras on the descending vehicle, while the *Pavonis's* own cameras provided live video from several other angles. The large screen split four ways to show the landing from the different angles. When the *Pavonis* touched down and its engines automatically shut down, everyone emitted a shout for joy and began to clap. Will leaped into the air, shook Charlie's hand, and hugged Bonita.

"We have a perfect landing at Aurorae Valley, Mars," reported Greg Sandusky in Mission Control. They could hear shouting and cheering around him.

"It made it!" said Will. "We have a man-rated space vehicle on the planet Mars!"

"It's amazing to think!" added Bonita.

"And humans follow in a year and a half!" said Charlie.

The dust cloud kicked up by the landing was beginning to clear and the ranger's camera began to offer an unobstructed view of the vehicle in the early morning sunlight. It gleamed silver, with a fanciful image of a gryphon splashed across its base and the word "Pavonis" written above. The vehicle was streaked with soot marks from the heat of entry, but it had landed

fine. In the distance, they could see hippogryph 1, landed 26 months earlier, and hippogryph 2, which had set down two days before.

"How much supplies do they have?" asked Bonita, pointing.

"Fifteen tonnes each," replied Will. "The first hippo landed with the ranger, 3 Prospector-450s, the drill, 10 kilometers of wire, 3 tonnes of solar panels, a tonne of hydrogen, a sunwing, and a tonne of miscellaneous equipment. Hippo 2, which landed two days ago, brought the 10-tonne hab, a tonne of hydrogen, 1 tonne of equipment, and 3 tonnes of solar panels. The *Pavonis* has 2 tonnes of hydrogen, 4 tonnes of solar panels, 2 two-person buggies, and 3 tonnes of equipment and spares."

"And since the *Pavonis* can make all the fuel it needs to get to orbit, the methane and oxygen in the hippos is useful surplus," added Charlie.

"And Columbus 1 will arrive with two gryphons?" asked Bonita.

Will nodded. "Each can transport six in an emergency, but normally will carry three. The *Pavonis* provides one emergency vehicle for launch to orbit, plus ten tonnes of cargo. So we now have 40 tonnes of cargo on the Martian surface."

"That's quite a lot, for an 18 month mission," said Bonita.

"And Columbus 1 arrives with two more hippos," added Charlie, excitedly. "Fifty tonnes more, including the cargo on the two gryphons."

Sensing his enthusiasm, Will turned to Charlie. "So, do you want to go to Mars?"

"Oh, definitely! I'm taking every course on Martian and lunar geology that Brown has!"

"Good! Get good grades, and I bet you'll get into the Astronaut Corps. They're looking for young people with specialized skills."

"Will you recommend me, then?"

"Absolutely."

Charlie paused. "Do *you* want to go to Mars?"

Will smiled, then nodded. "Yes, I do, and the landing makes me even more excited about the possibility. I plan to apply before the deadline."

"It's December 31."

"I know."

Bonita looked at them both. "I can't go on a two-year trip for a decade, with a small child, but maybe I'll apply later. Charlie, too bad you can't apply for Columbus 1."

Charlie shook his head. "No, I'll have to wait until at least Columbus 3 or 4; I've got to get my Ph.D. and get into the Corps first! A lot of work to do!"

"That's for sure," said Will.

"The *Pavonis* has shut down its propulsion system and issued an all clear signal," announced Greg Sandusky, up in Mission Control. "That should trigger the ranger's program sequence."

Will pointed to the screen. "Let's see."

The others in the room nodded and turned to the view screen. The image on one of the screens was moving; the ranger was indeed moving in under its own robotic software. It approached to within ten meters and circled the gryphon to photograph it from all sides. "The *Pavonis* landed only two meters from its intended landing spot," reported Sandusky. "It is oriented toward the east and is just 2 degrees from the intended orientation."

"Great; that means the solar panels can be extended as planned, because all the rocks have been bulldozed away by the ranger," said Will. "The *Pavonis* should open its power arrays next; watch."

A minute or two later, four doors opened in the base of the gryphon, 90 degrees from each other. A large pillow began to inflate inside each door as Martian air was pumped into it. Each rolled outward and fell a meter and a half to the ground with a rolled up solar array on top, bouncing when it struck and cushioning the roll. Then the four rolls, responding to compressed air, began to unroll as well, slowly and steadily. When they reached their full length, the air pressure began to overflow into other inflatable ribs and the array unfolded further, until the one-meter wide roll became an array lying on the ground, twenty-five meters long and three meters wide.

The process took half an hour; they watched patiently. The ranger didn't have to do anything because an air pump was sufficient to open the arrays. Finally, Will summed it up. "Each array has 75 square meters of area and is 35% efficient in converting sunlight to electricity. When the sun is overhead, each array can make 12 kilowatts of power; about 100 kilowatt-hours per sol or Martian day if there's no dust on the panels or in the air. The vehicle has four arrays, so ideally it can produce 400 kilowatt hours of power per sol. It takes 3,500 kilowatt-hours to make a tonne of methane and oxygen propellant from liquid hydrogen and Martian air, so the *Pavonis* can make a tonne of fuel in about nine sols. It needs 30 tonnes to reach low Martian orbit, so that takes about a year, if the atmosphere is fairly dust free."

"And the ranger can connect the various solar arrays together?" asked Bonita.

"Yes, it'll pull a power cable between them and plug them together. With the *Pavonis*. Aurorae's peak solar power production is now 108 kilowatts, which is pretty impressive."

"So, what's next?"

"Exactly what you mentioned: connecting the two hippos and the *Pavonis* together electrically. After that, we'll try to extract the hab from the cargo bay, place it, and inflate it. The

software is not very good for that task, though, so the hab may have to wait for humans to arrive."

"I see there's quite a long list of places to visit, over the next two years."

"Yes, and we have a lot of flexibility because the Prospectors can drive onto the ranger's trailer and it can haul them somewhere quickly—it has excellent obstacle avoidance software—then the Prospectors can drive off the trailer and move around an area, and they can always return to the ranger to recharge their batteries if they drain their power faster than their arrays can recharge them. The ranger can carry two tonnes of methane and oxygen and it can always return to the hippos to recycle its water and refill its tanks. So we can mount some pretty sophisticated expeditions from here, without any astronauts on the surface. Once astronauts arrive, they'll have a hundred kilos of samples to analyze and date."

"How far will the ranger venture?" asked Charlie.

"I doubt we'll drive it more than 20 or 30 kilometers, because there's a lot to see in that distance, and the TROVs can work only a tenth as fast as humans can. We'll explore the base of the escarpment and maybe visit Tower Rock, twenty kilometers to the east. That'll keep the team here quite occupied until Columbus 1 arrives in thirteen months."

"How are things at Aurorae?"

Startled, Will turned around; it was Zeke Swift! "Quite well, Dr. Swift! I apologize I didn't hear or see you coming. Dr. Seth Cooper is about to enter Tranquility Lava Tube #3."

"Oh?" Swift turned to the big screen on the wall. He saw Cooper, the Commander of Northstar 13, and two of his three companions—the image was coming from the camera on the

helmet of the fourth astronaut—standing outside a rubble-filled tunnel entrance in the side of a crater. “Can they actually get inside?”

“They’ve stuck a ten meter boom in with a camera on the end. The cratering event filled the lava tube with rubble, but there is a passageway about four meters high on the right side. We’re verifying the integrity of the roof right now.” Will pointed to another image on the upper right-hand screen where a close-up of the cave’s roof was visible. Will activated his microphone. “So, Coop, what do you think?”

“We hit it with a sledge hammer and nothing fell!” replied Seth Cooper. “There are a lot of cracks, and a lot of stuff has fallen in the past. But the roof has stood through moonquakes for how long; twenty-six million years?”

“That’s the estimate,” confirmed Bonita, who had taken over the main communication while Will was talking to Zeke.

“It looks fine, so we’re going in,” said Coop.

“Acknowledged,” replied Will, with a shrug. He turned to Swift. “A camera image can’t tell you that much; the guys there can see a lot more. And on Mars, surface exploration support in Houston can’t help much.”

“True. How many lava tubes on Mars?”

“Thousands, most likely! We’re aware of over a dozen skylights and several dozen partially collapsed tubes. But we don’t know of any near Aurorae.”

“A shame; perhaps we should have considered other landing sites.” He turned to the main screen; Coop was leading his team into the tube. The pile of rubble reached the roof in spots, but he turned to move between two heaps. He had to get down on his knees and crawl through; the cameraman caught the whole thing. The image shifted to Coop’s helmet. He stood up and made a

slow 360 degree turn, his helmet lights brightly illuminating the tunnel. He walked down the debris pile as his three companions came through; the tunnel was only twenty meters across and high. “It’s smaller than Skylight Tunnel, Marius,” observed Zeke.

Will nodded and muted his microphone. “Marius is one of the larger ones on the moon. We’re aware of a skylight 100 meters across and ground penetrating radar has detected a tube 250 meters in diameter in Mare Serenitatis, but it doesn’t have a skylight. The really big ones collapse and become rilles unless they have thick roofs, and if they have thick roofs, it’s a long way down, and they’re hard to enter! Northstar 13 has entered four tubes and explored two others remotely, and they’ve all been smaller than Marius Skylight.”

“And what have they found?”

“Small quantities of minerals, mostly calcite and some iron minerals. The surface of the moon doesn’t have a lot of rock outcrops; they tend to get pounded by meteorites over time. The few outcrops we have seen do have some minerals, also, but the tubes had temporary atmospheres and water, so they tend to be more mineralized.”

“Economic deposits?”

“Nothing by terrestrial standards, and probably nothing that can be mined and exported to low Earth orbit, not soon anyway. But if we ever start to manufacture items on the moon, importation of raw materials will be quite expensive, and in that economic environment there may be a basis for mining. What we really need to do is enter lava tubes that have never been breached. Their ambient temperatures are a constant minus 20 Celsius at the equator, colder in higher latitudes. They could contain ice.”

“Oh, and what’s that?” asked Zeke, noting that the main screen was now focused on a mineral vein in the tube’s wall. They listened to the banter for a moment.

“Calcite,” confirmed Will, repeating Coop’s conclusion. “That’s pretty common. But calcium carbonate has carbon and oxygen, so it’s potentially useful. We also find some hydrated minerals, like the stuff coating the floor and walls of Marius Skylight Tube. Northstar 14 will bring equipment to extract water and other volatiles from it and we’ll see whether it’s useful.”

The astronauts were moving again down the tube; their power and communications cable could be see dangling from the belt of one astronaut and slowly unreeling. The floor was lightly rubbled with small bits of rock that had ricocheted off the walls after the cratering event; otherwise it was a rough surface of solidified lava. The walls and ceiling were similarly irregular. “A typical lava tube,” said Will. “They’ve got two kilometers of cable, if the tube proves to be that long.”

“I probably should return another time to ask about Mars,” said Zeke. “Thank you for all you do, Dr. Elliott.”

“You’re very kind, but Bonita can coordinate our support for a few minutes. Let me lead you over to the Aurorae TROV controls.” He pointed to the left and they walked a few steps to three cubicles just a few meters away. Two men sat there, watched and waiting to speak. “This is Roger Anderson and Jerry McCord,” said Will. “I suppose you’ve all met already; Roger was commander of Northstar 6 and Jerry commanded Northstars 2 and 12.”

“Yes, indeed, we have met. It’s good to see you gentlemen again.” He shook hands with both.

“It’s so good to see you again, Dr. Swift,” said Jerry.

“So, you gentlemen are driving TROVs?”

“Familiarizing ourselves with the Martian surface,” replied Roger. “Both of us have applied for Columbus 1.”

"As has Will," note Jerry.

"Ah, of course. That makes sense; the more experience you have, the better."

"The trick will be hold onto them after the applications are submitted on December 31," said Will. "I can't tell you how grateful we are to have experienced planetary geologists in here, helping!"

"I'm sure there will be a steady stream of volunteers who want to apply for future Mars missions," said Jerry.

"I hope so," replied Will. "But to respond your question, Dr. Swift, we extracted the buggy from the cargo bay of the *Pavonis* right away—two weeks ago—and fueled it up. It has a manipulator arm, so it was able to extend a power cable from hippogryph 1 to hippo 2 and then to the *Pavonis*, thereby creating the outpost's incipient power grid. Hippo 1's power is now going to the other two vehicles to convert their hydrogen into methane and oxygen. As expected, we were not able to extract the hab from hippo 2's cargo bay; it needs to await the arrival of astronauts who can time the movement of everything live. Five days ago the ranger drove to the escarpment with the three TROVs and they're exploring there."

"That's what we're running," said Jerry, pointing to his screen, which showed the rubble pile at the base of the escarpment. A boulder was just centimeters from the camera.

"And how much can you do?"

"We have fuel cell power as well as solar arrays, so we can do a lot more than the old rovers," replied Jerry. "We can get refueled by the ranger any time. The two of us are moving all three TROVs as a partnership. We can explore about fifty meters a day."

"Pretty good. And what's the status of the drill?"

Will shook his head. “It’s stuck, just like the drills on Phobos. In about three months, an updated drill will be used at Marius to drill into the northern lava tube. If it works better, new parts will be on Columbus 1 to upgrade the drills.”

“That has proved frustrating. If we could have drilled down and hit water, maybe Columbus 1 could have flown to Mars with less hydrogen.”

“There’s a good chance Columbus 2 will be able to rely on Martian water,” replied Will. “At the equator, you have to drill down pretty far to hit the ice table.”

“Sounds like everything is on schedule, then,” said Swift. “And Northstar has worked out very well. I had never planned to be involved in the return to the moon, but it has proved very useful for Project Columbus.”

“Next year, Northstar 15 will include three manufacturing experts who will see whether they can manufacture some of the parts of a radio telescope from nickel-iron,” said Will. “If they can set up a system, a very large radio telescope could be built in a far side crater in the next few years. An infrared telescope will be set up in Whipple crater in 2036 and if it proves successful, a much larger instrument will be designed for launch in 2040. A large optical telescope is in the design phase as well.”

“Yes, servicing is much easier at Peary than in space,” said Zeke. “The moon has some pretty amazing advantages.”

“If I may ask, do we know which nation will be providing the sixth astronaut for Columbus 1?” asked Roger.

Zeke nodded. “Japan. The US will supply 2, the Europeans 2, and the Russians 1. Qatar offered a billion dollars for a seat, but NASA said no. The Japanese are looking to expand their presence at Peary and may even consider a separate lunar station. Their Sunfire solar thermal

engine has immense potential, too; Thunderbirds can launch liquid hydrogen into orbit cheaply enough. The Sunfire can move cargo to low lunar orbit using less than half as much propellant as a chemical stage, which will save money. So they're making important contributions to space exploration. They've earned a seat."

"Good," said Roger, who was relieved Columbus 1 wouldn't include any Arabs.

Zeke looked at Will. "Say, would it be helpful for the Director of Lunar Surface Exploration to go to Peary to keep up with the facilities there, every few years?"

Will considered the question a moment. "Yes, sometimes it would be. The crew changes every six months and trains here, so we meet the crew and we plan the geological objectives of the trip with them. Most of the time, the crew accepts the geological objectives we propose; they generally are not publishing scientists, but astronauts providing geological information to published scientists. Some are published researchers and have their own research agendas, and we accommodate them as best we can."

"I understand that, but I suppose the Director of Lunar Surface Exploration would benefit from seeing the current state of the shelters, rangers, and the new areas of research like lava tubes."

Will shrugged. "Yes, theoretically, that could be of use."

Zeke smiled. "Good. Because if you're interested, as Director, we can squeeze you in as a thirteenth person. The gryphons have now been rated for up to 14, thanks to our low Earth orbit experience, but for now we're accommodating two crew and ten passengers. The late March tourist flight will stay on the moon an entire month. The June and December flights last only a week and the September tourist flight will involve a two-week stay. We will try different lengths of stays and see how demand varies. If NASA and other governments are willing to set up grant

programs, we could do 6 or even 8 week flights for scientists and engineers with special research projects."

"That's an excellent idea," said Will. "A month-long visit would be useful. I left the moon on June 28, 2031; two and a half years ago."

"Tell Redding you want to go this March and rearrange your schedule. We won't charge NASA anything because the flight is already full. There will be the cost of consumables, but Peary has a lot and you'd only consume a hundred kilos of food while there, a quarter of which is grown there."

Will nodded eagerly. "Alright, that'd be great! Thank you, Dr. Swift."

"It's the least I can do. If I could, I'd extend the same offer to Redding, but he might find the trip harder to justify. Maybe I'll extend the offer to him, anyway. I'd better go and let you get back to work, Dr. Elliott." He looked at the others. "Thank you, all of you, for your incredible work for Northstar and Columbus. I find it very inspiring."

"Thank you, Dr. Swift," replied Roger Anderson.

Swift waved to everyone and walked out of the surface exploration support area. They watched him go, then Roger said to Will, "I'm very jealous! What a fantastic opportunity!"

"It is, and it is very generous of him, considering the cost."

"True," said Jerry, whose eyes and lack of comment suggested he felt a harder jealousy than Roger.

"I'd better get back to Coop's exploration of Tranquility Tube 3," said Will, seeing Jerry's reaction. He had had enough trouble from Jerry in the past without making it worse. He nodded to both men and walked back to the front of the room where the screens showed various scenes of the lava tube.

“They found some stalactites and a bit of pyrite,” reported Bonita, offering a quick update.

Will nodded. “Nothing outstanding.” He looked at the scene and saw great piles of debris on the tube’s floor. “Are they coming up on the site of the 20-meter crater?”

“I think so.”

Will checked the GPS and activated his microphone. “Hey, Coop, check that ceiling carefully. You’re approaching the basement of the 20-meter crater.”

“Acknowledged, Will. I know that. Glad to have you back.”

“Sorry for the diversion.”

Coop and the others turned their headlamps on the ceiling and everyone began to scrutinize the images for cracks and projecting rocks. It was very difficult to be sure of the ceiling’s stability; it always was. Coop and the others retreated a short way and they debated the situation for a few minutes. The tube had been shaken by moonquakes many times over millions of years, so the ceiling was probably safe. Finally, Will gave them permission to proceed cautiously. They delicately climbed over the debris—so as not to create any vibrations—and continued down the tube.

“Look, it’s blocked completely!” said Coop a minute later. He shined his headlamp on the lava tube ahead of him and it showed a wall of loose rock and dust straight ahead.

“Huh.” Will looked at the GPS coordinates and the map. “There is a slight depression on the surface above, but it doesn’t look deep enough to fill the tube. Obviously it is, though. Head back.”

“Acknowledged.” Coop stopped at the base of the rock pile blocking the tube and panned across its surface to make a good picture of it. They picked up few loose pieces of basalt and

dictated descriptions; they were quite ordinary. So they headed back to the opening, 1.5 kilometers away. They left the wire in the tube to provide wireless communications for any future visits.

They climbed back over the debris accumulated in the tube under the 20-meter crater. One of the astronauts slipped and fell on the debris as he descended the pile, scattering rocks across the floor.

There was a muffled sound. “Whoa, rock fall!” exclaimed Coop. He turned his head and the light illuminated a cloud of dust behind them.

“Get out!” exclaimed Will.

The images on the four screens all grew scrambled and bouncy. “We are! We’re running!” replied Coop.

“We’re all here!” added someone else.

“The vibration of the falling astronaut must have been enough to shake something loose!” said Will.

“And there are a few other rocks scattered about; other things have fallen, too!” said Coop. “We’re getting out of here as fast as we can!”

“It’s a long 1-kilometer trek,” said Bonita to Will.

“The worst should be over, now,” replied Will. “Except for the claustrophobia this experience creates!”

“It changes everything,” she added.

He nodded. “It sure does!”

“This is such an impressive building!” exclaimed Taraz Nuri, as they entered the main entrance of the Northstar-Columbus Command Center.

“Actually, it’s pretty cheap,” replied Will. “Swift was given permission to build it on the grounds of Johnson Spaceflight Center and he kept it simple. That’s one of the reasons he has been so successful; he knows when to spend some extra money and when to save it.”

“I guess so,” replied Stephen, looking around. “It’s not too large, for controlling lunar and Martian exploration.”

“It employs only 300 people.” agreed Will. “I’ll walk you past Mission Control, but I can’t take you inside; that requires a special ID badge.” He pointed to the main corridor and led his mother, father, sister, brother in law, and nephew down it. The latter, little Paul, was just three and wanted to run around, so Taraz picked up his son and put him on his shoulders.

They stopped to look through a big set of glass windows at Mission Control. At the time, nothing was happening; a crew of just four people was inside monitoring systems. “There are at least twenty-five in here during a launch, a rendezvous, or some other big event,” said Will. “In four days, Northstar 14 goes up, and this place will be hopping with activity.”

“That’ll be quite exciting,” said Catherine.

“So, you’re going back to the moon in March?” asked Taraz.

Will nodded, “For a month, to check out everything.”

“Are you going down into a lava tube?” asked Catherine.

“I’ll probably go down into the Marius Skylight lava tube; we have an expedition going back there for three weeks right after I arrive. It’s in good shape because it’s buried deeply. Tranquilitatis 3 was small and shallow and had been pounded much more. I don’t think we’ll be sending anyone into shallow lava tubes any time soon!”

“That was so frightening,” said Catherine. “When I heard about the collapse, I thought about you!”

“Lava tubes have advantages and disadvantages, and collapses are the big disadvantage. But they need to be explored for their minerals and their potential for habitation. Marius has a roof fifty meters thick and very little rubble on its floor, after 3.5 billion years of moonquakes. It’s in excellent shape. But that doesn’t mean a five kilo rock can’t fall off the roof and crack your helmet. At least you’re safe from radiation.” Will sighed. “It was really generous of Dr. Swift to give me a ticket.”

“A long way to go for an inspection trip!” said Molly.

Will chuckled. “It is. I’m glad he didn’t offer me a ticket on the January 2d flight; you all would have to cut your visit short!”

“We’re glad to spend the week with you,” said Catherine.

“And I get to meet my nephew!” said Will, smiling at Paul.

They started down the hallway. Will pointed to a large room with cubicles and tables covered with equipment. “This is the Northstar 14 crew area; the people in there are going to the moon next week. They have their own space with their own kitchenette, to encourage them to bond together.”

“You know them all?” asked Taraz.

Will nodded. “Some better than others. Everyone who plans to go out on an expedition has been downstairs to drive Prospector-350 TROVs or has attended classes and seminars on lunar geology. We’ve videotaped a series of lectures and demonstrations, and now we meet with people seminar-style to answer questions and quiz them.”

“And Northstar 14 will have eighteen crew members?” asked Charles.

"Actually, twenty; someone is staying on from Northstar 13 and will be on the moon a solid year, and I'll be counted as a member when I'm there. It's our largest crew yet."

They continued down the hall past another room with two buggies, two rangers, a portahab, several Prospector TROVs, and a Conestoga. Will pointed. "The vehicle room, where you learn to control them and especially to fix them. The really big one is a Conestoga. It hasn't gone to the moon yet; the first one goes up next year. See the big door? They can take the vehicles out for a spin if they want."

"How well do they drive?" asked Taraz.

"Pretty well, but they aren't designed to exceed about 40 miles per hour. It's impossible to go faster than that on the moon anyway."

They continued down the hallway. As they neared the end, a woman came out of the cafeteria. Will was surprised to see her. "Ethel McGregor, what are you doing here!"

"Will Elliott, how are you?" She smiled and offered her hand, but then decided to hug him instead.

"I'm fine. I'm giving a tour to my mother Catherine, my father Charles, my sister Molly, my brother in law Taraz, and my nephew Paul. Ethel and I were on the moon at the same time; she was on Northstars 4 and 6 and I was on Northstars 5 and 6."

"Very pleased to meet all of you," she said. "Will's a great geologist and a marvelous human being. You all should be very proud."

"Oh, we are!" replied Catherine.

Ethel turned back to Will. "Koenraad has had to drop out of Northstar 14; his mother has a fast, terminal cancer. So they've called me up, because I know the equipment he was working on."

"Nickel-iron processing equipment?"

She shook her head. "This is equipment to make plastics from methane and ammonia. It's the last prototype; the next model goes to Peary for use and will be on Columbus 1 as well. It should save a lot of money, since imports from Earth to Mars cost 10 million dollars a tonne. I'll also work on a new carbon extraction system for Peary; it takes carbonaceous chondrite, crushes it into sand-size particles, and subjects it to a stream of hot hydrogen, which reacts with the carbon to make methane and other hydrocarbons. Since the reaction is exothermic, potentially it can produce power for Peary as well."

Charles nodded. Will said, "That's important work. How's Reginald?"

Ethel's face grew sad. "We're getting a divorce, Will. These last two years haven't worked out, and when I put in for Columbus 1 he drew the line; that's two and a half years away, after all. This six-month trip to the moon is a relief, actually."

"I'm so sorry, Ethel."

"Thanks, Will. I know you went through the whole thing before. If you have any advice, I'd welcome it."

"Let's do lunch tomorrow; you know where to find me."

"I'm working in here." She pointed to a lab next to the cafeteria. "It has the plastic synthesis equipment and the three-d printers."

"Okay, I'll look for you there."

"Thanks." She looked at the others. "It's good to meet all of you. Enjoy your tour."

"Thank you," said Charles, with a smile.

Ethel walked down the hall and disappeared into the lab; Will followed her with his eyes, "She's pretty," said Charles.

"Yes, she is. I hope she ends up on Columbus 1. Not just because I like her; she's an absolutely amazing mechanic and engineer. She can fix anything."

"That's what you need, going to Mars," agreed Catherine.

"There are a lot of divorces in the Astronaut Corps, aren't there?" asked Molly.

"Yes," replied Will. "And a lot of sleeping around, not to put the matter delicately. The international crews make things even more complicated, in a way. I can't marry a British astronaut; she can't join our corps and I can't join hers."

"They need to let married couples go to the moon," said Taraz.

"Believe it or not, we don't currently have any couples in the Astronaut Corps," replied Will. "It involves long hours; someone has to stay home with the kids."

"I hope you retire soon, then," said Catherine. "Because you'd make a great father, Will. A great husband, too."

"I hope you're right," replied Will, trying not to be irritated that his mother was repeating herself. "If I go to Mars, I suppose I will retire after I return. Maybe I can get a NASA administration position."

"Go teach at a university," replied Charles. "Much more relaxing, you'd have independence, and it's creative."

"Yes, it's a very attractive option," agreed Will. He sighed. "We'll see what happens."

They started down the hall to the stairs. "I won't show you the top floor; it's just offices and administration. The basement has Mars and Lunar Surface Exploration, the moon shelter—where people can practice maintenance—engineering offices and labs, and a few offices for Project Columbus."

"Where is the equipment for Project Columbus?" asked Taraz.

"You mean, rangers and shelters? The vehicles are the same ones as on the moon, so the Columbus crew will train with the ones you saw. The shelter has a different design, but the life support equipment is the same. The current plan is to have Columbus 1 train on the moon for three to six months, probably at Marius to minimize their radiation exposure."

"I'm curious: why do you want to go to Mars?" asked Taraz.

They had just come out of the stairs at the basement level; Will stopped in the hall and they all stood around him. "There's the thrill of being on the first mission, obviously, and going down in history. I won't pretend that the glory, if you want to call it that, isn't exciting and attractive. But to be one of the first geologists on a new planet; think of the things to discover and describe! You see, the earth and moon are two end members of a spectrum; Mars is right in between, in the middle. When the Earth formed, it was pounded to saturation with craters, just like the moon; one of those impacts threw off a ring of material that formed the moon. So the moon tells us a lot about how the Earth formed. Then Earth acquired an atmosphere, an ocean, cratering continued, and life arose. That phase of Earth history was completely eroded away subsequently and is lost. But it is preserved in different ways in two places. The moon has chunks of Earth that were blasted into space by impacts—terraclasts, we call them—and they give us scattered glimpses into that period. The other place is Mars, where an entire world that had an atmosphere without oxygen, an ocean, and cratering is still available to us to study. Life may have arisen on Mars as well as on Earth; if so, we may be able to study the process there by analyzing the geochemistry preserved in the rocks. In fact, we may be Martians, because life probably arose there first and could have been carried to Earth on Martian meteorites. It's immensely exciting; a crucial part of our story—our history—is preserved in the Martian archive, as it were."

“That is exciting,” agreed Taraz.

“And who knows what it will tell us about ourselves, eventually,” added Charles.

“Yes, exactly. We should not assume it’s just abstract, useless information. It may prove important to human self-understanding.” Will shrugged. ‘We’ll see.”

16.

Return to the Moon

March/April 2034

"Thanks for all the stories, Dr. Elliott," exclaimed Sergio DiPonte, picking up his flight bag. "This flight to the moon was absolutely memorable as a result."

"Definitely," agreed several others.

"Oh, it was a delight," replied Will, who had told every space story he had during the last four days. "I suspect this is the reason Dr. Swift gave me special accommodation on this flight! It was very good to meet all of you."

"I'll definitely encourage my son to consider space flight, though right now he wants to be a banker!" added Sergio, who was the President of an important Italian bank.

"Who knows, I may see him up here, some time," said Will, picking up his own flight bag.

They could hear the docking tunnel scraping against the gryphon's lower deck hatch. A moment later, latches clanked shut around the hatch. There were popping noises as the tunnel pressurized and the air shifted the heavy fabric against minor leaks, sealing them off. A minute later the hatch opened inward and Jerome Lamoreaux appeared. "Welcome to Peary Station, everyone. As you passage through the docking tunnel, you will hear faint hissing sounds at each end from escaping air. This is normal; there is nothing to be afraid of, the tunnel is quite secure. Please watch your steps, as the tunnel has a steep ramp downward to the ground. Please put your flight bags over your shoulders and keep both hands free to hold the railings. Follow me into the portahab." He turned and walked back down the tunnel, followed by the passengers and, finally,

the pilot and copilot. Will and Jerome shook hands and nodded to each other quickly, but had no time to talk.

Once everyone was settled into the portahab, they heard the sounds of an astronaut outside detaching the tunnel and folding it back against the vehicle. Once they had an all clear, the driver pulled away from the gryphon. He circled the cone-shaped space vehicle so that everyone could see it out the windows, then headed to Peary, while Jerome gave everyone a welcome and introduction.

The vehicle circled Peary as well. Will was impressed by how much it had grown. The original cylindrical shelter, 24 meters long and 6 in diameter, had received a second shelter of the same size, then acquired a node with a vehicle docking area on the earthward side, a welcoming lobby, and attachment points for two future inflatables. The round, flying saucer shaped Lunotel was next, extending the station's axis 12 more meters; then a greenhouse was added, at right angles to the axis, to the "far" side facing away from the Earth; then a third shelter was added to the greenhouse; more recently a second, larger greenhouse was added to the third shelter. Altogether, Peary's complex of buildings was now 50 meters long and nearly 40 meters wide. All of them were covered by water bags a meter high to provide protection against radiation, and most had bags of lunar regolith on top of them. Solar panel arrays poked up from a nearby hillock into perpetual sunlight and tracked the sun; a large heat radiator filled a nearby hollow that was in perpetual darkness. Along the approach road from the spaceport was an unpressurized garage for Peary's vehicles and TROVs.

The portahab backed up against a docking port and achieved an automated hard dock. Jerome rose from his seat nearby and opened the hatches. He stepped through and warned everyone to watch their step. As the tourists entered, several members of Northstar 14, including

Commander Halyna Rodchenko, were there to greet everyone and help them find their way to their rooms in the Lunotel module and shelter 3. After Rodchenko finished her welcoming talk, she waved to Will and led him aside.

"Welcome to Peary," she said. "How long has it been?"

"Two and a half years. It's good to see shelter 3, the new greenhouse, and the garage. It's nice to be in lunar gee again, too!"

"It is a rather convenient gravity level; there's enough gravity for soup and coffee, but not too much. You're in shelter 3; the rooms there are a bit larger and more comfortable."

"Many of the tourists are there, too."

"The Lunotel was reconfigured about a year ago to accommodate eight. Jerome, Patrice, the flight crew, and two tourists are in shelter 3. One of my crew is there, too, because he stayed over from Northstar 13." She took Will's flight bag and led him into the old greenhouse, which was now filled with herbs and fruit trees. One corner was filled with flats of strawberries. She pointed. "They're delicious, and now they're being pollinated by butterflies. See that one? The station is way too small to support a bee hive." She led him into the lower level of shelter 3 and across its entire length to the spiral staircase at the end. "As you can see, we're using every square centimeter of space. The basement of shelter 1 is devoted to geology, the basement of shelter 2 to equipment repair and maintenance, and this basement is devoted to in-situ resource utilization. The new greenhouse has a basement as well and it's used for storage. We really need a fourth shelter. Every crew complains about that."

"I know, I've heard it every time, but especially now that we're flying up to eighteen personnel here every six months. I'll reinforce the message."

“Please do. You have the ear even of Swift. I don’t think anyone could have imagined the work on the moon would expand this fast.”

“I doubt it’ll continue.”

“Perhaps you’re right. But if they want Peary to be able to assemble optical and radio telescopes, it’ll have to have a larger facility.”

They climbed the spiral stairs and Will found himself in front of door 322, which was his room. “Come in for a minute, Halyna, so we can talk,” he said. She nodded and followed him into the space.

He gave the cabin a quick glance. The rooms in the old shelter were 2.5 meters deep and 3 wide; his cabin was 2.5 meters by 4, a noticeable improvement. He pulled out the chair at the desk for Halyna and sat on the bed next to his flight bag. “I want to assure you that I am not here on an inspection trip to see how you are doing or to interfere in any way. I’m here to refamiliarize myself with the moon and its facilities and return to Houston with suggestions for future expansion, such as the fourth shelter. I plan to devote four or five hours a day to my Houston duties and the rest to Northstar 14, and I am available to you for work assignments at that time.”

“Thank you, Will. I appreciate your frank words and I will match them with my own frank comments, if I may. While I may be the boss here, in some sense you are the boss of the boss. You are the person who coordinates the overall exploration of the lunar surface, which puts you in a higher position than me. So your presence here puts me in a rather difficult position.”

“I’ll be here only one month out of six. You’ve already been here two months; you are established as the leader, and I have no desire to undermine you. You are doing an excellent job.

I have very high respect for you and your accomplishments. So I do not wish to interfere in any way."

"I appreciate that. But I doubt I can assign you to galley duty or geological support in the lab."

"No, please do both. I enjoy kitchen work, and I need to understand more about the latest generation of analytical instruments here at Peary."

"They've become quite powerful."

"So I gather."

"I wish you weren't going to Marius on Monday. The expedition there will be small, and inevitably you'll dominate the discussion."

Will hesitated. "If there's anything I need to see, it's the lava tubes. We need to send some engineers here to study their structural integrity because the Europeans definitely plan to build in Marius Skylight. Bonita has been very helpful, but when she was in Marius, we weren't asking the right questions. Coop's expedition gave us a lot of new data, some of it frightening. Your expedition to Gruithuisen was immensely helpful; that lava tube was half intact, half collapsed, in numerous segments, and between the photographs, the ground penetrating radar, and the seismology we expect to develop a good idea how to evaluate structural integrity. I'm not an engineer or even a structural geologist, but I can learn and I have to oversee the process, so I need to have some personal experience."

She nodded. "I understand. The new ground penetrating radar system can map cracks quite well."

"Yes, it's impressive. A few small explosions on the surface to do more seismic profiling will help, and detailed photography of the tube's floor afterward, compared to the Northstar 12

imagery, should reveal fallen particles as small as 5 millimeters across. That'll give us a measure of the ceiling's general stability. Drilling into the unopened north tube is very important; it should have a very, very thin argon atmosphere, and its micropressure should tell us how airtight that tube is."

"The possibility that it could contain ice is very important."

"Exactly. And if we can scrape up some of the floor deposit in the Skylight Lava Tube to haul back to Peary, we'll have a lot of material to use in the design of a volatile extraction unit. As you know, Darmstadt wants some of the stuff so they can prepare an analog material for lab use. There are rilles in the Marius area to explore, too. I want to go down for the full two weeks. NASA's worried about the European plans, and maybe I can help calm them."

"That would be good, also." Halyna nodded. "Alright, I can accommodate all that. As for your time here, if you help with the tourists, that might actually be best, because it'll free up the time of my people to do their primary tasks. I'll be sure to schedule you to work on the new geology lab equipment with Dharmapala; he can show you how they work. If you want to do any kitchen work, that's actually outside my purview; you'll have to talk to Jerome."

"Alright." Will offered his hand. "I'm looking forward to working with you, Dr. Rodchenko."

"Thank you." She smiled slightly and they shook hands. "I'll leave you now to settle in. See you at the welcoming dinner tonight."

"I'll see you then."

Will watched her go and wondered why she was so formal; probably because, in a world still dominated by men, it gave her the most respect. He turned to his flight bag, pulled out his

clothes and other items, and put them away. He laid down on the bed to rest, but found he really couldn't; his time on the moon was precious. He rose to walk around the station.

He went into the new greenhouse, which was larger than the old one and had as many as three levels of plants lining a central corridor. He had to be careful walking through the space because the plants brushed against him on both sides; overhead pots dangled peas down on his head. Butterflies flitted around. Different levels and blocks of plants were in darkness as the power was rotated among them.

From the greenhouse, he walked across shelter 3 and then through shelter 2 and 1 along the lower level, then back to the lobby through the upper story. He was about to walk into the Lunotel when Jerome came out of shelter 3. "Will, I was just looking for you to say hello!"

"It's so good to see you again, Jerome!" Will walked over to him to shake hands; Jerome hugged him instead. "It's been a long time."

"It has, but I've enjoyed being in touch with you. How was your flight?"

"Pretty good. The gryphon accommodates 12 people adequately, thanks to the training of the crew. We made a three-day stop at the Pax Hotel, so the tourists had the time to adjust to zero-gee and the space to enjoy it. I hadn't anticipated that delay, but I actually took it as vacation time. Then I was surprised to see that we were pushed to the moon by a Thunderbird-H!"

"Yes, we're not making enough methane. We still don't have the equipment. But we are supplying extra oxygen to low Earth orbit, so many future gryphon flights will use terrestrial methane and lunar oxygen. The stop at Pax has been an excellent addition to the itinerary; the clients are very pleased with it."

"How much time have you spent on the moon, now?"

"I arrived on December 12, 2030 and left on June 28, 2032, after 18 months, so I broke your 16-month record; no offense! I returned here January 2, 2033—two months ago—on a two year contract."

"Two years! You're staying two years?"

"Yes, of course; didn't you hear? I'm in the station just about all the time, so my radiation exposure's okay. And now I'm married, you know, to Patrice Kowalski. Let me introduce you to Patrice."

"Oh, sure!" Jerome pulled on him toward shelter 3, so they went in and up the spiral stairs to Jerome and Patrice's cabin. Patrice was sitting in a chair sending an email; he stood up immediately.

"Patrice, this is my good friend Will Elliott. Will, my new husband, Patrice."

"So pleased to meet you." Will shook Patrice's hand. "I heard that the Lunar Hotel, Inc., had hired a second staffer who was French, but I had no idea the two of you were married."

"Yes, it is very convenient for everyone!" exclaimed Patrice. "No one wants to stay here for more than six or so months because their spouses and families are on Earth. And if you have a husband and wife here, you have to worry about pregnancy; no one dares start a family here, in the low gravity. But two husbands? We're together, we're happy, we share all the work, and we earn a very good salary!"

"I can imagine. You guys are going to be the heart and soul of this place. No one else will be here as long."

"I'm already the veteran," agreed Jerome. "I don't take orders from the Commander. Patrice and I do all the cooking and cleaning for all of Peary Station; the Lunotel has the contract with NASA. So we have our independent responsibilities. When the tourists are here—8 weeks a

year out of 52—we also drive them around and brief them about use of moon suits. So we work 15 hours a day during those weeks, and have a quieter time the rest of the year."

"So, how did this happen, Patrice? I suppose Jerome arranged it?"

Patrice nodded. "We were living together in Paris before he applied to serve as cook and manager of the Lunotel for six months; it was a short contract. But he loved it and extended it, and the company was very happy to have him stay; at that time it would have cost them over $30 million to fly up a replacement! But we missed each other."

"And this place grew," added Jerome. "When it had just six astronauts, the Lunotel, and two half-empty shelters, one cooking and maintenance position was plenty. But 18 astronauts, up to 12 visitors at a time, three shelters, the Lunotel, two producing greenhouses, and a half dozen chickens . . . it really does take two people! The Northstar crew always had to delegate someone to help me. So I said, 'look, I want to marry Patrice, you don't want to lose me, and you need two people up here anyway. He's a prestigious chef and very good with his hands."

"He has me changing the filters," said Patrice.

"So they agreed to hire both of us for a two-year contract," continued Jerome.

"I congratulate both of you; this is a very good arrangement for everyone. And I think it highlights a problem we have with spaceflight: people have to leave their loves behind."

"Definitely!" said Patrice. "If they send a husband and wife up here, they don't have to worry just about an unwanted pregnancy on the moon; they also have to worry about infertility when the couple returns to Earth. If we return to Earth, we can adopt."

"There is always radiation damage to your health, though," said Will.

Jerome nodded. "Especially for me, because when I arrived, this place had less radiation protection. Now, all the shelters have a meter of water, half a meter of ice bags, and another

meter of regolith bags on top." He pointed to the low ceiling of their room. "And we have another meter of water right here over our heads. When we're in here, I figure we get about as much radiation as someone on top of Mount Everest. Not too bad."

"So, if they set up a hotel in the Marius Skylight Lavatube, would you go there?" asked Will.

Jerome shrugged. "It depends on whether it's bigger and involves more responsibility. I am trying to recruit a replacement team for us, so we can spend a year on Earth, then two up here, then a year on Earth again. Maybe I can recruit a management team for the Marius Hotel!"

"These places do need continuity," said Patrice. "From what I have seen and heard so far, that's the biggest problem here. The nations don't know what they want here and don't want to spend money. The price of transportation dropped so fast, they didn't know what to do with the place. It grew rather haphazardly; think of the layout, there's no place for it to go next! Shelter 1 ends at a slope, so it would be difficult to add onto the station there, and it'd be hard to add a shelter 4 onto the greenhouse because you'd have constant foot traffic through it. If the Northstar consortium was willing to spend as much money now as they spent to get Northstar 1 here, the moon would have about thirty personnel rather than eighteen. My guess is that Mars will get all the attention and we won't grow at all."

"And they send a different team with a different commander every six months," said Jerome. "They have a different set of expectations and limited continuity between missions. That's a big problem here."

"I'm trying to fix that, where geology is concerned," replied Will. "We now have geological 'themes' laid out for the next three missions and we are fleshing out the themes with a

series of expeditions. In another year, we'll have finalized a dozen themes. We think this plan will result in a pretty comprehensive survey of lunar geology in the next decade."

"Good," said Jerome. "But they need to do that with engineering, too. The labs require reorganization every six months! It's crazy."

"It's politics," replied Will. "The engineering goals are being driven by different governments, by the needs of Project Columbus, and, increasingly, by corporations."

"Well, without more lab space, they won't be able to do more engineering," said Jerome. "For that matter, the 'big science' that people keep promising for Peary is impossible without more science and engineering lab space."

"Everyone in Houston is aware of that, but it isn't clear there's the will to do anything about the shortages," replied Will. "Peary Station is a facility designed for twelve that is accommodating eighteen, plus a steadily increasing stream of tourists."

"Yes; Mars will get the attention from now on," said Jerome.

"And the problem of loneliness will be compounded there," said Will. "Mars missions will last 2 ½ years."

"Have you applied?" asked Jerome.

Will nodded. "We'll hear in the next few weeks, too. If I get accepted, I'll plan to look for a wife after I return in 2037. If I don't get accepted, I'm not sure; if I get accepted to Columbus 2, I'd be back in late 2039 and would be 38. But after that, I'd probably have to postpone a trip to Mars for 15 years—until I'm about 55—or forgo the dream entirely."

Jerome nodded. "These are difficult decisions to make, and Mars is a long way away. You know, Zeke Swift was here in December for a week; he arrived on the tourist flight that brought

us back. He told us that he planned personally to go to Mars in 2040. Apparently, by then he figures enough fuel will be available in Mars orbit for a fast flight back to Earth."

"Really? That's ambitious. The transportation system will barely be established by then."

Jerome shrugged. "That's what he hopes to do. He wants to see the place settled."

Will nodded. "He's really determined. If anyone can get us to Mars, it is he. He didn't even want to go back to the moon, and here we are!"

"He's a remarkable man," agreed Patrice. "Good luck on your plan to go to Mars. And I hope you find a wife, too!"

Will smiled. "Thanks."

"In short, you guys went about it all wrong," concluded Anders Torvik, with a definitive tone of voice.

"Well, that's rather strong," replied Will. "You admitted that the seismic data of Marius Skylight's roof will be valuable, as well as the ground penetrating radar. As for inspection by a geological engineer, the experts at the Colorado School of Mines recommended that we do that as well, but failing that, the seismic and radar data would provide a good preliminary evaluation of the roof's stability. There was even someone there who was willing to go to the moon, but our quota of geologists for Northstar 14 was already filled, and it's a European project anyway."

"Politics," concluded Anders. "When will science ever be freed from it?"

"When we're all independently wealthy. Fortunately, the Europeans were able to rearrange their allocations to include a geological engineer: you."

"And the first Norwegian to go to the moon," added Anders, his Norwegian accent momentarily growing a bit stronger. "The big problem I have is with Sonny Chen's

supercomputer model. I've read his papers about the subject several times and even have commented about it in peer-reviewed publications. I simply can't believe that seismic and radar data are good enough to find and evaluate the cracks in the bedrock and assess overall roof stability."

"As I said, Chen's approach is meant to be complementary to visual inspection, which can only look at the rock surface, not the inside," responded Will patiently, though he was losing patience with Anders. "Ultimately, ESA decided to take both approaches, and the result will be the best we can do." Will turned to Dharmapala Peres, the third occupant of the ranger, which was floating weightless, attached to a lunar lander. "It's just about time to be ready for the landing sequence."

"Thirty seconds," confirmed Dharmapala, who was watching the clock. He checked his safety harness; so did Will and Anders.

The lander's engines growled a bit, then sprang alive. Liquid hydrogen and oxygen flowed under pressure to the combustion chamber and emerged at ten thousand miles an hour as superheated steam, slowing the lander's fall toward the lunar surface. The onboard computer steered based on the rapidly approaching radio beacons and lunar GPS signals, aiming for Marius pad number 4. In less than two minutes, dust began to fly across the lunar terrain as the exhaust blasted the pad bare of loose material. Then, with the slightest bump, they landed and the engines fell silent.

Dharmapala looked at the computer display. "Pinpoint landing on Pad 4," he exclaimed. "We have landed safely." There was no reason to report it to Mission Control; they saw the same display as he.

"Acknowledged and congratulations, lander 3," replied Mission Control.

Will disconnected his safety belts and stood. “Let’s go outside and get the ranger down off the lander deck.”

Anders and Dharmapala stood up as well and got ready for egress. They had to check Anders’s preparations; he had been added to the mission at the last minute and had had relatively little training. When they exited, inevitably they had to start by walking to the edge of the skylight and looking down into its inky blackness. It was impossible to appreciate its large size from the video. Will was impressed. Dharmapala looked nervous.

Then they loped back to their lander. Dharmapala deployed the ramp while Will and Anders disconnected the restraints. A safety review, of course, had concluded that the earlier system was inadequate, so now there were three cables that ran over the vehicle to disconnect and stow, as well as two locking bars associated with each of the six wheels to disconnect and a gate in front of the vehicle to unlock and open. It took the three of them over an hour, and they were fortunate; the other lander, which had transported Halyna Rodchenko, Teresa Dos Santos, and Ethen MacGregor, and which had arrived fifteen minutes earlier, was still struggling with one locking bar.

“No, we don’t need the help of you men,” assured Halyna, irritated when the men rolled over in their ranger.

“I may have to break the locking bar; it has cold welded to the deck,” added Ethel. “This ranger was left on the lander’s deck after the last expedition a month ago.”

“We violated regulations,” conceded Halyna.

They all heard a clinking noise over the common frequency. “I got it,” said Ethel. “It took the right tap of the hammer. Looks like the locking bar is intact and can be used again. But we had better brush on some silicone before reusing it, so it won’t cold weld again.”

“What if we had broken it?” asked Anders.

“We’d still have eleven locking bars out of twelve,” replied Halyna. “And even that’s overkill.”

Ethel entered the ranger and in two minutes she had it down the ramp and on the ground. They were six people and two vehicles, ready to go. Halyna pointed to the robotic truck, which was parked very close to the edge of the skylight next to the tube elevator. “We’ve got our tasks for this EVA. The geological engineer and the Director of Surface Exploration and I are going down to make a preliminary foray in the lava tube and clear the landing spot for the second tube elevator. Ethel, Dharmapala, and Teresa are deploying the drill and taking it to the Marius North Rille to drill into the closed lava tube there. Once the three of us come back up, we’ll start deploying the second tube elevator.”

They walked around the edge of the skylight while Ethel drove ranger 1 over. The drill was on a trailer of its own behind the truck; the tube elevator for cargo was on another trailer, with all the cargo for the lava tube floor already loaded into it. A third trailer, with a propellant manufacturing unit and deployed solar panels, had been towed south from Peary and dropped off 600 kilometers to the north of them at Aristarchus. While Ethel and Teresa attached the drill to the ranger, Halyna, Will, and Anders grabbed equipment from the truck and climbed into the tube elevator.

“We don’t have to worry about cold welding; Mission Control moves the elevator up and down every three days,” commented Halyna. She looked to make sure everyone was seated, then pushed the button. They started down.

At the bottom, the light over the exit hatch turned green, so they opened it and stepped out onto the rock pile, illuminated by the lights on the roof of the tube elevator. They activated

their headlamps and plugged powerful lamps into their life support packs, so they had even more light. Anders pointed to the left and they headed into the lava tube to the spot, about twenty meters from the skylight, where the shelter was supposed to go.

They shined their lights on the walls around them. “Amazing,” said Will at the huge space. The metric system lacked the emotional impact of the measurements of his childhood; the tube was over 200 feet wide and 150 feet high. They could plainly see the cable left by Northstar 12, which would give them power and communications for ten kilometers or six miles, both up and down the tube.

“Imagine the hundreds of thousands of cubic meters of molten rock that poured through here, when the moon was young,” said Halyna. “And now it forms thousands of square kilometers of battered lunar surface.”

“And the tube has stood for almost four billion years, in spite of moonquakes and impacts of all sizes, close and far.” Anders shone both of his lights straight up at the ceiling, so Will and Halyna did the same. Some areas of the tube had a bumpy ceiling and one had to wonder whether the protrusions could break loose, but the area they had chosen had a fairly smooth and uniform ceiling.

“That looks good,” said Anders, after a few minutes. “Of course, the only way to be sure is to get up there and look close up. I hope the boom camera can give me enough data, since it’ll be a long time before we have a way to take a close look.”

“How risky is it, considering the ceiling hasn’t dropped any debris for 4/5 the history of the Earth-moon system?” asked Halyna skeptically.

Anders didn’t answer at first. “It is true that it has held up perfectly since before there was practically any life on the Earth, and in that period of time there have been powerful

moonquakes and impacts. But it may very well be that rocket launches and rumbling heavy equipment, in the next century, will shake the ceiling worse than it has been shaken in the last 4 billion years. Leaking gas and water vapor may weaken the rock as well. If a 200-kilo rock falls on a shelter and depressurizes it, killing everyone inside, we will have failed our responsibility."

"That's why any construction down here, eventually, will require a system of overhead nets," said Will. "They're already working on the design."

"The tube is almost too big for them, too," said Anders. "We'd almost be better off starting with a smaller tube. But this one will provide us incredible potential for expansion."

"Will Marius Skylight ever be a city?" asked Will aloud.

No one responded to that; they weren't even sure what to do with the idea. They stood there for several minutes, scanning the ceiling with their lights. Then Halyna said, "Well, we have half an hour or so while we can explore a bit, for our own satisfaction. Let's do that. Then we've got to clear the landing spot for the second tube elevator so we can get the cargo down here. We've got a lot of work ahead of us."

17.

Crew Selection

April 2034

"So, we're in luck," said Will, looking at the drill. The spot where they set it up didn't look at all unusual; flattish lunar ground in the middle of an old rille, which was several kilometers wide and had hundred-meter sides of slopes and cliffs.

"Fifty-three meters in eight days," said Ethel, in her understated way. "The diamond head did an excellent job of chewing through the basalt."

"The fuel cells used up a tonne of hydrogen and oxygen," said Halyna. "But what do we have?"

Teresa dos Santos smiled turned her tablet so that they could see the screen. She had to shield it from the bright, overhead sun. "North rille lava tube does indeed have an atmosphere. It's 50 pascals; one two-thousandth of an Earth atmosphere of pressure and about one tenth the pressure of the Martian atmosphere. It's mostly water vapor, and at 25 below zero Celsius, that's the vapor pressure of ice. There are traces of argon, too."

Halyna smiled. "So, there's ice down there?"

"There must be some, because the water vapor atmosphere appears to be in equilibrium with ice."

"I'm amazed it hasn't all leaked out after 4.5 billion years!" said Will.

"It has frozen shut all the cracks," said Ethel.

"So, how much water vapor?" asked Halyna.

“That’s about half a gram of water per cubic meter of vacuum,” said Ethel. “Marius Skylight Lava Tube has a total volume of about 10 million cubic meters. If this lava tube has the same volume, as it appears to have, that’d amount to 5 tonnes of water vapor.”

“Nothing to sneeze at,” said Dharmapala. “And if we can add heat and evaporate the ice—however much ice there is—it’d keep coming out!”

“Correct,” said Ethel. “Europe now has a solid reason to build a station at Marius Skylight.”

“How difficult would it be to open a tunnel—an airtight tunnel—into the lava tube?” asked Halyna.

“This expedition can’t do it,” said Ethel. “But once there’s a station here, the equipment to build such a tunnel could be hauled in. I’d draw down the water vapor atmosphere first, to minimize losses.”

“Several years, then,” said Halyna. “But it’ll happen, if for no other reason than seeing what minerals form in the tube. Marius Skylight Lava Tube clearly had an atmosphere as well, before the skylight formed and let it escape. Let’s seal up the shaft and head back to the shelter. We have a lot to celebrate tonight.”

“Did you all finish setting off the seismic charges?” asked Teresa, who had been helping Ethel that day.

“Yes,” replied Anders. He wasn’t standing outside with them, but in the portahab attached to ranger 2, monitoring equipment. “The seismometers we installed in the Skylight Tube have detected some minor debris falls, but nothing larger than about a hundred grams, and we set off some of the charges directly above the tube. The data has already gone to the supercomputers at Cal Tech.”

“And nothing fell on the shelter. Of course, we didn’t set off any charges near it,” said Halyna. “Let’s head back to the Skylight and eat supper there. Will, you come with me; we have some business.”

“Okay,” Will agreed. He headed to ranger 1 with Halyna while the others headed to ranger 2. He opened a private line to her. “We’re calling Redding?”

“Yes. This discovery is the excuse to push the U.S. to ‘keep up’ with Europe and expand Peary.”

“The gymnasium argument?” Will and Halyna had been brainstorming about expansion of the Peary over the last few evenings.

“I think so; it’s the easiest one to make.”

“Okay,” agreed Will.

They entered the ranger, closed it up, and pressurized it. While it pressurized, they removed their life support packs and stored them, running off the thirty minute reserve in the suits themselves. Once the air pressure reached standard, they removed their helmets and gloves. Halyna commanded the ranger to follow the trail 10 kilometers back to the skylight, then she called Redding.

The Director of Mission Control didn’t answer right away. Finally, his face popped onto the screen in front of them. “Hello, Halyna. Oh, I see that Will is with you. Greetings to you both, and congratulations for a very successful day.”

“Thank you, Redding,” Halyna replied. “We’re thrilled to find a ‘lunar atmosphere’ in north tube. It’s quite amazing. Marius Skylight now has a local source of water.”

“But probably not a huge source,” replied Redding. “Maybe hundreds of tonnes; maybe a thousand tonnes. But probably not more than that, and not billions of tonnes, like Peary.”

“The success is as much psychological as economic, Redding,” replied Will. “The water is enough to get Marius Station started, but once it’s started, importing water from Peary will be easy enough, now that the Aristarchus Trail is upgraded for automated driving all the way. And today we scraped up a hundred kilos of crust off the floor of Marius Skylight Lava Tube. The rotating brushes worked very well once we piled a couple hundred kilos of rocks on top of the unit. When we put the crust in the experimental oven in Peary, it should yield ten percent carbon dioxide and five percent water. So that’s even more volatiles for Marius.”

“Alright; more volatiles,” said Redding. “You finished setting up their shelter today, too, right? So Marius can now accommodate three comfortably and more in any vehicles that are located there.”

“But Columbus 1 will probably be assigned to set up a six-person hab,” said Will. “It’s the logical training mission, and the duplicate Mars hab can’t be set up on the lunar surface because it has no micrometeoroid shield. Swift has offered it to ESA at cost. Marius will soon be set up to accommodate nine.”

“But they won’t send nine there. They may not send more than three, half the year, at least until there’s a hotel there as well.”

“The Mars hab will serve as a hotel when there is no crew,” said Halyna. “That will reduce the operational costs.”

“What we need to do is use this opportunity to expand Peary,” said Will. “The cheapest logical addition would be an inflated gym twenty meters in diameter and forty meters long. One end would connect to the open end of shelter 1; the other end would connect to the end of greenhouse 2. It would give an escape route between shelters 1 and 2, on the one hand, and shelter 3, on the other. It would hugely expand Peary’s tourist services because people would

have a huge space in which to jump, run, and bounce around. It would provide a node for the addition of new shelters. And if the gym were equipped with a large airlock, the space could be used to assemble large structures. It'd be an essential addition for the radio telescope under consideration."

"And much cheaper than a dedicated radio telescope assembly facility," added Halyna.

Redding scowled. "So, now the two of you are lunar station architects?"

"These aren't our ideas; they're on the Peary website," replied Will. "But this is a unique synthesis. No one has proposed a gym that could also serve as an assembly space. It'd be easy to do, and it'd be cheaper. The people trying to design an assembly facility want it to have radiation shielding and all sorts of bells and whistles; by the time they're done, it'll cost a billion dollars."

"You're right about that," conceded Redding.

"The other thing that is now clear: Peary is barely large enough for a crew of eighteen," said Halyna. "Any sort of accident and it'd have to be evacuated to the rangers and to Earth. It needs a gym space and a node for additional shelters."

"Alright, alright," said Redding. "Write it up. There's a meeting of a few agency reps in Tokyo in late June. That's the time to make a presentation. If the Lunotel people are behind it, too, that'd be even better."

"I can be available then, if NASA wants to add me to the delegation," said Will. "And over the next year, I'll be glad to support the effort any way I can. Dorinda Stetson had wanted me to be a more general brainstormer and advisor about development of the moon. I feel I can do that, now. My duties as Director of Surface Exploration have fallen into more of a routine."

Redding stared at Will, surprised. "What are you talking about? Have you been reading your email?"

Will frowned. “No; why?”

“Will, you’ve been selected for Columbus 1! The email just went out half an hour ago!”

“Really?” said Will, shocked.

“Congratulations!” exclaimed Halyna, surprised.

“Yes, you, Laura Stillwell, Ethel MacGregor, your friend David Alaoui, Sergei Landsberg, and a Japanese physician named Makihiko Yamamoto. Training starts August 1st for launch next July. Congratulations.”

“Thank you! Wow, this is a shock.”

“The Moon man is going to Mars. I suspect the world’s attention is going to Mars as well; this may deflate the balloon of lunar exploration. Commitments won’t terminate entirely, but expansion will be very difficult for a while. Cutting the cost of transportation will be the key. The gym idea is clever and inexpensive, and relies on tourism for part of its justification, so it may be possible.”

“Thanks,” said Will. “And my commitment to present the idea still stands; I’ll have time before August 1st.”

Redding shook his head. “Will, take a nice, long vacation, because training will be intensive and then you’ll be away two and a half years. When you come back, you’ll be a celebrity; your life will be changed. Don’t worry about the gym idea.”

“That’s good advice,” said Halyna.

“Alright,” said Will. “Thanks, Redding.”

“Thanks for all you do, Will, and congratulations again; they couldn’t have chosen a better man, and I mean that literally and wholeheartedly. Halyna, thank you for your dedicated

service to Northstar 14; it has been an incredible success, and the Marius expedition in particular has been very significant, and has gone forward flawlessly. I am very impressed."

"Thank you, Redding," she replied.

"Have good evening, both of you. Some celebration is in order, up at Marius. Good bye."

"Bye," they chorused back, then Halyna closed the circuit.

She looked at Will and he could see something new in her face: perhaps it was a greater respect for the young man, or a touch of jealousy, or physical attraction. He wasn't sure. "So, we have two members of Columbus 1 with us," she finally said.

"Yes, we need to congratulate Ethel."

"We do need some special food and drink, too. Anders is cooking tonight, so maybe he can come up with something special. The water vapor in the lava tube is worthy of celebration, all by itself."

"It is. We have a lot to celebrate. The moon has a lot more resources than anyone suspected."

"And it has proved a pretty good jump-off point for Mars, too; more than the Mars fanatics thought. But now it'll have to rely on tourists to grow."

"For a while, anyway, until people start to think of it as an expensive Antarctica."

The ranger slowed; it had reached its usual parking place near the tube elevator. There was a beep. "You ready for docking?" said Dharmapala. They could hear loud talking behind him.

"Yes, we are," said Halyna.

"Okay, here we come," said Dharmapala.

Halyna activated the docking mechanism for the rear airlock. They had been docking airlock to airlock, which allowed more rapid and convenient entrance and exit from the portahab attached to ranger 2. This converted the ranger cabs into large airlocks for suiting up—one for men and one for women—and since they had excellent air filtration systems for eliminating lunar dust, that worked well. The only disadvantage was the need to crawl out through the circular hatch under the windshield. A curtain down the middle of the portahab at night split that space between the sexes, though from now on they'd alternate which sex would descend the tube elevator and sleep in the shelter below. Halyna had been using ranger 1's cabin as her quarters and office.

They heard a series of clanks as the two airlocks docked, aligned themselves magnetically, and locked together. Will opened the inner hatch for Halyna, but just then Dharmapala opened the outer hatch and said, "Will first!" Will looked at Halyna, shrugged, and entered the portahab.

"Yeah!" they all cheered, and they began to applaud. Will smiled and blushed; he didn't do that very often.

"Thanks," he replied, and he turned to Ethel. "Congratulations to you, also."

"Thank you, congratulations to you." He reached out to shake her hand; she approached to hug him. They did both.

"That's right, but no kiss on the cheek," said Halyna. "A trip to Mars is no place for romance!"

"I agree," said Will and Ethel simultaneously. Then they looked at each other and laughed.

"Well, we have a few hours before the gentlemen descend to the shelter for the night," said Halyna. "Anders, let's break out the ice cream for dessert, make some soda from our CO_2 supply, and pull out the frozen steak dinners. Let's celebrate! We have a lot to celebrate, too!"

18

Change at the Helm

June 2034

"I'm still in shock," said Will. He looked at Larisa Tatarinov sadly and repeated, "I'm still in shock."

"Why? It's been over a month. You didn't know him very well; you met him what, five times? He was driving his Lamborghini too fast." She shrugged.

"Larisa, Zeke Swift was no ordinary man. He was a genius; both in engineering and in entrepreneurship. A rare man. When he designed and built the first Thunderbird, he did it for $300 million. NASA did an independent review and concluded they'd have spent $3.6 billion and taken twice as long to do the same thing! His first capsule cost less than the launch escape system for a capsule NASA canceled later! The Thunderbird Heavy cost almost nothing to develop, even though it used propellant cross feed that everyone knew they could have developed for several decades, but no one bothered to do it. The Heavy had almost as much lift capacity as a $15 billion rocket NASA had to build because Congressmen wanted the money spent in their districts. Swift's competitors stayed in business as long as they did because of government subsidies; they weren't competitive. He developed vertical landing technology, which allowed reuse of stages and drastically cut the cost of reaching low Earth orbit, forcing everyone else to develop cheap competition. He didn't even want to go back to the moon, but his system made it easy and cheap . . . he was a miracle, really. When we heard, half of Mission Control was crying." Will paused because of a tear forming in each eye.

Larisa was startled. "Our perspective in Russia was so different, because he made life so complicated for us. We went from the world's largest launcher—because our launches were the

cheapest—to number three. The Chinese were willing to subsidize their launches, but we weren't."

"The Europeans were furious, too, until Thierry Bergé came along and made a deal with Swift to invest $200 million in the Peary Resources Company. That, and the very real threat that the Chinese would get to the moon and claim the resources, prompted Congress to get behind Project Northstar. I think everyone has been mad at Swift, at one time or another."

"But no one thinks he was killed?"

"A few conspiracy theorists, but no; he was angry, he was driving fast, and the freeway was wet, which it never is in Los Angeles in May. He was killed instantly."

Larisa looked at the conference room door. "We should probably get inside. So, what do you think about going to Mars?"

"Going to Mars. I'm going to Mars . . . I've had to say it to myself over and over. Sometimes I wonder whether it's a dream. Mars was never all that magical to me, but I know it is to millions of people. This is a voyage like no other, or at least not since Apollo 11, 66 years ago. So that's incredible. Almost literally, it's unbelievable. . . . But otherwise I've been wrapping up things here. My last day as Director of Lunar Surface Exploration is June 15. Bonita Jackson then takes over, and she'll do an excellent job for at least two years, but I think she plans to resign from the Astronaut Corps and get a teaching job. My condo will be rented for me by a management company, once I move out, probably next spring. I actually haven't had much time to review the plans for Columbus 1 yet, I'm too busy wrapping up the current phase of my life."

"And what will you do between June 15 and August 1? Prepare a few last papers for publication?"

"No, I'm going to the western Himalayas for three weeks! I'm joining a hiking group, though we aren't tackling any big peaks because it's monsoon season. I'll visit Tibet, China, and India as well. It'll be a fantastic break from everything."

"It sounds marvelous, Will. I'm envious. Valery's not interested in doing anything like that." She pointed. "We had better get in now, or it'll be too late for coffee and doughnuts. I wish NASA would provide better refreshments!"

They flashed their badges at the door and entered. NASA's Administrator of six months, Fred Ross, was standing in the corner with Redding Desmarais, who looked concerned. After Larisa got her refreshments, Will lingered, and sure enough, Redding came over to him.

"I'm just about ready to quit," he whispered.

"The meeting with Asaph Swift?"

Redding nodded. "He hasn't done morale any good in Mission Control. He wants to trim expenses by twenty percent. And he doesn't have his father's charm."

"He's moving fast to take over and change the direction of Swift Space."

"And what direction? Greater profits? I don't know how we can cut expenses twenty percent, except through layoffs. But how can we do that? Right now we have two fully staffed twelve-hour daytime shifts and two half-staff night shifts per week. All launches, dockings, and landings are supposed to happen during the fully staffed shifts; the half-staff shifts are for emergencies only. But the number of launches per month keeps increasing, especially to LEO. I'm sure the goal is to get it up to at least one event—a launch or landing—every day. We'll need to increase staff, not decrease it. We already have days where there are two events we have to monitor!"

"Did he tell you what direction he's considering?"

"I think he wants to cut the cost of tickets and generate more business to low Earth orbit."

"That makes sense as a business strategy, since the moon and Mars will be too expensive for some time. I'd stress safety."

Redding shook his head. "There was a safety review that was completed two months ago. He says the report shows areas where there are potential savings. I don't believe it. I've asked Ross about it, and I'm sure he'll manage to pry a copy out of Swift."

"Good. That's all you can do."

Redding nodded, resignedly. They headed to their seats at the NASA side of the table. The conference involved the space agencies of the United States, Europe, Russia, Canada, Japan, India, and Brazil, plus Asaph Swift and several representatives of Swift Space.

Frederic Ross rose and welcomed everyone to Houston. "I think our first item is a moment of silence for Zeke Swift. I don't think anyone can express the depth of our loss. Zeke was a national treasure; he was an international treasure. He has opened up space in a way that no one could have imagined, when he started thirty years ago. Dreams inspired by the Apollo program, fed by the optimism of the promise of the Space Shuttle, dashed by the reality of that flawed vehicle, then nearly snuffed out by three decades of aimless effort, were re-inspired, revived, and proved realistic by this man. We are grateful that his son will continue in his father's footsteps and provide strong leadership into the future. Could we now bow our heads in respect for the late Zeke Swift."

Everyone bowed their heads and a minute of silence followed. Will said several Bahá'í prayers silently, and it brought tears to his eyes; tears for Swift and tears for his own future, which had been radically changed by the New Zealand immigrant. Indeed, the entire future of

humankind had been changed as profoundly as when humans first left Africa, or when Columbus knit the hemispheres together. No wonder it was called Project Columbus.

"Thank you, everyone," said Ross. He looked around. "Dr. Asaph Swift has asked to address us about his father, and I understand he has some things to say about Northstar and Columbus as well. Asaph."

"Thank you, Dr. Ross." Asaph Swift rose to address the three dozen people. "Your words about my father warmed my heart and will be long treasured. His death has left a huge hole in my life as well, and huge shoes for me suddenly to fill. I seek to honor his memory and fulfill his dreams. His long term objective is known to everyone: the settlement of Mars and creation of a civilization on that world. His means are also well known: cheap, reliable access to space through simple, reusable vehicles. He had the genius to make the first possible, and it will make the second inevitable.

"It is that order of efforts—lowering the cost of access to space, then progressively settling more and more people on Mars—that I have been pondering almost every day since my father's sudden and tragic passing 36 days ago. Swift Space is now my responsibility, and making it the vehicle of my father's dreams must now be my passion.

"My father has long been pondering the fact that the Thunderbird, which has been under development and improvement for almost thirty years, is approaching the cheapest price that is possible. With full reusability—at least ten launches—it appears we can get the price down to 500 dollars per kilogram or a half million dollars a tonne. We're half way there, currently. Even a million dollars a tonne is a revolution, compared to the Space Shuttle era, when a 25-tonne module was launched to the first International Space Station for a half billion dollars, or 20 million per tonne.

"My goal, over the next few years, is to reduce launch costs to half a million dollars per tonne. To do this, I am instituting stricter cost controls throughout the company with the objective of cutting costs ten percent on average. I have also concluded that it is possible to raise the number of passengers per Gryphon flight to low Earth orbit from 24 to 36, especially with a new flight plan that reduces the time from blast-off to docking from six hours to four. This, plus cost cutting and some accounting changes, will allow us to reduce the cost of a ticket to orbit to half a million dollars. According to market surveys, this will broaden the market to hundreds of thousands of people. We believe a week at the Pax Hotel or the new Interplanetary Ibis Hotel—which will be just a few kilometers away and can be served on the same flight—will be under a million dollars and that both hotels can be continuously supplied with tourists. That means that in the next four years we will increase flights from twenty a year to eighty, and that increase in the flight rate will allow us to halve the cost of launching cargo to orbit. Half a million dollars per tonne is achievable."

He paused; there were a few gasps in the room. "This reduction, however, will not reduce the cost of Projects Columbus or Northstar in the short term. Peary Resources will have to provide hydrogen and oxygen to low Earth orbit for half its previous price or go out of business, and to do that, it will require additional investments that Swift Space will build into its contingency fee, even as it reduces the propellant costs. Peary Resources plans to place at least one engineer full time on the moon so that chondrite and carbon dioxide mining can proceed more effectively and methane can be produced more cheaply. We are also establishing a department here in Houston devoted solely to remote operation of the methane, hydrogen, and oxygen production facilities. The result should be an expansion in methane production and reduced costs for hydrogen and oxygen production.

"A reduction in the cost of flights to the moon over the next few years is not impossible because a second destination will soon be available. Marius will provide dramatic scenery of rilles and lava tubes that Peary lacks. We think that if we offer a two week visit to the moon, plus one week in low Earth orbit and a one-day visit to the L1 Gateway, for the current cost of a one week visit to Peary, we can increase tourist flights to six. We also anticipate a decrease in the cost of cargo delivery once the Japanese Sunfire solar thermal engine becomes available. Thunderbirds can launch hydrogen into low earth orbit for only ten percent more than the cost of other cargo. A Sunfire can put a tonne of cargo into low lunar orbit using one tonne of hydrogen, as opposed two tonnes of propellant for a chemical engine. Thus delivery lunar cargo will soon be only 2.5 times the cost of delivery to low Earth orbit, rather than 3.75 times, as it is today. With better recycling, newer equipment, and a greenhouse that grows a larger portion of the food, imports per person should drop from 1.5 tonnes per six months to only 1 tonne, also, so the cost of consumables should halve soon, then halve again when the cost to LEO drops.

"However, we see no reduction in the cost of flights to Mars in the next six years. In fact, our accountants tell us that we must exercise more care than ever to control costs. In particular, we will be considerably more conservative in accepting new technology and its development cost into a government's contribution.

"One further comment. Any further reductions in the cost of passenger flights to low Earth orbit will also require winged vehicles capable of landing on runways. Such horizontal-landing vehicles experience much gentler gee forces during reentry. The cabins, also, will be laid out more like modern passenger jets and thus will be more comfortable and space-efficient than capsules. Swift Space, therefore, is committed to the development of a vehicle it calls the Swift Shuttle, which will be launched atop a reusable Thunderbird first stage

initially. Eventually, an air-breathing hypersonic vehicle will replace the Thunderbird. We think it has the potential to reduce launch costs by half again."

There was silence while everyone pondered Asaph Swift's comments. Dr. Helene Colmar of the European Space Agency did some quick calculating on her tablet, then said, "Dr. Swift, by my calculation you just said that in a few years you plan to be launching 2,880 tourists to low Earth orbit per year; that's 36 times 80. You'll also be launching six tourist flights and two Northstar flights to the moon per year, for a total of 96 tourists and astronauts, and six astronauts to Mars every other year, an average of three per year. Over five years, 14,400 tourists paying an additional $100,000 each would provide $1.44 billion toward development of the gryphon, which you told us will cost $1.5 billion to develop. How is it fair to make the moon and Mars pay a third of that cost each?"

"The gryphon was developed for Mars and lunar transportation; it is being adapted for low Earth orbit tourism. It has three uses, and they are all equally important, hence the division. This was agreed at the last meeting, two years ago. As for your calculations, they are correct based on the numbers I gave you, but we will have to wait and see whether the numbers materialize."

"There was an agreement to a three-way split, two years ago," persisted Colmar. "But at that time, no one imagined that the scale of tourist launches would grow so large, or the costs would drop so fast. Your father said that a gryphon would cost $100 million to build and would fly ten times. But if you're now talking about 80 tourist flights per year—and I doubt, two years ago, there was even an assumption there'd be 20 per year—I suspect the manufacturing cost of the gryphon will be less or the number of flights before retirement will be more, or both. That should reduce the cost of manufacturing lunar gryphons or increase the number of their reuses."

“I agree, in theory. We hope to be manufacturing three times as many gryphons and this will reduce the unit cost thirty percent. We are now assuming 14 flights before retirement. That number could eventually grow to 20 as our ability to refurbish improves.”

“So, what prevents any of your competitors—who will be hard pressed to match your prices—from suing you and us, on the grounds that the lunar and Martian flights constitute an illegal subsidy? For that indeed is what they are; they reduce the cost of tickets to low earth orbit by close to $100,000!”

Swift opened his mouth about that comment, then closed it. “Well, Dr. Colmar, they have lawyers, you have lawyers, and I have lawyers.”

“We do indeed,” she replied. “And I’m sure they’ll be busy over this one.”

“If lunar gryphons cost seventy-five million to make instead of one hundred million and can fly fourteen times instead of ten, that’s 140 customers paying a bit over half a million each for the vehicle, rather than 100 paying a million each,” noted Chakravarti, who had also pulled up the calculator function on his tablet. “If the cost to reach orbit halves, and the cost of fuel from Earth orbit to the lunar surface halves, and the cost of consumables on the moon halves, it’s hard to believe the cost of flying an astronaut to the moon doesn’t halve. And if the cost of a tourist flight halves, surely that will more than double the number of tourists? That will cut costs even more.”

“Correct,” replied Asaph. “But remember my father said Swift Space was assuming the number of flights to the moon per year would grow to ten over the next seven years. These developments only get us up to eight. So we can’t be renegotiating signed contracts.”

"Yes we can, if there are big changes in the conditions," replied Sobolev, the Russian representative. "You negotiated to include a contingency to cover unanticipated costs. It sounds like there are unanticipated profits instead."

"Let us remember that there won't be huge changes in costs in the next two years," said Ross, intervening. "The changes Swift proposes are indeed along the line his father was assuming would happen. The costs of Northstars 16 through 19 and Columbus 1 won't be affected. But after that . . . I think we will need to renegotiate, Asaph."

"Of course; the contract signed two years ago was never meant to last seven years," said Asaph. "There is another approach to take, though: the difference between the contracted price and the actual price, if it is less, can be plowed back into the lunar facilities. There is a logic to this approach because a drop in price generates an increase in numbers and that requires an expansion of facilities. Peary needs a large enclosure for exercise and equipment assembly, for example. We can look into a way of calculating the contingency supplement so that surplus will go back into the lunar facilities."

"We can add that into the mix," said Ross. "Clearly, Dr. Swift, we're going to reexamine the costs of Northstar and Columbus very carefully."

"Yes, clearly. But please remember that cutting your costs now will raise them later, because you will slow our progress toward the goal of half a million per tonne."

"Dr. Swift, you can't use our subsidies to undercut competition," replied Colmar.

"I understand that!" snapped Asaph. "My father made it very clear, two years ago, that prices would fall in the future. I just gave you a report that indicated he was right and by how much. And now you are attacking me and accusing me of dishonesty. Let us clear up these misunderstandings!"

“Dr. Swift, if you get tourist volume to orbit to 2,880 per year and cargo down to half a million dollars per tonne, how much will a flight to the moon cost?” asked Colmar.

“Ticket alone, excluding consumables and other necessary cargo, but including insurance, and profit? Three to five million. In any luck, we’ll be there in four years.”

There was silence in the room as people contemplated that amazing number.

“I have another question, Dr. Swift,” said Helene Colmar. “Forgive me for such technical questions, but I have a doctorate in physics. If there’s such a shortage of lunar methane, why not just haul it up from Earth? Why should Peary go to the trouble and expense of mining and refining chondrite? Surely you can’t make a profit from it.”

“Once the cost of hauling cargo from the Earth’s surface to low orbit drops to a half million dollars per tonne, we will not be providing lunar methane to low Earth orbit facilities. We could probably do it profitably, but it may not be worth the additional investment. Peary Resources will be profitable at that price for transporting lunar water, however. It will also be profitable for sale of methane to the L-1 Gateway and cislunar space. Remember that rocket engines always burn hydrogen-rich; the performance is better and the engines are protected from the corrosive effects of hot oxygen. As a result, 100 tonnes of hydrogen-oxygen fuel require 122 tonnes of water and produce 22 tonnes of ‘waste’ oxygen, which is essentially free. Extracting carbon from chondrite allows us to use that oxygen.”

“Why not develop the Gryphon-H and drop the use of methane entirely for lunar transportation?” she persisted.

Swift shook his head. “The gryphon’s cargo bay is the right size for the expanded propellant tanks necessary for hydrogen-oxygen propulsion, but a better use of our funds is to move the methane and oxygen tanks down and double the size of the passenger capsule, which

we plan to do in the next few years. At that point, a gryphon could carry 56 to low Earth orbit and up to 30 to the moon. That will produce yet another drop in the cost of passenger tickets. But at the moment, the facilities to serve that many passengers in low Earth orbit or on the moon don't exist."

That caused a loud murmur. "So, when, Dr. Swift?" asked Colmar over the loud noise of the crowd.

"In eight to ten years, barring a major world economic crisis, it is possible that tickets to low Earth orbit will be down to a quarter million dollars—excluding accommodation—and tickets to the moon will be down to 2 million or less."

Everyone turned to their neighbor to comment all at once. Seeing the breakdown in order, Frederic Ross said, "I think we should take a 15 minute break to talk through this news. Afterwards, we can resume asking Dr. Swift questions."

Will turned to Redding, who was sitting next to him. "Well, now you know; any twenty percent cut in Mission Control is temporary!"

"Yes, if he gets the expansion in service he wants, staffing can only go up," agreed Redding. He thought a moment. "He doesn't have the persuasiveness of his father."

"He's not as articulate, either. Half the audience is mad at him, rather than being thrilled with him."

"You're right, but that's partly because he's taking advantage of the governments to pay for his tourist service. He'll drive everyone else out of business and create a monopoly that way, too. That won't go over well at all."

"It could force higher prices, too," said Will, shaking his head. "Still, who would have thought that the revolution in prices would continue? A quarter million to go to orbit; can you imagine? It'll make headlines today."

"It will. It will thrill millions of people. Equally important, dozens of corporations will be looking at low Earth orbit research and manufacturing, or lunar mining and scientific research opportunities. There are already three proposals for telescopes at Peary before the National Science Foundation and various European governmental agencies."

"I know, and more proposals are popping up every day. It's quite exciting. But I want to know what this will do to Project Columbus. It will have to lower its prices."

"It also gives the moon an enormous advantage, and that makes up for Mars's allure," noted Redding. "People have been saying that Project Columbus will suck off support for the moon. But if the moon gets that cheap, it'll undercut Mars instead."

"I think you're right," said Will. "I think I'll ask him." Will rose and walked over to Asaph.

Swift was surrounded by a large crowd of questioners, some enthusiastic, some skeptical, some angry. While he was waiting, Will pulled out his smart phone and found the notes he had taken that afternoon two years ago when Zeke Swift had laid out the cost of Columbus 1. Gryphon development and production totaled $57 million per passenger, but if the vehicle was thirty percent cheaper and the development cost was half covered by orbital tourism, Will figured the number dropped to $30 million. The hippogryph automated cargo vehicles added $22 million more per passenger; he left that unchanged for a moment. Propellant added $45 million per passenger, but that was now cut in half to $22 million. Infrastructure already placed on the surface added another $50 million, raising the total to $124 million. Adding 35% for insurance,

interest, and profit raised the cost to $166 million. If the gryphons and hippogryphs were reused and had already been paid for on Columbus 1, those costs were eliminated for Columbus 3 and the total was $75 million before the 35% was added, $100 million afterward. He suspected the propellant numbers were too high, too. Mars transport could drop quite significantly!

By the time he had worked through the numbers, Swift was down to one questioner, so Will walked over. Swift looked relieved to see him; the questioner had been persistent and unpleasant. “Dr. Elliott, right? It’s very good to meet you! Congratulations on your selection for Columbus 1.”

‘Thank you,” replied Will. He decided not to point out that they had already met twice. “I’m curious whether you have done any calculations for the costs of Columbus 3, 4, and 5?”

Asaph shook his head. “No, we haven’t. One reason is because there are too many uncertainties when we look that far in advance. The other is because, frankly, Mars colonization was my father’s passion, but orbital tourism is mine. We have the possibility of opening low Earth orbit for the upper middle class. Not for the masses; not yet. But we can at least reach down to the upper end of the middle class, and that’s very exciting. The moon follows as a logical corollary because it’s just a three-day flight away, and now that we have infrastructure there, it inevitably will become a tourist destination. But Mars represents a completely different situation. A gryphon can fly to Mars during one opposition and back to Earth the next, so it can be reused only once every four years. There’s no way a gryphon will get reused even ten times, let alone 14 times; 14 reuses will take 56 years! The tourist market is virtually impossible to develop because even with ample supplies of cheap chemical propellant, a tourist would need to spend 12 months in space to spend one month on Mars, and there aren’t many people willing to spend that much time floating in the middle of nowhere. I’m afraid I’m not the one who will

make Martian colonization possible. Not for the next decade or two, anyway. That will have to await some other entrepreneur."

"I see," said Will, startled. "Because there's immense potential for reducing the cost of tickets, just based on your calculations and those of your father two years ago. If gryphons were used for lunar *and* Martian flights, they could indeed get in 14 uses in a reasonably short period of time, and you wouldn't have to build as many gryphons for lunar transportation."

"Yes, that's true, and perhaps that can be considered. " Swift saw Will's disappointment and shrugged. "But not any time soon."

19.

The Team

September 2034

"It was a heart attack."

"How did it happen?" asked David Alaoui.

"Well, he went out to mow the lawn early in the morning, before it got too hot; it was pretty hot in Stamford that morning anyway. I had bought him one of those solar powered robotic grass cutters, but he preferred to use an old fashioned lawn mover that doesn't even have a motor; the blades turn only if you push. He wanted to stay in good shape. He just retired a month earlier and was worried he'd have a heart attack because he wasn't working anymore!" Will shrugged. "Apparently his heart just stopped."

"How terrible. And you were in Kashmir?"

"I had finished hiking in the Hindu Kush, in spite of the rain, though the monsoon season was pretty light and we had a lot of good days. I was in Srinagar and was scheduled to fly to New Delhi and Sriharikota two days later, then back here two days after that. I couldn't get out of Srinagar any earlier, either, but once I was in New Delhi, a very nice ticketing agent helped me rebook. I was home for the funeral, though they postponed it one day."

"That's a blessing. I'm so sorry, Will. My dad was killed in an automobile accident in the French Alps—not far from Geneva—ten years ago. It was such a terrible shock. We were completely unprepared and it took months to recover."

"It was terrible for my mother, in particular, because she's all alone now. I'm so glad NASA was able to postpone the start of our training a month. We needed the time to get together, grieve together, and decide what she would do, especially with me leaving for 2 ½ years."

“What’s she doing?”

“Mom’s going to rent out the house for a year or two and go live with Molly and Taraz in Santa Cruz, Bolivia. She can work at Universidad Núr, which is a Bahá'í-inspired university there. In a month we were able to get most of my father’s affairs wound up. It was good to spend some time with my sister and her husband, too. I only see them once a year.”

“When did you see your father last?”

“Late February, for the Bahá'í holiday then. He was so proud of me. And when he heard I was selected for Columbus 1 he was beside himself in happiness.”

“I can imagine. My mother and parents in law were, too.”

“So, are Aisha and the boys still here in Houston?”

“Yes, they arrived with me on July 15 and we spent two weeks touring the US. Then in August, when training was postponed, we spent a lot of time seeing Texas. We flew to Disney World, too.”

“So, I can still meet them?”

“Yes. They’re leaving next week, flying straight to Morocco. My in-laws have said my mother can come to Fez as well and live with them while I’m away, which is really great. My mom is French, but she speaks fluent Moroccan Arabic and loves the culture. She converted to Islam too, before I was born.”

“That helps a lot. What have I missed? I haven’t had time to read anything. I’ll feel like an idiot for the next week or so.”

“You haven’t missed anything. Makihiko Yamamoto—Laura calls him ‘Moto,’ but he doesn’t like that nickname—flew home to Kyoto right away. He has his own family crisis of sorts; his mother has breast cancer, but it’s in remission again. He came back two days ago.

Sergei Landsberg arrived with his wife and boys two weeks ago; we've seen him a few times. Laura Stillwell and Ethel MacGregor have been here the entire time, but I haven't seen either of them very much. Ethel's been driving Prospector-400s."

"She has a flare for geology," said Will. "She was at Marius when I was there in March. She ran the drill that broke into the north lava tube and participated in several expeditions."

"I was following the events as closely as I could from Paris. I've run TROVs on the moon and Mars since I got here, but I have the impression that Bonita isn't very happy having strangers in the control area."

"Yes, I'm afraid that's right. We had our difficulties in June, before I left for India. She decided to make some major changes and started before I left, which was not very tactful, since I was still officially in charge, though I was occupied with other matters. That, and the conference in mid June really wore me down; it was a terrible month for me."

"Yes, Colmar was not happy about the conference at all. Asaph Swift did not make a good impression and now he has two lawsuits to deal with."

"He's green, but he seems capable enough. The conference ended up being a big waste of time. No one was willing to increase commitments to the moon or make any to Columbus 2 yet. The plan to lower tourist launch costs was highly controversial; people were suspicious Swift was transferring government subsidies for Mars and the moon to his tourist business. And Asaph has no interest in Mars at all, unlike his father. That, and Bonita taking over before I had left—though I have to have lunch with her and assure her there are no hard feelings—then a nice month in a hot and humid India, then my dad dying . . . it's been a crazy summer. It's made me wonder whether I should go to Mars at all."

"What? Why?"

"Well, if I settled down, married, started a family, got a teaching job . . . things would be much more balanced, emotionally satisfying, and less frustrating!"

"Not necessarily. Wives, children, a house, and a university can all be very frustrating. No, you're meant for this historic mission, Will. I feel the same about myself; God has prepared me for this. This mission won't be easy, but we're meant to be part of it."

"Well, I hope you're right."

Just then Laura Stillwell entered the cafeteria. She spotted Will and David at a corner table and hurried over. "Come on, guys! We were supposed to start ten minutes ago!"

"Oh, what time is it?" David looked at his watch. "Sorry, Commander, we'll be right there."

"Thanks. I want to get us started and down to business right away. We've lost an entire month of training, after all." She tossed a quick glance at Will. "We've got a lot of ground to cover." Then she turned and walked away.

"We had better go," said Will.

"Yes. But can you explain her to me?"

Will frowned. "What do you mean?"

"Well, she often doesn't look at me when she talks to me. She's pretty formal with me; I don't think she likes me. But she doesn't even know me."

"I can't say I know her very well, either. I overlapped with her a little bit; Northstar 4, which she commanded, was leaving Peary when Northstar 5 arrived. I wasn't Director of Surface Exploration until Northstar 7. She entered the astronaut corps from the military; I think she was a Navy pilot."

"Okay. Maybe she's shy; but that doesn't make sense, either. And I overheard her quizzing Redding about your leave and was it really necessary and maybe it would be better to replace you with Roger Anderson or Jerry McCord or another geologist. That struck me as premature."

"I felt bad being unavailable, but we still have 11 months. That is a rather strong reaction. I was surprised she didn't greet me just now."

"Or offer condolences. Well, never mind, let's go." David rose, so Will did the same. They walked out of the cafeteria, down the stairs, and to the area that had been assigned to the six of them: a large room with a table along one wall with six chairs and six wall screens for work; a large view screen on the far wall with a semicircle of comfortable chairs in front of it; a round table with six chairs behind the semicircle; and a coffee maker, refrigerator, and cabinets with snacks and condiments. It was designed without private spaces; they were a team in that area. Laura Stillwell, Sergei Alievitch Landsberg, Ethel MacGregor, and Makihiko Yamamoto were seated on the semicircle of chairs.

"Ah, here they are," said Laura, pointing to the empty seats across from her. "Gentlemen, welcome. Will, please introduce yourself to Moto. I think you know everyone else."

"I do." Will turned to Japanese physician. "Very pleased to meet you. I look forward to working closely with you, over the next 3 ½ years."

"Thank you, call me Makihiko. I look forward to the collaboration as well. I am very sorry to hear about your father."

They shook hands. "Thank you, and I gather your mother was ill as well. I hope she is recovering."

"Yes, it appears she will make a full recovery. She has the best of care."

Will sat. He glanced at Ethel, who smiled, nodded, and said, “Sorry about your father.”

“It’s been a long month without you, Moonman,” exclaimed Laura. “But I think everything will work out fine with Columbus 1, in spite of the training delay. This afternoon, Redding Desmarais will come down to welcome us. Unfortunately, he’s leaving Mission Control in two months to go work at NASA headquarters, but we’ll meet the new Director as soon as he or she arrives. Next week, Frederic Ross, NASA Administrator, will be here, and he wants to meet us as well. We will have the usual parade of dignitaries from time to time; no doubt Vice President Coombs will be here as well.”

Laura leaned over and pushed a button on her tablet. A slide appeared on the large screen. “Just today, the dates of our sojourn at Marius Skylight were confirmed, so here’s our full schedule. We’re here in Houston in September and October to review basics. We’ll also go over the greenhouse and animal pens—”

“Animals?” said Will.

Laura nodded. “Rabbits and chickens are accompanying us to Mars. In November, we’ll split our time between here and Brownsville Spaceport, where the Gryphon *Olympus* will be prepared for launch. Currently, it’s called the *Aristarchus* and has been shuttling astronauts and tourists to the moon, so it requires some modification—”

“The *Aristarchus,* huh?” said Will. “I flew to the moon and back on it in the spring! I hope Swift Space is counting the flight toward the Project Columbus portion of the amortization of the development costs.”

Laura scowled, irritated by the interruption. “I would have no idea; I’m not even sure what you’re referring to. Let’s stay focused on the schedule, okay? We’re spending time at Brownsville to work on the upgrade of the *Olympus* to interplanetary flight condition. That way,

we're familiar with the systems and can do repair work. All six of us will be involved in the work. When we're here in November and December, we'll be tearing apart and reassembling the ranger and portahab.

"After a two-week vacation, in January we're heading to the Antarctic Dry Valleys for a month, where Moonman and Alaoui will, no doubt, teach us a few things about geology. When we come back we'll have about a month here until our launch to Marius in the *Olympus.* After a stop at the L1 Gateway, we'll land at Marius on March 20.The Europeans will have already lowered a hab down into the Skylight; they'll have training with the crane that we won't have, so they'll get it down there for us. Marius will have two rangers and a portahab—they arrive in November—which will be at our disposal. We'll live in the *Olympus* under emergency accommodation at first, then in the three-person shelter—"

"How long will the emergency accommodation last?" asked Makihiko.

"About a week; we need to know what it means for all six of us to live in the same 45 cubic meters of space, in case one of the gryphons and the inflatable transit habs are disabled. The three-person shelter will provide us 300 cubic meters more space; which is roughly equivalent to one gryphon and one transit hab, so it'll teach us about a different emergency configuration. Anyway, once at Marius we'll place the Mars hab, inflate it to Martian atmospheric pressure, set it to Martian temperatures, and use it to test our Mars suits for two weeks. Much cheaper than using a big vacuum chamber here on earth, and we can add weights there to simulate Martian gee; we can't do that on Earth.

"Once we've finished practicing with the Mars suits, we'll finish setting up the Mars hab; that will give us the experience to do the same at Aurorae. We'll spend the rest of our time at

Marius exploring together as a team; that's our best bonding time because we'll be there on our own for almost three months.

"On June 9 and 10, we'll fly back to low lunar orbit to enter a Polaris capsule and return to Earth. Landers fueled at Peary can't fly to Marius and then to orbit with a full load, so we'll go up in two landers. We can't leave Marius on the *Olympus* because it'll be heading to the L1 Gateway in early May; an Indian crew will be there to load it up with Mars-bound cargo, fuel it, and prepare it for trans-Mars injection."

"Why can't that be done in June by us?" asked Makihiko.

Laura looked at him patiently; Will was surprised, since he had interrupted her more often than he, and she had scowled at him. "Timing. It'll take a month for the *Olympus's* cargo to fly up from low Earth orbit via a Sunfire solar thermal cargo vehicle. A second Sunfire will be transporting the cargo for the *Elysium* and we need to be sure there's enough time for both cargos to arrive. These will be the first flights of the Sunfires beyond geostationary orbit and with heavy cargos. We'll arrive at Gateway from Earth on the *Elysium* on July 15, which will give us between one and three weeks to transfer its cargo from the second Sunfire. If we stayed at L1 Gateway from June 18 until trans-Mars injection on July 24—assuming we leave on schedule—we'd soak up an additional 5 weeks of radiation unnecessarily. Also, NASA wants us back here for a final round of medical tests and briefings and for a last visit with our families. So we'll return to Houston for several weeks and blast off in the *Elysium* from Brownsville Spaceport on July 12."

"And the trajectory to Mars is a free return trajectory, I understand?" added Makihiko.

"It takes about six months to get to Mars and 18 months to return to Earth, if an emergency makes that necessary," confirmed Sergei.

"There's a family of free return trajectories," replied Laura. "There's also a 140-day trajectory that takes 3 years to return to Earth, but we don't have enough fuel to get to Mars that fast, or enough consumables for the 3-year return. One reason we're flying to Mars in two gryphons is so that we can complete the mission if either one has serious problems."

"And we have a backup gryphon on Mars, nearly refueled, to provide yet another backup," added Will.

"Now, why isn't the *Pavonis* fully fueled?" Laura asked him, irritated. "I understand that Surface Exploration used the ranger and Prospectors so much, there wasn't enough power left to complete refueling."

"Partly true," replied Will. "The *Pavonis* should be fully fueled by the time we arrive, unless there's a severe dust storm. But remember there are two hippogryph automated cargo vehicles already at Aurorae. Both arrived with a tonne of liquid hydrogen and both now have 18 tonnes of liquid methane and liquid oxygen. The *Pavonis* needs 35 tonnes of methane and oxygen and already has 24 tonnes. So there's already plenty of fuel on Mars for the launch of the *Pavonis* and half the amount needed to launch either the *Olympus* or the *Elysium.* We'll arrive with enough solar panels to fully fuel either of them, plus run our vehicles and equipment."

"That's comforting," said Laura, though she sounded irritated by the delay.

"When do the hippogryph cargo vehicles depart for Mars?" asked David.

"April," replied Sergei. "They launch to low Earth orbit from Cape Canaveral, refuel in low Earth orbit and again at the L1 Gateway—automated, the Indians don't have to do anything—then head for Mars in May. They arrive in February. Our two hippogryph trans-Earth injection stages will launch from the Colorado spaceport in April and May, push our cargo into low Earth orbit, ride to L1 with the Sunfires, be refueled at Gateway, will provide our trans-Mars

injection firing, will aerobrake into Mars orbit separately from us, and will wait there 18 months to push us back to Earth."

"And there is a hippo on Phobos, the *Stickney,* partially refueled with Phobosian propellant," said Ethel. "Unfortunately the drill is stuck and can't penetrate deeply enough into the moon to make very much. But it probably will have made enough to be a backup for trans-Earth injection. Either hippo on the surface, fully fueled, could also launch itself into orbit and transfer enough propellant to a gryphon for trans-Earth injection."

"A lot of possibilities," said Laura.

"This is a very complicated mission; much more so than a Northstar flight," commented Will. "Gateway and Peary have been accumulating our methane propellant for months; that's one reason the gryphons for Northstar and for the tourists are being pushed to the moon by hydrogen-oxygen stages. Columbus 1 requires two gryphon launches, four hippogryph launches, and one launch with the Sunfires and their hydrogen tanks, all from Earth, and two Thunderbird launches from Peary with methane and oxygen propellant."

"One of the reasons it's so expensive," agreed Sergei. "But two years ago, Columbus B had to complete three launches from Earth and one from the moon, and two years before that Columbus A needed two launches from Earth. The fuel depots in low Earth orbit, Gateway, and low lunar orbit have gotten a lot bigger and can handle the load."

"It's also the reason there's no tourist launch to the moon in June. Northstar 15 has a seven-month mission ending in late January, Northstar 16 has a seven month mission from February 1 through late August, and there are no lunar cargo flights at all between late February and September," added Laura. "Columbus 1 gets all the capacity for lunar transport."

“What are the contingencies if a gryphon misses its landing pad at Aurorae?” asked Makihiko.

“Each gryphon has enough food for its three-person crew to complete an 18-month mission on the surface,” replied Laura. “The gryphons are quite small as habs, but adequate in an emergency. Each has a greenhouse that can be used for additional living space, as well as a place to grow food. Each has two cabrios—‘buggies’—for local transport. And each gryphon has enough deployable solar panels to manufacture the fuel it needs to return to orbit 18 months later.”

“But that really isn’t a serious possibility,” said Sergei. “Our satellites give us excellent data about the density of the upper atmosphere and we have reliable GPS coverage. Project Columbus has landed six vehicles on Mars, and all of them have been within a half dozen meters of the landing point. If the miss is less than a few hundred kilometers, the rangers could drive over and bring the people and cargo to the primary landing zone.”

“Are the three-d printers ready to go?” asked David.

“The printers have always been ready,” replied Ethel. “The question is whether the equipment for making the indigenous feedstock is ready. We hope so, but we’ll have several hundred kilos of materials with us, just in case.”

There was a lull in the conversation. Then Will said, “I’d like to hear our thoughts about being on an historic mission.”

“Good question,” said Ethel, nodding, and David nodded as well.

Laura shrugged. “Like you said, it’s historic. We go out, we follow the mission plan, ideally we complete some of the supplemental mission objectives, and we come back to Earth.”

“To fame,” added Sergei.

“That’s not what I mean,” replied Will. “This project is the brainchild of Zeke Swift. His long-term goal was to make humanity a ‘two-planet civilization.’ We’re the founders of a new civilization, potentially.”

Laura considered that argument. “Well, maybe. Project Columbus has some bells and whistles NASA never would have included, like the drills and propellant manufacturing plant on Phobos. NASA would have come up with a simpler plan with a super-booster and fewer launches, and would have included reactors.”

“A ‘simpler’ plan that would have never included the moon and would be getting us to Mars in the 2040s after spending another hundred billion,” said Will.

“Look, I’m not interested in debating politics; we’re going next year,” replied Laura. “We’ve got good equipment based on a lot of lunar experience. I can’t see how our mission becomes the opening chapter of a new civilization; we’re not staying. Columbus didn’t found a civilization.”

“He accidentally made one possible, though,” said Ethel. “We may do the same.”

“Maybe, but it doesn’t change what we have to do,” persisted Laura, her voice rising slightly. “Maybe a genius like Zeke Swift could have jump-started the colonization of Mars. Maybe. But he’s dead, and geniuses like him don’t come along very often.”

“I . . . think it might change what we do,” said Will, speaking slowly and carefully so as not to irritate Laura further. “The in-situ resource utilization we’ll do isn’t just for us; it’ll lay the foundation for Martian industry. Our expeditions need to look for copper and gypsum and salts, not just for remnants of life. Our greenhouses and animal husbandry will lay the foundation for Martian food production.”

Laura stared at Will. Clearly, she was at the limit of her patience. “Well, if you happen to spot copper ore, make a note of it, but we’re not going to spend a day evaluating its potential. If we raise some extra vegetables, great; we’ll freeze them for Columbus 2. But we’re not going out of our way to raise extra, and remember that all our animals have to be slaughtered and our greenhouse mothballed because Aurorae will be abandoned for nine months before Columbus 2 arrives.”

“We don’t have time to do a lot of extras,” added Sergei.

“That’s right; we don’t have the time,” said Laura. “We’ll do our mission and leave the future of Mars for the future.”

Mars opposition, March 25, 2029 (launch of TROVs and satellites, Jan 2029; arrival, late Sept. 2029)

Late August 2031: Will takes position of Director, Lunar Surface Exploration, for 2 years, renewable
Meet Asaph Swift, director of LEO tourist operations
Late August 2031: Northstar 8 (7 astronauts, 5 tourists) goes to moon in a Gryphon capsule Commander: Douglas Morgan

Mid-late October 2031: Will begins to date someone; it doesn't work out
Introduce Moises Arroyo
Shelter 3 set up at Peary
Will proposes new approach to astronaut training and surface exploration to Desmarais, latter is shot down;
Hippogryph lander, ranger, TROVs, solar array lands at Aurorae; talks to Zeke Swift about moon exploration and astronaut recruitment
Northstar 7 departs; NS8 takes over
Will and Morgan talk about NS 8's science objectives, agree on them

December 2031: Northstar 9 (8 astronauts, 4 tourists; Larisa Tatarinov, Commander) goes to moon in Gryphon ; Peary gets mice colony and 2 biologists; experimental hard-cryo equipment arrives; Theo Brown (engineer) dislikes the tourists and poor quality astronauts
Jan. 2032: Indians (commanded by Kalidas) set up Gateway
Jan. 2032: Shelter 2 set up by Chinese at Shackleton
Feb. 2032: NS 8 departs; Congress cancels Liberty shuttle; Swift gives up Redstar name and his project becomes NASA's Columbus

April 2032: Northstar 10 goes to moon with 8 astronauts (including Moises Arroyo and 1 Chinese and 2 plastic technicians), 4 tourists
Condor at Peary is repaired and rendered functional.
Will arranges for Condor 1 to fly to south pole with methane and Chinese astronauts refuel Condor there
Solar storm; Larisa and others get a high radiation dosage

July: Meeting to reconfigure the Northstar flights to 2 per year, 12 astronauts each, and 2 tourist flights per year, 12 tourists each (or some tourists and some astronauts)

August 2032: Northstar 11 goes to moon with 10 astronauts, including two Russian basalt construction experts

December 2032: Northstar 12 (commanded by David Alaoui) goes to moon with 12, simultaneous with a tourist gryphon with 8 and 2 astronauts

Late Feb. 2033: launch of Pavonis and hippogryph cargo lander to Mars
David takes expedition to Marius with plans to stay a while
Late March: Gryphon goes to moon with 10 tourists and 2 crew

April 10 – May 27: second Marius expedition (6 weeks)

June 27, 2033: Mars opposition
Late June 2033: Northstar 13 goes to moon with 18 astronauts (American commander)
Russians launch mission to asteroid
Vice President visits with new NASA Administrator
Russian mission to asteroid, July 2033

late Nov./early Dec. 2033: Pavonis and Hippogryph cargo lander lands on Mars
American commander ventures into a lava tube; there is some trouble
Will sees Ethel; she is added to Northstar 14 at last minute
Swift visits Northstar Command
Family visits, asks why he wants to go to Mars

Late December 2033: Northstar 14 goes to moon with 18 astronauts (Ukrainian commander)
Another Marius visit, and to visit Reiner Gamma

Spring 2034: Zeke Swift dies in auto accident

Columbus 1 crew selected, summer 2034

Mars opposition, Sept. 15, 2035 (Columbus 1 launch, July 24; arrival, February)

Plots:
Peary gets a new, Mars-sized greenhouse, chickens, rabbits (late 2032)
Ethel returns to test new carbonyl and plastic synthesis equipment to make lunar equipment (Dec. 2033)
Infrared telescope placed at bottom of crater
Plans for big farside radio telescope
Asteroid miners come to test equipment
Work in Douglas Morgan (MF4), Theo Brown (MF3), Yevgeny Lescov (MF4, born 2000), Emily Scoville (born 2004; MF 6)

Travel calculation: Thunderbirds can put 14 tonnes into orbit for $30 million ($2,100 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

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