

The Hub, the Rock and the Ring

Novel preview chapters

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Hi there,

If you're reading this, it means you've heard of Exodus Space Systems and our plans to remove hazardous space debris from low Earth orbit. We want to do this because these thousands of old satellites, satellite parts, and rocket bodies are threatening the satellites on which we depend for valuable services like GPS, our internet & communications, Earth observations and so on. We predict that space debris removal will be a thriving industry in years to come, and we aim to be a leading player in that industry.

But this is not the limit of where we want to take this company. I've often said that the question we should be asking when it comes to the human exploration and settlement of space is not "where next?" whether that's the moon, Mars or asteroids. Better to ask "How many?" How many people can we have living in space, at *any or all* of these locations? We aspire to have 50,000 people living in space by 2050, and our goal is to help create the technologies that enable this settlement.

I started writing The Hub, the Rock and the Ring a couple of years ago, and have updated it as our technology has progressed. This is my vision for what that future (50,000 people in space in 2050) might actually look like, what its people would be doing, and how that kind of economy would sustain itself. These 6 preview chapters are perhaps the first eighth of the novel, which I hope to eventually finish if I get the time.

I hope you enjoy it!
Mike Le Page
August 27th, 2018

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Dr Maggie McDermott

March 23rd, 2052

“Why not go to the asteroids from Mars? It’s closer, isn’t it?”

It had been 2050: Maggie’s final year at university. The CEO of the Asteroid Mining Association had been invited to give the students an overview of the dozens of mining companies running expeditions to the asteroids. He could barely contain his excitement when he reported that more than fifteen thousand people had now ventured out beyond the Earth-Moon system, with five thousand at Mars and the rest at hundreds of asteroid “stepping-stone” colonies, all working to establish the first outposts of civilisation around the solar system.

The CEO had grinned at her question. “That’s a great question, and thank you for asking it... Unfortunately, the answer is a combination of economics and orbital dynamics, two of the most boring topics known to man...” His exaggerated tone of voice inspired a few chuckles around the room.

“But it’s really important to understand this, or else none of the rest of it makes sense.” He paused to make sure everyone was listening.

“Water, carbon, and energy: that’s all you need to make rocket fuel, anywhere in the solar system. Luckily for us, they *are* everywhere, especially in the inner solar system where solar energy is so plentiful. So whether you’re on Mars, or mining asteroids, we can always make rocket fuel.”

“But here’s the rub: there’s only one place in the solar system where making rocket fuel is *cheap*. So the first part of the answer to your question is simply economics... We go to the asteroids directly from Earth because the fuel we need to do it is cheap, *on Earth*.”

He walked over to a table at the front of the lecture theatre, on which sat a globe of the Earth.

“But there’s a second part to this answer, and that’s the orbital mechanics part... Remember, orbits are *planar*...” He held out his whiteboard marker, moving it in large horizontal circles around the globe. “...If you’re a satellite in orbit around the Earth, there’s lots of stuff you can do with a small amount of precious rocket fuel, as long as you stay in this flat *orbital plane* of the orbit.”

He started spiralling out his marker into larger horizontal circles “You can make it bigger or smaller... or even nice and *elongated*...” he started making long looping motions around the globe with his hand, still on the level.

“...And all of that is pretty easy on fuel. But as soon as you try to change the *plane* of the orbit... to make the orbit more *inclined*” his hand started moving the marker until it was circling almost vertically over and under the globe on the desk. “Now *that* is expensive.”

“So the point is this... because Earth is the only place where making rocket fuel is cheap, and changing planes takes lots of fuel, we try to avoid changing orbital planes when we’re not at Earth. Okay?”

“Now, if we think about the layout of the solar system, the problem is that Mars is on a different *orbital plane* from Earth, so to get to Mars and build the colonies there, those astronauts *already* had to go through one plane-change maneuver... And that’s fine, because Mars is our biggest colony.”

“But all the asteroids we want to get to, are *not* in the same plane as Mars. In fact, all the big asteroids are each in their own *separate* orbital planes. So if we went to Mars, and then to the asteroids, we would need to make *two* plane change maneuvers, where if we go straight from Earth, we only need to make one. *That’s* why we don’t go via Mars.”

He glanced at Maggie once more to check she was with him.

“What you do have right, is that we need stepping stone colonies. So instead of making Mars that stepping stone, we use small asteroids that are in the *same orbital plane* as the asteroids we want to get to.”

Maggie especially remembered the moment that recognition had flickered over his face; his double take at seeing that she had already known the answer, had fed him a question that would educate the rest of the audience.

“Hang on. You’re Maggie, right? Diedre McDermott’s niece? They told me you’d be here today.” The CEO smiled when she nodded. “I like Diedre, she’s good value. Give her my best when you talk to her next.”

The CEO looked up to address the rest of the audience. “Maggie’s aunt Diedre is at one of those stepping stone colonies right now. That expedition is one of my favourites, so let’s use it as an example. We want to get out to an asteroid called “16 Psyche”, but we shouldn’t call it an asteroid really, because it’s a big planetoid, 250 kilometres across! And made of nearly solid metal. More nickel, iron, and platinum than has ever been mined in the history of the Earth. It’s definitely somewhere we want to be.”

“But we can’t go directly there, even with the rocket fuel we can put in a ship during the LAP.” He grinned at one of the students in the front row. “That’s Launch Assembly Process for those of you keeping track.”

“So instead, we’re building a habitat at a stepping stone rock: a small asteroid that flies close to Earth every seven years, then loops out into the belt where it crosses paths with 16 Psyche. That rock... what’s it called again?”

“Mirrabooka”, Maggie responded.

“That’s right. ‘Mirrabooka’ is the Australian aboriginal name for the Southern Cross constellation. It’s not a very big rock, but it *is* big enough to give our astronauts radiation shielding, it has enough water and CO₂ ice to make the extra rocket fuel we’ll need, and most importantly of all, it’s in almost exactly the right *orbital plane* for us to send humans to 16 Psyche in... was it 2060?”

“Yes”, Maggie responded.

“2060. Only ten years away Maggie. You could be on that mission you know...”

It was the first time someone had actually voiced the idea she’d been toying with for years... to join her aunt on this mission. It didn’t take much of a push in the end. Here she was now, age 28, two weeks since leaving home, four weeks away from arriving at Mirrabooka. If all went as planned, she wouldn’t return to Earth for thirty years or more.

Maggie was still making her own notes on who was doing what at the colony. Once they arrived on board, there would be nineteen people in all, each with multiple specialties. Maggie herself would be one of the first qualified anthropologists to visit the belt. Her collaborators back home wanted her to document her initial impressions on the sub-culture of this isolated group of individuals so far away from the sun. The psychologists had done their best to assemble a compatible group, but it was the sense of camaraderie going forward that would affect the success or failure of the mission; especially once it came time to transit onwards to 16 Psyche.

Her personal connection to this mission – her aunt Dr Diedre McDermott – was probably what had swayed the selection decision in her favour. The youngest sister of her father, Diedre had been the cool geologist aunt who came home twice a year with rocks and stories from all over the world. 16 Psyche had been a hot topic in the geology community ever since the first probe had arrived and found more accessible iron, nickel, and platinum than had ever been mined in the history of Earth. Of course her geologist aunt had wanted to go, and it didn't surprise anyone when Diedre was offered a place on this mission.

Neither was anyone surprised when Maggie decided to follow in her footsteps, but she knew her reasons for coming were somewhat different... more to do with how the lessons learnt in sustainability at this colony could be applied back home. Still, she was a little nervous: it was going to be the first time she had met her aunt as an adult. The occasional video message didn't really cut it when you were trying to get to know someone.

Maggie looked over the notes she had made so far. In her mind, it was easiest to group the crew in the order they arrived at the rock. Three generations of crew, who transited during the three passes of Mirrabooka by the Earth in '38, '45 and now, '52.

In '38, the original crew of nine had arrived in orbit around Mirrabooka, joining the robot mining and construction equipment that had been sent in '31. There were two ships in that transit: a crew ship with living quarters, and a cargo ship carrying the EAP DeTA (Extended AquaPonics-optimised DEployable Toroid Array) and enough supplies to keep a small crew alive just about indefinitely. It was they who had deployed the DeTA habitat module, and docked it to the crew/cargo ships (collectively called the "hub") and set the whole thing spinning. It was also they who started mining operations and construction of the Massive Toroid Array (MaTA) in earnest.

There was a wide mix of primary specialties: Chad Hooper, Trent Kally, and Mikhail "Misha" Solovyova were former space agency astronauts, now the lead architects of the mining and construction operations. There was James Malson, navigator, programmer and IT specialist, as well as Valeria Rojas, electrical engineer and communications officer. Dr Peter Chu, general physician and surgeon, was married to Didi Williams, head of extended aquaponics, while rounding out the crew was Dr Diedre McDermott as the lead scientist, specialising in geology, and Dr Maud Schneider, as dentist and 3D printing technician.

In '45 it was just four crew making the transit. No dedicated crew ship for this one, since all that was needed were supplies for building the MaTA. That meant a small crew module tucked into the nose of a cargo ship, and an opportunity to fill the gaps in the existing specialties. Dr Mithran Subramaniam was a science administrator with expertise in medical and biotech, and was later promoted to colony commander. Dr Ken Carvalho was a clinical psychologist and physiotherapist. Dr Jack Suliman was another EAP expert, who happened to also be a second doctor and anaesthetist. Miko Tanaka was a chemist, but her specialty was in custom electronics that could be 3D printed using the platinum resources on Mirrabooka.

Now, in '52, Maggie and another five crew were in this crew module, tucked into the nose of yet

another cargo ship full of supplies for the MaTA. She had them listed as Grant Preece (UK), Jacques Brun (France) and Dean Hooper (USA), Tresna de Luisa (Australia), Danielle Ng (Canada) and Maggie McDermott (Ireland). They were all much younger than everyone else that would be at the hub, but they were also the first of the group that was expected would transit to 16 Psyche and live the majority of their working lives out there.

The sheer size of the asteroid mining boom now meant it was better to have fit young candidates out on mission sooner and have them learn their specialties on the job. Of course, they'd all graduated with their Masters of Space Mining at the International Space University, but that was really just a general education required by the various asteroid mining companies.

Maggie took a moment to glance at the other five in their bunks, each attending to personal matters during the quiet time before lights out, wondering what would come of this grand experiment in human exploration. They had all become fast friends in the last six months since they'd been selected, but it was hard to believe they would have become friends if they hadn't had that in common: they were all so different! It was the ultimate example of throwing people together, making them dependent on each other for their lives, and seeing what would happen...

Grant Preece

May 1st, 2052

*Somehow...
Down, on the ground, where I first met you,
There was a man, with a different view,
Especially when it came to women...*

Didi Williams's voice rang out in the quiet of the dining area, her jazz croon sweeping everyone along as it always did. No less than Ella Fitzgerald incarnate, some said. Hearing her sing in person for the first time, Grant had to agree. He watched her continue, her fingers caressing the keyboard like an old friend:

*That man...
He to whom I dedicate this birthday song,
There was a smile that could do no wrong,
Especially when seducing women...*

Grant looked over at Chad Hooper, former NASA astronaut, grinning so hard he looked like he might sprain something. It was his 60th birthday, and the whole crew was gathered for the celebration. The icing on the cake was that Chad's son Dean was among the new crew that had arrived at Mirrabooka just in time for the party. The music picked up pace, and Didi was joined by Dr Ken Carvalho on bass, Trent Kally on drums.

*But that man, with all his tricks,
Left his girls, gave up his kicks,
Where is he?
What 'bout me?*

Didi's smirk was infectious, naughty. The audience giggled nervously as the final member of the quartet and Didi's husband of 35 years, Dr Peter Chu, picked up his cornet and lightly bounced over

to join her in the low spin gravity. She shrugged at the mock disapproval on his face, continuing defiantly:

*Go to space, (they said) you'll find this man,
He'll be cute, (they said) good with his hands,
A dreamy kiss...
...And I got this?*

Raucous laughter burst across the room as Didi stuck her thumb out towards Peter, who couldn't help smiling back at his wife. Trent managed a rim shot before Didi led them into the chorus:

*Here at the Hub, the Rock, and the Ring,
There's no way to say,
It's not his day,
We'll mark the date,
And celebrate,
Our MVP, come and see,
The most exalted celibacy king.*

Chad's belly laugh reverberated throughout the spacecraft. Didi pushed on, lifting her left hand to indicate her ring finger:

*He has two balls, a cock and no ring.
But do you ever hear,
The women cheer,
Our own Don Juan's
Unleashed his charm?
Won't he pick me? Can't he see?
I'm looking for another way to sing...*

None too soon, Peter cuts in with his cornet, to universal laughter, and it eventually settles into a regular jazz solo. Grant wasn't really a jazz man, but anyone could appreciate a quartet this good.

"Not too shabby eh?" James Malson bounced up next to him lightly, handing him one of the beers shipped in especially for the party. "Been hearing them practice that tune for weeks, but Didi's been humming it the whole time. I wondered what the words were. Knew it would be something like that."

"She's good." Grant mused. "They all are. Was Chad really that much of a womaniser? Back before he came on mission?"

James smirked. "It was 'Chad the cad' at the time, so you tell me. Dean never spoke about it?"

"Nah. Only spoke about his mum, really, and how much trouble she gave him for coming out here." Grant paused, watching Chad and Dean, father and son, listen to the music together. "Chad left them to come on mission when Dean was twelve, so that was what, back in '37?"

"Yeah. Chad was there during LAP in '38, so that would be about right."

James and Grant lapsed into silence, sipping their beers and watching the band from the edge of the group. The two Brits had quickly gained a rapport in the week since the cargo ship had arrived at the Hub, which was in orbit around Mirrabooka ("the rock"), and the MaTA under construction

("the ring"). James Malson, navigator, had been tasked with bringing Grant up to speed on navigation.

"Big crowd in here," James spoke finally, gesturing around them at the nineteen individuals that were sitting or standing around the biggest space on the hub. "Now that you kids have arrived, I wonder if we're ever going to have any peace and quiet ever again."

Grant didn't need to be a Brit to read the dry sarcasm in the older man's voice. "Don't worry, I'm sure that by now, all you geriatrics must be deaf enough not to notice us."

James chuckled, and Grant found himself scanning the group for the five travel companions who had come with him from Earth. He spotted Tresna de Luisa talking to Danielle Ng on the far side of the group.

"And we're not *that* young. Tresna might be the prodigy, but she's still 23, and Dean's 27. Danielle, Maggie and myself are 28. Jacques is 34."

"Still kids." James retorted, gesturing at the remainder of the crowd, most of whom were in their forties or older. "We're close to max carrying capacity now, so you kids better know your stuff, or you know, eat less." The wry smile on the man's face took the edge off the words.

"Of course... We did all graduate with masters of..."

James did his best not to roll his eyes as he cut him off, "The MSM, I know. I helped design the course. I'm sure the psych evaluators did their job well too. We're destined to be one big happy family, building new homes for humanity across the solar system."

Grant chuckled, not just at the mention of the company motto, but also the unrelenting sarcasm. "What, you don't think it will happen?"

"Eventually, sure." James' voice took on a more serious tone. "But there's still too many mistakes that could happen, especially now that we've got new blood in the mix... And just one mistake, one unforeseeable, unknowable mistake is all it takes." James fixed Grant with a pointed look. "You kids better *know your stuff*."

"We do..." Grant took the point, trying not to dwell on the negative. Everyone living in space knew about the potential for disaster, but being reminded about it was always a bit of a downer.

They watched as Miko Tanaka wormed her way between the people in front of them to sit beside James. Earlier that day the small Japanese woman had served as a guide for the "kids" on the first transit down to the rock's south pole, giving them their first tour of the radiation shelter and processing station.

Grant couldn't help but notice the slight tension as Miko sat down slightly too close to James, then readjusted herself to a more professional distance.

"James. Are you going to say a few words?" Her voice was just loud enough to be heard over the music. "You, Trent, and Misha have always been Chad's best buddies."

"Maybe." James answered, looking down at Trent's hands flying across the drums, and across at the Russian pouring Chad another vodka shot. "I think Trent and Misha will have it covered though."

“Oh, come on James,” Miko pushed. “You should say something! He knows how much you hate public speaking, so he will appreciate it even more if you do.”

“I’ll think about it.” James said, hoping that would make her stop.

“You do that.” She flashed them a quick smile (one clearly meant for James), then made her way back towards the band.

When she’d gone, Grant voiced the question on his mind. “So... You and her?”

James coughed and looked more than a little uncomfortable as Valeria Rojas turned around in front of them and flashed Grant a brilliant smile by way of answer. “Oh for sure! Miko and James have been seeing each other since... when was it James?”

“Val, not now.” The colour had gone out of James’ skin.

“...oh I remember.” She grinned bitterly at Grant. “Since just *before* he broke up with me. Chad’s not the only womaniser in that boy’s club, you know.”

“God damn it Val.” James muttered under his breath, before looking at Grant by way of apology. “Grant’s only just arrived, and you *know* it was more complicated than that. Leave it be.”

With that, James turned and loped across to join Misha, Chad and Dean.

“It’s okay sweetie.” Valeria said to Grant as he watched the older man go. “Nothing you started that wasn’t already burning. We’ll sort it out.”

Grant took a long swig of his beer, and listened to the quartet finish the song “Celibacy King” with a flourish. The crew burst out in sustained applause, Chad especially, grin having never left his face. His belly laugh boomed out again as Didi addressed him with a curtsy and a “your majesty”.

Eventually the applause died down and Chad moved to address the group.

“Thank you everyone. You know how much you all mean...”

“Not so fast old man!” Didi cut in with a wicked smile. “We have something for you first...”

Didi turned towards the small pantry pod at the side of the kitchen, calling out, “Diedre? You ready?”

Along with the rest of the crew, Grant turned and saw Diedre and Maggie McDermott emerging together with a cake. But the collective gasp was let out when they turned to the crew and showed that the cake had a single candle on top, its naked orange flame flickering lazily in the low gravity.

Grant’s eyes (along with half the crew) quickly found Dr Subramaniam, mission commander, and watched for his reaction to this blatant breach of the rules.

His irritated eye-roll was apparent to everyone. “Didi...” he started with a sigh.

“Oh, fuck off Mithran, the filters can take it this one time.”

She didn’t waste time on the piano, launching into a jazzed up rendition of ‘happy birthday’, to which everyone joined in singing with gusto. As they finished the habitat smoke alarms started

screeching at deafening volume. Chad blew the candle out without hesitating, then doffed his imaginary crown towards Didi in a gesture of thanks.

James was already at a control panel, cancelling the smoke alarms, much to everyone's relief.

"So... As I was saying." Chad started once more. "You all mean the world to me..."

"Enough mooshy mooshy!" Misha interrupted with good-natured cheer. "Tell us all about your lady-loves!!"

Laughter, hoots and cheers; especially from the older women in the room.

"Yes Chad," Diedre McDermott lilted heavily in her Irish accent, still holding the cake and imitating Didi's song. "*What 'bout me?*"

Grant noticed Maggie blush and back up a few steps, trying not to be embarrassed by her aunt. Maggie had always been a quiet one, but he had heard enough to know Diedre was the complete opposite.

"Now, now!" Chad held his arms up trying to regain control as the older women in the module catcalled him. "There's only one woman who has my heart, and that is this guy's mom." He pulled Dean into a close bear hug.

His face turned quizzical, looking Dean in the face "Unless you brought it back for me?"

Dean shook his head, to more cheers and laughter.

"Anyway... *as I was saying...*"

As Chad launched into his speech, Grant noticed that James was avoiding eye contact with both Valeria and Miko, trying to enjoy the moment. Between the goading from Misha and Trent, and the hoots from the rest of the crew, James never did end up giving a speech.

An hour later, Grant spotted James doing more shots with Chad, Misha, Trent and a few of the others. Much as he might have liked to hear some more of those stories, Grant was happy to retreat to his quarters. Parties had never been his thing anyway.

Jacques Brun

May 3rd, 2052

"Now," Didi Williams tapped at the diagram on the whiteboard on the module wall with a hunk of dry wood. "I know you would have seen something like this at ISU, but this is the way we do it here. Jack Suliman and I have worked pretty hard on this EAP farm to make sure it will support 19 of us, so if you can slot in and do your part without complaining too much we would really appreciate that. Yes?"

The six of them stood around Didi wherever they could find space, in the first of the cramped DeTA chambers. They nodded in affirmation.

“Study it now, and then I’ll talk you through them as we walk around the DeTA.”

They’d hardly had time to glance at the twelve chamber, clock-like diagram before Didi set off bouncing along the floor with its gentle upward curve, hopping past fish tanks and hydroponic grow beds as she spoke.

“Here in chamber 1, we have a standard aquaponics setup: so trout, salmon or shrimp in the tanks, with starchy veg, leafy greens, fruit and nut trees, as well as staple grasses growing in the beds. You’ll see a lot of corn as we go around, but there’s also some wheat, soybean, sugarcane and hemp. There’s also dedicated sections for potatoes and tomatoes. Temperature and humidity varies from chamber to chamber, but point is, fully half of the twelve DeTA chambers are dedicated to aquaponics for food production. That’s chambers 1, 2, 3, plus 7, 8 & 9. Okay?”

The kids found themselves nodding once more as they tried to keep up with her, their strides unsteady in the Mars-equivalent gravity. It was just as Didi said for the first three chambers, but as they opened the airlock to the fourth chamber, the smell of chicken manure hit them hard. Jacques tried not to gag.

“Chambers 4 and 10 have the chicken coops,” Didi continued as she picked up a bucket and started throwing food scraps into the cages. “You get used to the smell. They eat just about anything that we don’t, and lay us eggs in return, so it’s a good deal. We also get to eat chicken once a fortnight or so, depending how well our roosters are doing their job. Break the rules and you’ll get double duty cleaning here.”

“That,” Didi turned to them with mock seriousness, “is the *second* worst punishment on the hub.”

The six of them looked at each other before Jacques finally asked the question. “The worst punishment, would be... what exactly?”

“I’m so glad you asked,” Didi replied with a grin as she put down the bucket and they moved into the fifth chamber, where the cutting antiseptic smell reminded Jacques of a hospital. Banks of grey opaque tanks lined the walls. “Chambers 5 & 11. Utterly disgusting: Utterly necessary. Known as the Septic, Compost, Worm and Maggot farming modules, or SCWorM if you like that acronym better.”

A murmur of recognition passed between them, as well as a good idea of what the worst punishment could be.

“As you know, when your personal waste collection vessels are full, you’ll need to bring them either here or chamber 11, and insert them into one of these four apertures here. Same goes for chicken shit or any fish solids you might collect during your cleaning shifts.” Didi demonstrated what she meant by taking a spare waste collection cartridge and inserting it into one of the four slots in the processing unit. It was as she lifted the flap that a truly foul stench hit them. This time they all gagged.

“If they’re working as designed, your waste unit will be cleaned here and the products will be washed through into the septic tanks, where they incubate with the necessary bacteria to turn it into something the maggots can use.”

Running her finger along the outside, Didi traced the route the imaginary waste would take, tapping on a second aperture halfway along the unit. “Here, is where we put in egg shells and other organic matter as compost, basically, it’s anything the chickens won’t eat.”

Following it along to yet another bank, she opened a door in the unit and carefully withdrew a draw with clear brown fluid sloshing at the bottom. A mesh insert above was covered in a seething mass of maggots, worms and other invertebrates.

“Notice,” she cut in before anyone had a chance to gag again. “This one doesn’t smell as bad. More like soil than shit. This is what we feed the fish, or the chickens if they’re low on protein.”

Didi Williams gestured to the draw full of bugs, no longer flippant, and fixed the six kids in the module with a deadly serious glare. “Do whatever you need to do to feel okay about this, because I need you to be able to look at this, and monitor these bugs’ condition like your lives depend on it. *Because they do.*”

She paused for emphasis. “Of course you did the MSM, so you know this in theory, but quite confronting to see the reality of it, right? As of seven weeks ago when you left Earth, all your lives depend on the health of these bugs right here...”

“We have food reserves of about 12 months on board at any one time... Somebody remind me how often Mirrabooka flies by Earth?”

“Every seven years.” Dean replied, soberly.

“We have four of these units here, four more in chamber 11, and we’re currently at 19 crew, 56 chooks, and eight hundred fish or so. Do the math and it works out we need at least six of the eight units in action to have enough carrying capacity for all of us so we maintain our reserves. Anyone care to guess how many SCWorM units we’ve had out of action at one time?”

“All eight.” Tresna spoke up. “I read it in the report.”

“Correct: all eight were down at the same time. Happened in 2042. Of course, it would have been a year before we actually ran out of food, but remember, what we care about is not just how much food we have in reserve, but how much food we can *sustainably produce*. Having all eight down, means having zero carrying capacity. Not a good situation to be in.”

Didi’s cheeky grin returned in a flash. “You’ll find at least one of them breaks down every other month or so. You just wait until it’s your turn to fix it.”

“Since Diedre and I pulled that little stunt with the candle on the birthday cake, our punishment is that we’ll be fixing the next three breakdowns.” She laughed merrily. “But did you see Mithran’s face? So worth it.”

Didi led them through the airlock into the sixth chamber, where another assault of strong smells hit them, but this time they were sweet, with eucalypts and tea trees fighting for space with small olive trees and rose bushes. The aquaponics setup was smaller this time, with the fish in the tank ornamental, the plants in the grow beds being herbs and spices.

Mithran Subramanium and Jack Suliman were both at the far end of the module, Mithran practicing his yoga asana, while Jack was kneeling on a prayer mat.

Didi continued in a hushed voice, “Officially, modules 6 & 12 are where we keep the strongly aromatic vegetation, but there are a number of medicinal compounds Jack can make using the plants in here, so it doubles as a something of a pharmacy. As you can see though, they’re the

closest thing we have to a botanical gardens on the hub, so we've agreed to make these two chambers the quiet rooms. We come here whenever we want a bit of R&R."

Mithran finished his pose and rolled onto his feet, bouncing over to join them. "How is the EAP induction going Didi? Show them everything yet?"

"Just about. Going to take them around the other six chambers now, then I'll show them the roster."

"Very good." He took a moment to make eye contact with each of them, but settled on Jacques. "Just remember to book in a meal with me in the next week. I want to get to know each of you better. Didi here might be the best chef this side of the solar system, but I do make a good dhal..."

"I remember..." the words were out of Jacques mouth before he thought about it. He was grateful when Didi saw the look of embarrassment on his face and took the moment to usher the rest of them away, showing them some of the more unusual plants in the chamber.

"Sorry I didn't talk to you much at the party." Mithran said quietly when they were alone. "I wasn't... I wasn't sure how I would react to seeing you again."

When Jacques didn't say anything, Mithran continued. "What has it been? Eight years? I must admit I didn't allow myself to believe this could actually happen..."

"Why not? I said I would come..."

Mithran raised an eyebrow. "As I remember it, you were top of your class at that Parisian fashion school when I got the call. I honestly thought that was the end of our time together. Didn't you?"

"I said I'd come." Jacques repeated himself.

"But then you go and drop out of fashion school, start a five-year engineering double-degree, win a scholarship to do an MSM, and *then* get selected for this mission. What are the odds on that working out? Who could possibly live up to those expectations?"

"I said I'd come." Jacques felt a little like a broken record, but he couldn't think of what else to say.

Mithran smiled despite himself. "You are crazy. You know that right? Go back to your group, we'll catch up properly later."

"D'accord." Jacques turned and made his way back to the group, singing on the inside.

Tresna De Luisa

May 6th, 2052

Tresna rechecked the attachment to her suit before disengaging the spring-loaded camming device from its crevice in the rock. Moving over the surface of Mirrabooka in zero gravity was much simpler than rock-climbing would ever be, but the tools were the same, and she checked them with the same diligence. It was bad enough being the youngest person in the crew... she was not going to be known as the first schmuck who had to be rescued because they accidentally floated away from the surface of the rock.

“Good work Tresna,” Trent called over the coms. “This isn’t a race kids, just steady as she goes, complete the drill and you’ll get to see something amazing.”

Tresna turned to see Trent looking down at them through the window of the transfer craft, floating a dozen meters above. A few kilometres above that in orbit, she could see the Hub spinning in the sunlight: the two ships were joined tail-to-tail so the crew section could get the highest gravity. Attached to that was the DeTA, with its distinctive segmented shape, and counter-rotating flywheel. Below her, the asteroid known as Mirrabooka was little more than an oversized boulder, 50 metres across and shaped like a potato, yet it still felt incredibly massive by comparison.

The “adults” had been alternating as guides for the “kids” ever since they arrived, but Trent had won out on this one, the day when the new crew finally got to EVA inside the now structurally complete MaTA (Massive Toroid Array). Officially it was another training exercise, this time to get experience transiting across the surface of the rock in their suits, but they all knew this would one day be home to one of the first truly self-sustaining colonies, populated by all the people travelling to and from the belt. There was a sense of occasion that came with going inside the unpressurised shell of such a giant construction for the first time.

She looked over at Maggie who was about level with her, methodically picking her way across the surface with her hand-held camming devices. Grant was further over in that direction. Jacques was a little further ahead, but she’d lost sight of Danielle and Dean, both of them super competitive and racing ahead.

They’d started only twenty minutes earlier at the radiation shelter; an inflatable module buried many meters deep in the sandy asteroid regolith, and big enough for the whole crew in case they had to ride out a solar storm. Arriving in 2031, it had been the first man-made object to arrive at the rock, its position chosen automatically so as to nestle in a void between rocky outcrops. Because that position was nearly at the south-pole, the trek from the shelter to the MaTA construction site at the asteroid’s north pole involved climbing nearly halfway around the rock.

As the four of them worked their way over a ridge on the rock’s equator, it became clear just how big the MaTA was. Made from segments of fused asteroid regolith, and cantilevered out vertically above the north pole of the rock, it seemed like they had come across the remains of some giant alien’s ball and hoop game... the MaTA was easily wide enough to encircle the rock, yet slender in cross-section. Tresna saw Danielle and Dean again briefly as they climbed up the rim and disappeared inside the nearside of the large grey torus.

Just off to one side, the spider-mole was now anchored in place, a robot arachnid that had made thousands of trips to bring the raw material to the processing plant that held the ring secure to the rock. The two machines barely seemed substantial enough to have built such a structure. It was surreal to see the megalith MaTA floating above the landscape of the rock, a giant ring all but weightless in the zero-gravity.

“Not bad for fourteen years work I think,” Trent said over the coms, his Aussie accent understating the level of pride in his voice. “Plan is to have it sealed, pressurised, outfitted, orbited, and spinning in the next three years... Question is, are you kids up to the job?”

“Hell yes.” Tresna answered easily, her Aussie accent mirroring his in her excitement. She resumed her trek towards the mount point. “How did the external wrapping go in the end? The status updates were pretty dry reading you know...”

“Hah! Of course they were. Blame Mithran for that. Not too much to say though. We used all of the poly film we had from the '38 transit, and most of the '45 shipment too. Connectors lined up, minimal ice sublimation. Should achieve near Earth-surface radiation levels inside once we charge the grid.”

“Cool.” Tresna felt herself hesitate. “So the ice levels...?”

“Water ice was present at higher levels than we projected. Dry ice was about normal,” Trent answered. “So the ice layers of each segment are pretty much full... once you add the polyethylene wrap and the grid, it's easily the best radiation protection this side of 16 Psyche.”

Tresna was about to respond when one of her cams pulled free from the crevice it was lodged in. Her sudden intake of breath over the coms told everyone she was flailing as she started floating away from the surface, the cord to her remaining cam her only link to the surface.

She forced herself to stop panicking, taking a few deep breaths. There was no real danger here. They had trained for this. Just deal with the problem.

Tresna reached to one of the cranks on her belt to reel the loose cam in. Then she felt for the other one to reel herself back in towards where her remaining cam was lodged in a crack. She heard clapping over the com as she inserted her reclaimed free cam in another crevice and planted her boots back on the rock.

“Nice work Tresna. Happens to the best of us.” Trent said. “Old Mirrabooka here is just a big rubble pile after all. Some of those cracks aren't as secure as they look.”

Tresna saw that Maggie had moved towards her in the last few moments, and Maggie's voice now sounded over the com, “Are you okay Tresna?”

“I'm fine, Maggie,” Tresna replied, looking back at the crevice where her cam had been, now significantly wider than before. “One of these boulders over here just moved a bit...”

She paused as she saw something glint. “Hey... Is that what I think it is?”

A chorus of curiosity came over the coms as she left her cams in place and spider crawled back to the spot where she had come loose before. Sticking her glove deeper into the crevice, she fished out the nugget and held it up to the sunlight. It was big and lumpy like the sweet potato she'd cut up last night.

“Turn your shoulder camera on Tresna.” That was Trent again, sounding more excited. “Do you remember how to weigh it?”

Tresna passed the nugget from hand to hand, feeling its inertia press deep into her gloves despite the lack of gravity. “It's *really* heavy. Probably twenty kilos.” She paused for a moment, holding it up to her camera so everyone could see it on the video feed. “So fairly pure platinum I guess. How much would this be worth?”

“Hah!” Trent snorted over the coms. “If it's anything like the others we've found, it'll be a few tens of millions. Let Deidre and Miko figure that out... All I'll say is ‘congratulations Tresna,’ and ‘you just paid for your trip.’ Now stow that in your pack and get your arse over to the MaTA.”

Danielle Ng

May 28th, 2052

“On your marks...”

“Get set...”

“Go!”

Misha Solovyova’s voice crackled over the PA in the DeTA, giving the command that started the ring race. Danielle was ready, launching herself over the threshold into chamber 7. She did her best to keep moving forward without falling over in the partial gravity.

Running in a spinning habitat was always a weird feeling, especially in Mars-equivalent gravity. It was a different kind of gate to running on the ground, because you had to push more backwards and less down, while still adjusting for the upward curve of the DeTA. She was an athlete though: she would adjust.

She leapt over the threshold into chamber 8, where Diedre McDermott and Maud Schneider cheered her on, and she felt herself finally getting into some kind of loping rhythm. She wondered if the other relay team had figured it out yet.

This ring race was important, even if it made them feel like mice in a running wheel. The DeTA gave them partial gravity, but not the full Earth gravity they had been used to. Partial gravity was much better than the zero gravity they had to deal with for six weeks on the transit out, but it still meant they had to exercise much more than usual to stay healthy. A baton relay race was as good a way to exercise as any, and frankly, it was a lot more fun.

Danielle leapt through the opening to chamber 9, where James Malson sat watching a monitor. “You’re a second ahead Danni!” he called out as she raced past.

The race was between two teams of four, each one starting halfway around the ring from each other. Each team was allowed one runner at a time, and each runner had to do a lap of the DeTA. It kept going until one team’s runner caught up to the other team’s runner, or until each runner on both teams had finished three laps.

The chickens in chamber 10 squawked as she entered in a rush, trying to breathe shallow for the few bounds it would take to pass through the smell. No one was waiting in here to cheer her on, obviously. The same was true for chamber 11, and she bounded through, with only the echoes of her breathing for company.

She heard the cheering as she entered chamber 12 though, and the competitor in her couldn’t help but scope out the opposition team, ready to go as soon as their runner Maggie came back around. Dean and Grant stood towering next to Miko (the “adult” on their team). Interesting to see the comparison between quarterback build of Dean, the tall lanky broomstick that was Grant, and the whippet-like Miko, but Danielle couldn’t help but realise how fit they all looked in their exercise gear.

By contrast, her team had looked more like movie stars than athletes. Between them Jacques, Tresna and Dr Ken Carvalho possessed an entirely unfair set of genes for beauty, and if they had a mind to, could probably sell enough running shoes to fund a national space program: they just weren’t runners themselves.

At least this Vietnamese-born Vancouverite was fast. Danielle figured the other team would probably have the best of their respective matchups, so she needed to extend the lead against Maggie as much as she could. She stuck out her tongue at Dean as she passed and pushed harder.

“Four seconds ahead.” called out Misha as she barreled through chamber 1 at breakneck speed.

The DeTA was 160m around, she knew, so four seconds meant she was probably leading by a whole chamber or more. The effort was finally starting to put a strain on her breathing though, and she could feel herself slowing down.

It was the smell of the chickens in chamber 4 that caught her off guard, and she could feel a coughing fit coming on even as she entered chamber 5. They must have thought her crazy as she entered chamber 6, coughing her lungs out but still running forward like a maniac.

Valeria caught her as she handed the baton to Jacques and watched him start running, looking off balance but gaining some rhythm the same way she had.

“Good work runners!” Misha’s voice crackled over the PA again. “Danielle’s team is currently, uh... five seconds ahead... Now for Jacques versus Dean...”

Valeria handed her a bottle of water as she gradually caught her breath.

“I should have warned you about running through the chicken coop!” Valeria commiserated. “The second one is always the worst, cause it’s just as you’re getting tired and trying to push through the final stretch.”

“Yes, that was bad,” Danielle coughed out before taking a sip of water. “I’ll pace myself before I go through it next time.”

“For sure.” Valeria agreed. She looked sideways at Ken with a smile. “Never been much for these races myself, but our resident psychologist always did say they’re good for morale.”

“Not just me.” Ken looked up at the mention. “Plenty of good studies to confirm it... The feeling of running in one direction and seeing scenery move past is always going to be better than using a treadmill. As for races, we always want to have a constructive outlet to relieve competitive urges. Wouldn’t you say so Val?”

Valeria rolled her eyes “Ha Ken, very funny,” she said her tone indicating he had touched a nerve. “Miko and I work fine together. The fact that I want this team to kick Miko’s team’s ass is purely coincidental.”

“Uh-huh.” Ken acknowledged that in his best non-judgemental voice.

“Three second difference,” they heard James call from two modules down. It seemed Dean was making up ground fast.

They saw it action a moment later as Dean came gliding into the module with a weird, half-lobing, half-skipping gate. It seemed he was less running down the module than flying. He poked his tongue out at Danielle as he went past in the low gravity.

“What the hell was that?” Valeria asked, perplexed as he disappeared into the next chamber.

“Joping?” Danielle ventured the unfamiliar word. “Yes, I think that’s what it’s called. They started doing it in the LEO games last year.”

“Set a new speed record, yeah” Tresna interjected. “Only really works in low spin G though.”

“You know how to do it?” Danielle asked Tresna, curious. She’d seen Tresna be ridiculously talented at enough things already, it wouldn’t surprise her if this was another.

“Not really, but I’ll give it a shot,” Tresna said, noncommittally.

“One second difference!” James called from down the way. They could hear Jacques coughing hard as he closed the distance, burst into the chamber and handed the baton to Tresna. She was off with a light skip into chamber 7.

“Nice work Dean and Jacques!” Misha called over the PA. “And we are back to neck and neck. Miko versus Tresna!”

Danielle listened to Jacques regaining his breath, and sipping the bottle Valeria gave him, and then to the calls as they continued. The amazement on Ken’s face was obvious as Tresna kept pace with Miko. Valeria watched without comment when Miko bounded through their chamber lightly, seeming to know exactly where to place her feet and how many steps to take. She had clearly done this hundreds of times before.

Ken started limbering up as the two women came down their respective back straights, performing a few quick stretches with his ankles and quads. “Looks like this will be a live one hey Val?”

Tresna vaulted into the chamber with the baton outstretched and long blonde hair trailing behind her. Her breathing was better than the last two runners, but clearly starting to struggle.

“Great job girl!” said Valeria without pretence as Tresna handed the baton to Ken, who left quickly. “Miko is one of the best runners on the hub!”

“Great job you two!” echoed Misha. “Miko’s team ahead by a second, now Grant versus Ken.”

Danielle had underestimated Ken’s experience, or overestimated Grant’s fitness. Ken had made up the deficit quickly, and was a second ahead by the time Grant came through with his oddly uncoordinated bounds. It quickly became obvious that Grant’s height meant he had to duck his head to avoid hitting it on the airlocks as he went between modules. No wonder Ken was making up time.

Quite a lot of time: as Ken handed her the baton she heard Misha’s announcement: “Danielle’s team is four seconds ahead! We’re now on the second lap out of three!”

Danielle allowed herself a small smile: If they could gain four seconds each time the four of them went around, all they had to do was maintain their current performance and she’d win her first ring race at the hub!

But it wasn’t to be. She had been right about her team being more beauty than fitness. Her team lost time on their second laps and by the time Danielle started her third lap they were right back to level pegging.

In their third laps, her lead over Maggie was erased by Dean's win over Jacques, and then Miko put in the best lap time of the entire race over a flagging Tresna. When Ken started against Grant, he was already ten seconds behind. There was no way he could recover the distance.

Applause sounded through the DeTA as Misha announced that Grant crossed the finish line. "Team Miko wins again."

They made their way back up the access tubes to the DeTA's central module, which in turn connected to the crew ship. The zero-gravity was always quite the relief after high intensity exercise.

Dean called in her direction as soon as they entered the central module, "I thought you had us after the first set." He laughed, still giddy with the win.

"But then... this woman came along and BAM!" He tried to bow to Miko behind him, looking goofy in the zero G.

"Yeah well, it wasn't just her. You had to get all fancy on us didn't you?" Danielle retorted. "Joping..." her tone of voice conveyed her disgust.

His grin expressed exactly how sorry he was.

Soon a half-dozen conversations had begun as they all milled about in zero G, discussing the race. Maud and Diedre came up to congratulate them.

Diedre made a point of interrupting Danielle and Dean's smack talk, "Remember not to take it too seriously you two. It's just a friendly competition."

Maud patted Tresna on the back, "You gave Miko a real run for her money that first lap though."

"And Dean," she added. "It's ridiculous how much you remind me of your dad when he was young. He must be very proud of you."

It suddenly seemed like you could hear a pin drop. Dean's reaction was nothing like what Danielle might have expected. The balance of emotions on Dean's face turned suddenly negative, and it wasn't physical pain.

"Where is Chad anyway?" Maud continued, "I haven't seen him this morning."

"Here," Chad called as he floated towards them from the airlock to the crew ship. At first it seemed he was alone, but then Dr Jack Suliman, Didi Williams and Dr Peter Chu came in behind him, each looking grimmer than the last.

"Good that you're all here." Chad started, looking at his son with pity. "I have some news..."

That seemed to push Dean over the edge. The sound that came out of his mouth was a choked groan. With an abruptness that startled everyone, he grabbed a handhold and propelled himself back the way they'd come.

"No. Nope... Not hearing it."

There was a murmur of confusion among the crew as he brushed past Danielle and slid down the

tube towards chamber 7. Not that it looked as though he cared where he was going.

After they watched him go, the whole crew turned back towards Chad, who was still steadying herself with a handhold.

“Uh, yeah. So it’s not good.” Chad Hooper spoke quietly. “I have bowel cancer.”

Dean Hooper

June 12th 2052

Dean knew he was being an asshole. Someone close to you gets a cancer diagnosis, you’re supposed to feel for them right? Be supportive. Treasure your time with them. All that jazz.

But he couldn’t do it. Every time he looked at his father he couldn’t help thinking about how unlucky he was for leaving his mom and signing up for this mission. He couldn’t blame anyone else either: he had wanted to know his Dad and this was the only way to make it happen, so he had worked for years for the chance to come on this mission.

Unfortunately, during the same transit window in which he and the other five “kids” had travelled from Earth to Mirrabooka, a small cargo probe had made the transit in the opposite direction. A cargo probe carrying 228 kilograms of near-pure platinum, and blood samples from thirteen crew at the colony.

They had found “indicators”, whatever that meant. Dr Peter Chu had done the examination to confirm, and now Dean found himself locked into what was at least a seven-year trip, and his dad was as likely as not to be dead in what? Six months? A year?

They might get lucky, he knew. Cancer wasn’t necessarily a death sentence anymore. Chad had already started the chemotherapy while Mithran worked with the biotech experts back in Earthspace to develop a customised immunotherapy. If they had been at one of the hospitals in low Earth orbit, Chad’s odds of a cure would have been better than ninety percent. Out here however, where Mithran’s lab space consisted of a couple small modules the size of the kitchen’s pantry pod, and a set of biotech reagents that could fit in a single fridge-freezer, things were a lot dicier.

Long story short: Mithran would get one shot to gene-edit Chad’s white blood cells into something that could kill the cancer completely. Partial success would not do.

The success rate for these kinds of treatments beyond Earthspace? Well... there was that one guy who lived long enough to transit back to Earth where the treatment could be finished. Mirrabooka, again, was only two months into a seven-year cycle before they’d be anywhere near Earth again.

The outlook was not positive.

He was distracted from his thoughts by the slight nudge, and sound of interlocks engaging, as the transfer craft docked with the outer port of the radiation shelter module. Buried beneath the surface of the rock, it was the most isolated place at Mirrabooka. It was somewhere he didn’t have to make awkward conversation with his Dad, or with anyone else who was wondering how he was.

Danielle had given him a welcome distraction by challenging him to a game of zero G table tennis, thank god. Maud and Ken had come down with them to the shelter in the transfer craft, each having their own work to perform. The four of them disembarked into the module, each grabbing handholds to maneuver themselves in the zero G.

Dean followed Danielle down to the back to find the table tennis set, and they moved wordlessly to put on the Velcro-coated shin guards and sandals that would allow them to move hands-free in the cushioned platforms that were set at each end of the table.

The game itself was only a little different to its ground-based counterpart. The table tennis balls and bats were identical, as was the net, except for the small detail that there were four nets. The way it was arranged, each net was positioned midway down one of four table surfaces, and each table surface sat at right angles to the next, forming a square tube. The only real difference was that the table surfaces were made of see-through, rubber-coated Perspex instead of wood, meaning the audience could see what was happening from the outside.

They rallied, same as they had done during their Masters course in LEO. Danielle was a natural, her small size allowing her to pivot easily and achieve angles someone with his larger frame couldn't possibly match, and her hand-eye coordination was among the best he'd ever seen. Still, he enjoyed the challenge, and worked up a sweat quickly.

He did manage to get a few past her. At one point, he had to push and free-fall back into the webbing of his platform in order to get the shot, but the spin of his loop drive curled it back over the nets and into play, bouncing off two of the surfaces on her side before eventually getting caught in the webbing of her platform.

He heard clapping from the side, seeing Ken watching with the enthusiasm of a keen fan. "Nice shot Dean!"

"Uh, thanks." He muttered at the Brazilian psychologist, watching as Danielle fetched the ball and served it back into play. In the back of his mind he wondered whether it was time to go see the guy in his professional capacity. Wasn't like he didn't have a good reason.

He felt the shudder of the airlock interlocks engaging again, and heard the sound of another transfer craft docking. Shortly afterwards, he heard the sound of more voices. He missed the next shot.

"Ken, what's up?" Danielle asked the question before he could.

"Didn't want to interrupt you two, but we've just been told we're at code orange. Remember that sunspot James said would be pointing in our direction? Well, it's erupted in an X-class solar flare, so we're going to be stuck in here for the next two days or so. Might as well enjoy the table while you've got it to yourself..."

"Oh..." Danielle took a moment to absorb the news. A moment later she shrugged and served the ball. Dean missed it again.

"So, Ken." Dean was putting two and two together. "Does that mean everyone is coming to the shelter?"

Ken sighed, "Almost everyone."

"Almost?" Dean said, feeling his temper rising. "Why? Who isn't coming?" He asked the

question, knowing the answer already.

“Dean...” Ken spoke quietly. “Surely you know the Matheson protocol?”

Dean was silent as left the bat floating in the air and pushed himself across to the edge of the chamber. “I know the fucking protocol. But he’s getting treatment for *cancer*. You’re really going to leave him out there in a solar flare while he’s having *chemo*?”

Ken pushed himself into Dean’s path, blocking his way back to the airlock. “That’s part of the protocol, Dean.”

Dean looked down at the smaller man, wondering if he really had to force his way through. He relented: “Look Ken, I just need to go talk to him, then I’ll come straight back.”

“Two conditions if I let you go.” Ken was forceful now.

“First, you spend five minutes at the hub, tops. I want you back here inside thirty minutes.”

“Second, you’ve had your time for moping around like a sad sack. You come see me for a session next week and we’re going to talk you through this situation with your father. We’re all feeling it, so you’re not alone in this. Are we agreed?”

“Okay fine.” Dean said, gripping a handhold and pulling himself past Ken. The crew who had just entered the shelter looked at him in confusion as he floated down the centre of the capsule and boarded the transfer vehicle they’d just left.

“It’s okay, he’s going with my permission.” Ken said in explanation, then called out: “Half an hour Dean. I mean that.”

The transfer craft were automated for simple port-to-port transfers like this. Dean punched in the instructions on the console, strapped himself into one of the chairs, and waited as the airlock closed and the interlocks disengaged. A couple of short bursts from the thrusters and the craft was backing away from the rock, then flying back up towards the docking node between the DeTA and the crew ship.

He noticed a bright flash in his right eye, and couldn’t help blinking in response... So the solar storm really was starting. Not that it felt like a storm in any conventional sense. To call the solar wind feather-light was a vast overstatement, and as a matter of fact, there wouldn’t be any perceivable buffeting at all.

Just the occasional supercharged atomic nuclei passing through the ships hull, and ripping into his retina... or, you know, his DNA.

He noticed a couple more flashes in one eye or the other during the transit up to the Hub. The storm wouldn’t really get started in earnest for another few hours, but some of the high energy particles travelled close to light speed, which meant that the crew of a colony in the path of a solar flare had to seek shelter as soon as possible.

He felt the transfer craft dock at the node, interlocks engaging as before. His Dad was waiting for him on the other side of the glass, which was reassuring, until he looked at him.

It had been just over two weeks of chemo, but Chad Hooper was already starting to look haggard,

with his hair starting to fall out, and what was usually a big chubby face now looked pale, with distinct lines of pain.

The airlock opened, and Dean pulled himself though, ready to get in the first word.

“Look, Dad...”

Chad Hooper hit him in the jaw, hard.

“Well you’re a fucking idiot, aren’t you?” he spat the words as his son recoiled.

“Dad, what the hell?” Dean tried to recover his composure. “I just thought...”

“I *know* what you just thought.” Chad’s anger eased and transitioned into exasperation. “Ken told me what you said on the com as you were coming over. You even *think* of using the com, idiot?”

“I came here to bring you back to the shelter.” Dean replied earnestly, “You shouldn’t be out here. You’ve got *cancer*.”

“Ya think I don’t know that?” Chad was irritated now, but put the emotion to one side and went into teacher mode. “Look, you obviously weren’t paying attention the day they covered the protocol, so let me go through it while you shut up and listen...”

Dean looked at his father expectantly, nursing his bruised jaw.

“Solar flares don’t just affect biology; they can fry electronics real good as well. You get that, right? So what do you think happens if everyone’s down in the shelter when all the ports on the hub malfunction. Or the thrusters malfunction, or the coms go down, or *any one of a dozen other things go wrong?*”

“No one can get back on board the hub to tend to the aquaponics, and everyone dies of starvation, that’s what. So someone always has to stay behind on the hub, just in case.”

“But why *you?*” Dean was still angry at the idea of it. “That’s the part that’s unfair. Why not *anyone* else?”

Chad’s voice broke, “It’s *because* I’m the one most likely to die in the near future.”

“They’re doing everything they can to cure me Dean. Don’t doubt that. And if I do get better, then we’ll go back to sharing it around. But it makes no sense for anyone else to add to their lifetime radiation exposure while I’m compromised like this. And when it comes time to give me the immunotherapy, hopefully that will work for any damage I pick up this time around too.”

“Dean, I’m sorry for hitting you, but the rules are there for a reason. You’ve gone and upped your lifetime dose for no good reason, and getting emotional about my situation is *not* a good reason. Lapses in judgement like this... this *can’t* happen again. You understand me?”

Dean nodded slowly.

“Matheson’s protocol especially,” Chad continued. “First guy to die of cancer out here, and he followed it to the letter. Guy deserves some respect, don’t you think?”

Chad held out his hand. Dean sighed and took it, letting himself be drawn into a hug.

“Besides, I’ve set myself up a hammock in amongst the main water stores. So I’m not going to get that big a dose unless you keep me out here trying to play professor. Ain’t nobody paying me for that!”

Dean smiled as he touched the swelling on his face. “Yeah, well your teaching style could use some work.”

“Get back to the radiation shelter, smart ass.” Chad pushed him backwards through the airlock and hit the button to close the hatch. “I’ll see you in a couple days.”

Glossary

Aphelion, Perihelion and Semi-Major Axis: The orbits of Earth, Mars, and every asteroid around the sun are elliptical (oval) in shape. The first two terms are the points where the object is farthest from (aphelion) and closest to (perihelion) the sun. The semi-major axis is the average of the aphelion and perihelion distances and relates to how long the orbit of that object is. Earth, with a semi-major axis of 1 Astronomical Unit (AU), takes one year to orbit the sun. Mirrabooka (asteroid ID “2008 EQ”), with a semi major axis of 1.76 AU, takes two and one third years to orbit the sun. (16) Psyche, with a semi major axis of 2.93 AU, takes exactly five years to orbit the sun.

Apollo class asteroids such as Mirrabooka orbit the sun on substantially elliptical paths that cross Earth's inside orbit (Mirrabooka perihelion = 0.95 AU), but also travel out into the main belt (Mirrabooka aphelion = 2.56 AU). This makes them candidates for “stepping-stone” colonies, bridges for humanity between Earth and the large “anchor” main belt asteroids such as (16) Psyche.

Delta-V: Literally meaning change in velocity, delta-V is an indicator of the amount of fuel required to transit between two locations. Due to the unintuitive nature of orbital dynamics, delta-V is a much better indicator of the cost to transit between two places than the distance between them. Low delta-V transits are cheaper, but slower. High delta-V transits are often preferred for manned vessels because they are faster and reduce exposure to interplanetary radiation.

Deployable Toroid Array (DeTA): The light-weight DeTA “folding torus” is commonly implemented on human space craft with mission profiles requiring 1) significant delta-Vs to achieve rendezvous with target asteroids, 2) encapsulation inside the fairing of a heavy-lift launch vehicle, and 3) spaceflight durations in excess of 12 months where closed-loop extended aquaponics is required. The DeTA folded configuration is useful during high-acceleration maneuvers, whilst the deployed configuration can provide spin gravity at all other times.

Extended Aquaponics (EAP) builds on standard aquaponics (the combination of aquaculture - fish farming - and hydroponics - soil-free organic plant farming) with the addition of chicken farming, as well as septic, compost, worm and maggot (SCWorM) units, required to convert human and animal waste products into protein for chicken and fish food.

Exodus Directive: The full document can be found at <http://ipw.ama.org/ED>. In brief, this document organises the spread of humankind beyond “Earthspace” (the Earth-Moon system) by identifying “anchor locations” of value (e.g. Mars, Venus, and certain main belt asteroids), and then identifying Apollo-class Asteroids for “stepping-stone” colony locations. This process is based not

only on solar energy availability, size and composition (factors in determining the carrying capacity of colonies built there), but also the degree to which each asteroid resides in an orbit suitable for regular transits from Earthspace to these anchor locations.

LAP (Launch-Assembly Process): The staging process for habitats leaving Earthspace is known as LAP, and most often takes place at the lunar-orbiting Deep-Space Gateway. This is the position from which DeTA habitats, radiation shelter modules, mining equipment, and crew transfer ships depart, allowing insertion into a number of sun-centred orbits with ease.

LEO (Low Earth Orbit) Baby Gang: informal term for the first hundred babies born in LEO (and their parents). Similar clubs exist for the lunar-orbiting Deep Space Gateway and other locations of human settlement.

Massive Toroid Array (MaTA): Unlike DeTA, which provide a lightweight compromise between deployed and stowed configurations, MaTA are massive, large spin-radius habitats, built in situ around an asteroid resource. During water, CO₂ and mineral extraction, excess material is fused into segments that can tessellate in 3D space to form a torus or donut-shaped habitat. Each MaTA serves twin purposes: Firstly, they provide radiation shielded space at 1x Earth spin gravity, and secondly, they serve as a repository for water and CO₂ ice purified from the asteroid resource, meaning that transiting craft can quickly generate new rocket fuel.

The MaTA built at Mirrabooka has a diameter of 230 metres, a usable, radiation-shielded volume of over 8000 cubic metres, and a nominal carrying capacity of 50 individuals. This construction used just over 1% of the mass of the asteroid Mirrabooka.

Radiation in Interplanetary Space: Once mission lengths extend into multiple years, the radiation dose to occupants living in interplanetary space without sufficient shielding becomes a significant risk factor for cancer related deaths. Asteroid colonies become viable for extended crew habitation once a storm shelter module is buried below the surface of the asteroid in question, with crew at these colonies having an exposure of approximately 80 mSv/year, a significant reduction over background radiation levels. Most crew in these colonies will still reach their maximum acceptable lifetime dose in 25-30 years and these levels of radiation are not suitable for children or pregnant women. The construction of multiple MaTA at each stepping stone colony enables true settlement of the solar system by providing Earth-equivalent passive radiation shielding.