

COSMOS

THE SCIENCE OF EVERYTHING

ISSUE 98

BEYOND THE PALAEO

DULL DINOSAURS GET THE MAKEOVER THEY DESERVE



Afterlife A.I.

Tech gives a voice to the dearly departed

Seeing emotions

What if we could watch each other's raw feelings?

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A DAY IN THE (MOON) LIFE

The Artemis program is up and running, and humans could be back on the Moon's surface in 2025. What will life be like for the next generation of lunar explorers? **Jamie Seidel** gazes into the crystal ball...

Day 42: 05:55

The day starts just like any other. You wake up. Things get a bit out of this world from there. Even lying on the bunk with closed eyes, things don't feel right.

The sounds. It's not that there aren't any. It's just that there are so few of them that each one rings out crisp and clear, no matter how soft they are.

They've got no background noise to compete with.

Oh, the fans are droning on as they always do. No expense had been spared in the drive to keep them quiet. And it had worked. Apparently. For a time, at least. Now, each individual tick, grind and squeak has an almost physical presence.

The scrubbers are guaranteed to filter out 99.9% of all the hair and grime deposited in any human environment. Not to mention dust.

Dust. Don't mention the dust.

That 0.1% adds up quickly, your predecessor had warned. She'd "strongly recommended" you include a stash

of soothing salve among your precious 1.5 kilograms of personal luggage.



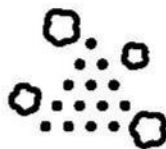
The trouble is, this isn't just any dust.

Dust you can handle. Dust you know. You'd lived with the burnt-red beast in your underwear for months during training at the Arkaroola habitat simulator, in South Australia.

But this is regolith. Every grain is tiny. Every grain is sharp. Every grain is electrostatically charged. In practical terms, it's a 0.07 millimetre piece of shattered glass that sticks to anything and turns it into industrial-grade sandpaper.

Not for the first time, you wish all the wind expelled at those lectures about the "regolith problem" had been canned and shipped to the Moon to erode the stuff.

Dust 1, Boffins 0.

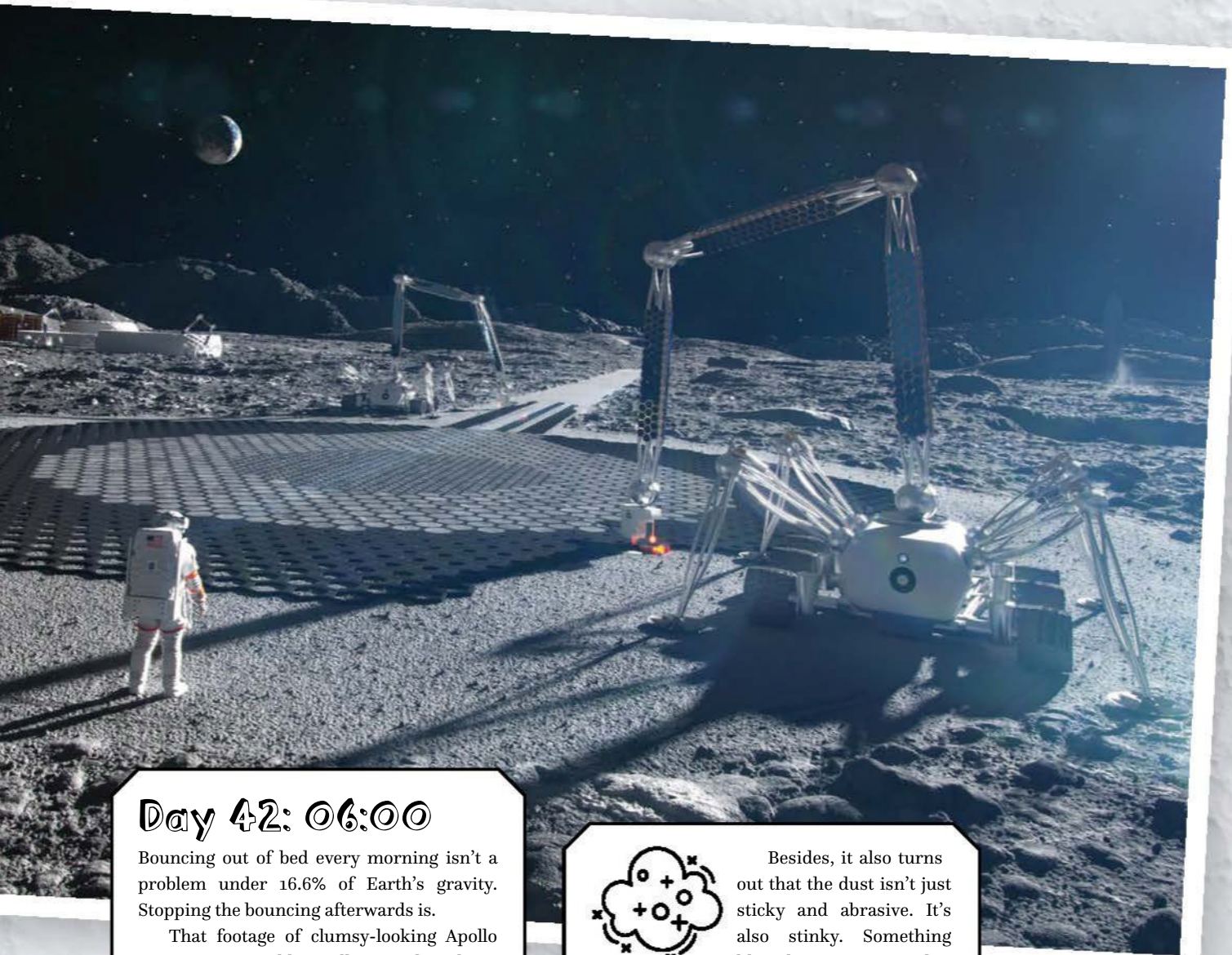


The lights come on. Dim, to save electricity. Time to get up – preferably without bashing your head on the roof again this time.

A crash. A curse. You hear your companion laugh. You sigh.

Ten square metres per astronaut, NASA's Lunar Cabin specifications had read. Not enough had been allocated to headroom.





Day 42: 06:00

Bouncing out of bed every morning isn't a problem under 16.6% of Earth's gravity. Stopping the bouncing afterwards is.

That footage of clumsy-looking Apollo astronauts stumbling all over the place? Halfway through your two-month tour of duty at Base Camp One, it's now just part of everyday life. Even in a form-fitting jumpsuit it looks like something H.R. Giger's Alien would cough up as a furball.

It's a nightmare web of crisscrossing bands, ribs, straps and springs designed to subject your limbs and muscles to directional stresses.

Essentially, it's a gravity substitute. It's supposed to resist the onset of all those horrible bone, muscle and coordination conditions that were such a feature of life for astronauts on the International Space Station.



It. Feels. Weird.

No matter how many elastic bands they've packed into the thing, it simply can't hope to satisfy all the subtle nuances burnt into your brain by 3.7 billion years of evolution.



Besides, it also turns out that the dust isn't just sticky and abrasive. It's also stinky. Something like burnt gunpowder.

Remember cap guns?

There are two bunks in the crate-filled cabin. A separate cabin houses the remaining two mission personnel. Between the two is a slightly larger dome for communal living and workspace. It has two airlocks – one leading to the garage, the other to a plant and equipment room.

No expense had been spared in setting up this off-world retreat. Except for aesthetics.

The walls are rigid foam-plastic shells. They'd been hauled here on the first Artemis missions before being inflated, hardened, reinforced – and buried.

Yep, dust again.

It turns out a metre of the stuff is all it takes to block out all but the most harmful solar and intergalactic rays. It may itch, but this property alone has saved tens of billions of dollars being spent on hauling heavy shielding up the steep climb from Earth.

A concept image of a "brickie" robot-rover laying a dust-suppressing landing pad at the lunar south pole.

The first Artemis astronauts on the Moon (right) won't be former test pilots; they'll be more like 'tradies' working to build a new community. And forget glittering crystal domes: humanity's first space outpost (below) will be more like a mud hut.

Day 42: 06:15

Bacon and eggs. Breakfast of the gods!

Aaaand a cup of coffee! Real coffee; in a real cup. Including the bitter brew on the shopping list had been a unanimous vote. And an expensive one.



The average coffee drinker consumes about 4kg of ground beans annually. For a two-month tour of duty on the Moon, that equals 666 grams each. Or 2.7kg (rounded up!) for the entire four-person team.

At a going rate of about \$1.5 million per kilogram for delivery...

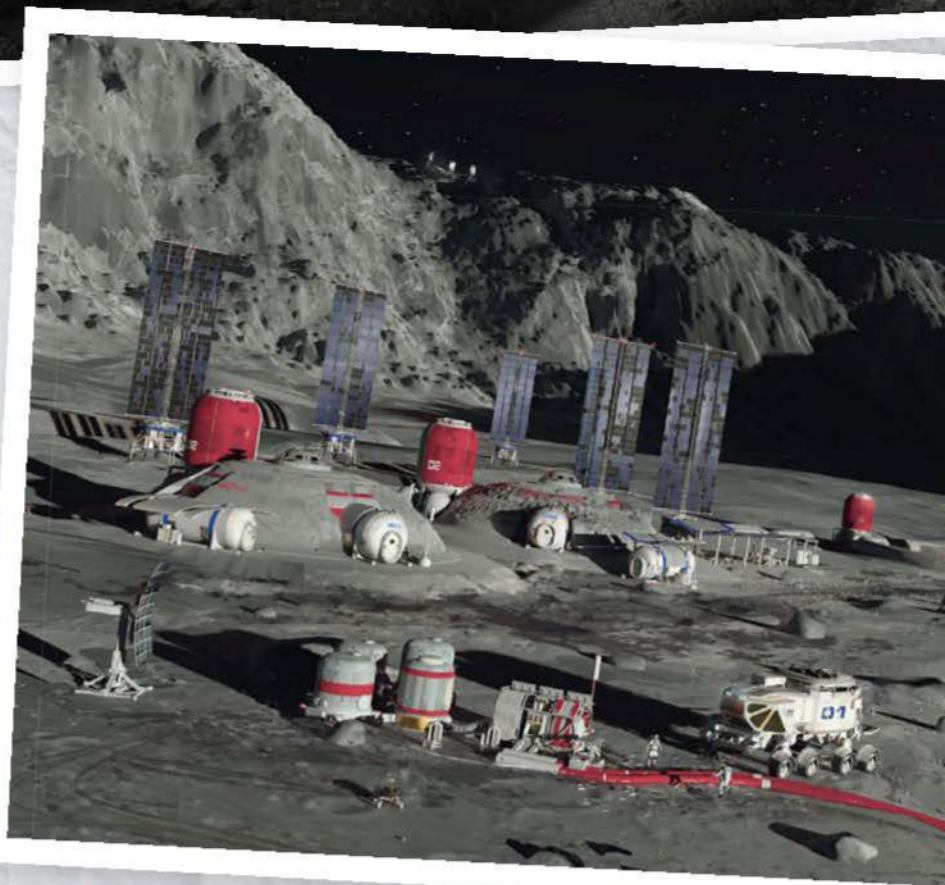


Hey, you're a brickie! Not a mathematician. Working out the cost of a lunar cuppa is outside your pay grade. Whatever it is, it's the price of good morale, and you're glad for a regular dose of home.

The eggs are also from Earth. Powdered, of course. But the bacon is indigenous. The "Moonpig" happens to be a remarkably adaptable pond weed floating in trays in the... plant room. Feed it some herbs and spices. Trigger a few gene sequences. Dry it. Toast it.

It's not bacon. But it'll do.

Almost every astronaut ever has lost weight – no matter what they've been force-fed. It's just one of the many poorly understood side effects of low gravity on the human body.



Day 42: 07:00

It costs about \$1 billion to ship you 384,400km to the Moon (weight after farewell lunch = top secret!). It's a long way to go for a desk job.

Yep. A desk. A folding chair. A headset. Several screens. A keyboard. Some game controllers. And an enormous whiteboard (cheaper to carry than a big screen).

It's a lot like your first job at an outback mine site really. The heat and dust kept you indoors then. What's a little extra cosmic background radiation – and an absence of atmosphere – anyway?

It's a balmy 0°C outside. It's forecast to stay the same for the rest of the day. Which means pretty much eternity.

Lunar Cabin (seriously, why not Moonbase One?) sits within the southern polar circle. That means perpetual sunlight strikes the ground at a highly oblique angle. So no blistering 120°C days and -130°C nights (which last 656 Earth hours, just saying) as elsewhere on the Moon.

That's also why you're here.

Well, the shadows are. They conceal ice. Mostly water. But there are a few other volatiles mixed in. It hasn't been boiled off into space. That means it can be mined and refined.

Add a little electricity, and you get oxygen and hydrogen. One to breathe. One to burn.

But that's not your job. Not today, at least. You're a brickie. You build things. And battle dust.



Your skillset includes words such as “habitat”, “sustainable human presence”, “launch pad”, “roads”, and ... “regolith suppression”. Which means doing whatever it takes to beat the stuff into submission.

But the best part is the robots do (almost) all the dirty work. You're the “human in the loop”.

Seriously, how hard can laying a bit of pavement be?

Remember Wall-E?

A.R.N.I.E. is a mobile kiln. He has an army of little helper bots scooping and sifting the regolith before feeding it into his onboard oven. He squeezes. And makes a deposit on the ground. Another helper bot waits for it to cool before wiggling it into position and welding it into place.

Day 42: 11:17

Mission Control is complaining that the Road-E Bots are milling about aimlessly. These guys have a tough life out in the elements.



Some dig. Some scrape. Some compact. Then along come those that sear.

Yep, they turn regolith into pavement by melting it – the official term is “sintering”. And all it takes is for a few millimetres of dust to be glassed, and you get yourself a shiny new road.

Why so much effort? Why burn through so much precious reactor energy? Why spend the big bucks on sending a brickie out alongside the glory gals (and guys) in farming, mining, and habitat?

Well, rover wheels kick up a lot of dust. And once kicked up, it stays up for a disturbingly long time. So paved paths are the simplest way to reduce the daily grind (literally) on just about every surface and piece of equipment on and in the base.

You sigh. If you're not clear enough with your instructions, unexpected things can happen.

There – in the utterly black shadow of a Truck-E Bot: an electrical extension cord snared on a jagged boulder. A Laser-E Bot had mindlessly kept pulling until the plug separated.

And that upset the whole work routine.

Rovers generally need minimal supervision once given a pre-defined task. The trick is feeding them the right amount of detail. Too little, and they make stupid mistakes. Too much, and they risk being micro-managed into a standstill.

You switch a nearby WaldoBot to manual. Then, using your game controllers, you wiggle it around to pick up both halves of the cord, blast the contacts free of dust – and slot them back together.

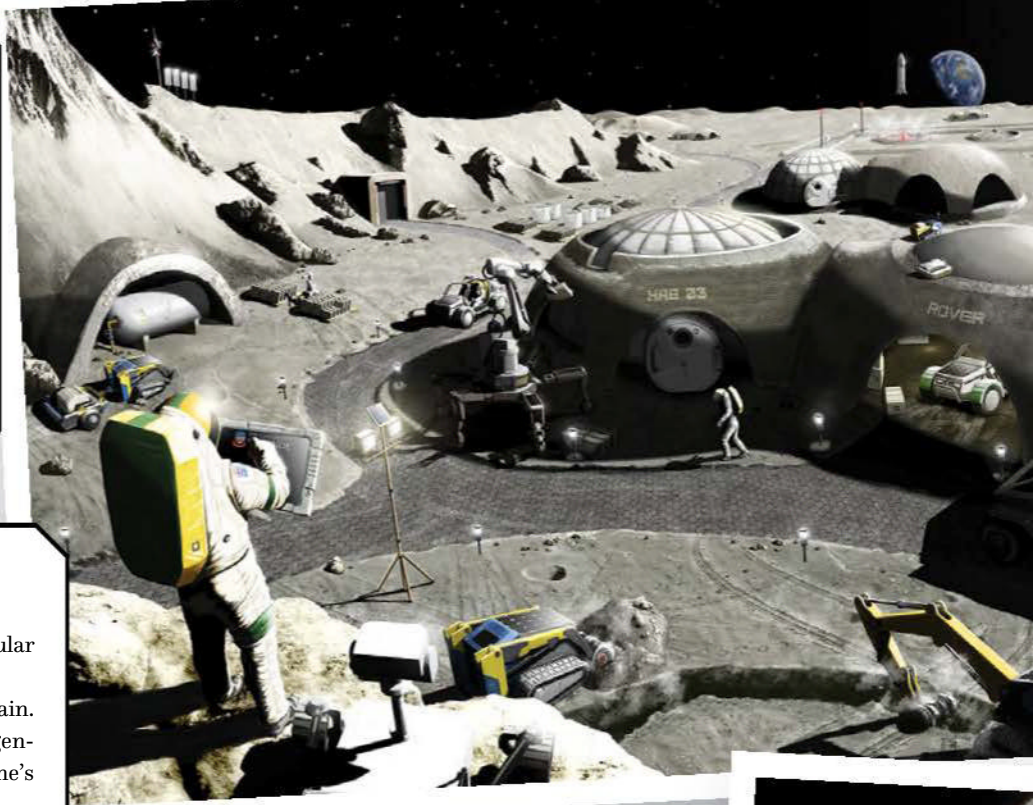
You glance at the panel in the corner of your screen where the ever-present Earthside technical consultant resides.

“Mission Control, time to talk about a raise.”

But the 2.7-second delay for the responding smirk to return kind of kills the moment.



This artist's impression of off-Earth habitation illustrates the importance of the sustainable use of local materials to support the NASA Artemis Program, which is a focus of research at the University of Adelaide's Andy Thomas Centre for Space Resources.



Day 42: 14:22

It's time for an E.C.A. (Extra Cabinular Activity). Or, in English, to go outside.

A.R.N.I.E. is screaming for help. Again. He's really just a big baby. A Volkswagen-sized baby. But his job is vital: he's building the landing pad.



Rocket plume + super-sticky dust = sandblasting.

Every time we get a new delivery or change in work rotation, hundreds of thousands of kilograms of Moon stuff gets blasted across the surface. Some regolith even gets propelled into orbit.

All those hyperenergetic particles could soon pose a severe problem for the Lunar Gateway space station, all those communications satellites – and your ride home...

A.R.N.I.E. is getting too hot. And his onboard sensors don't know why. That's why you're here. Kick the tyres. Tighten the bolts. Bash the casing to shake all the dust loose.

Doing that involves going outside. Seeing your footprint on the Moon's surface the first time was a moment beyond compare. An even-dozen Moonwalks later – not so much.

Going outside is a serious P.I.T.A. First, you have to get out of your G-suit. Under Moon gravity, that's some serious gymnastics right there! Then it's time to put on the super absorbent underwear. Not exactly a nappy... And there's the "urine collection device" (™) attached.

Don't forget the cooling suit. It's not that the sunshine's a problem. It's just that, without



atmosphere, there's nowhere for all your body heat to go.

Then there's the webbing holding all the biosensors and other gubbins that make sure everybody knows EXACTLY everything your body is doing...

Only then do you get to enter the airlock. It's not one of those double-doored things you see on all the sci-fi shows. Yes, a pressure door seals off the cabin. But the other door is your suit. It's a suitlock.

Its backpack forms an airtight seal with the cabin itself. A hatch in that backpack is how you climb (well, wiggle) into the pressurised, hardened shell. It looks more like an armoured deep-sea diving suit than anything the Apollo astronauts wore.

It's all about limiting the amount of dust that gets inside. But it's also supposed to protect you from radiation, extreme temperatures, micrometeoroids – and regolith.

Judging from all the scuffs on its surface and the way you struggle to get the seals to close, the dust is winning.

Apollo's astronauts had it easy. Their stuff only had to last 22 hours.



Day 42: 15:32

Panic attack! Breathe deep. It passes in a few moments. Nothing like practice...

The lunar landscape before you looks like a bad V.R. scene. The lighting's all wrong. The edges are way too clearly defined. And not only is the colour on the blink, but the black-and-white mode has dropped white for 50 more shades of grey. But one sight makes it all worthwhile.



You turn to face the Earth.

It hasn't gone anywhere. The Moon's tidal locked. That means the Earth always sees the same face of the Moon. From the Moon, it means the Earth never moves.

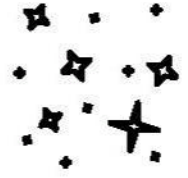
It's bright. It's blue and white. It's upside down. That's fine: There's Australia in its rightful place – on top of the world.

The rest of the sky is pitch black. There's no atmosphere to scatter the sunlight. That's also why every shadow is totally dark. And why every edge – be it artificial or not – appears so stark.

The stars, though, are crystal clear. And hypnotising.

Don't look up!

You do your best Neil Armstrong impression as you make your way around the cabin to the improvised vehicle park. They should be in the garage, but priorities change. Other, more important things need to be shielded from the environment.

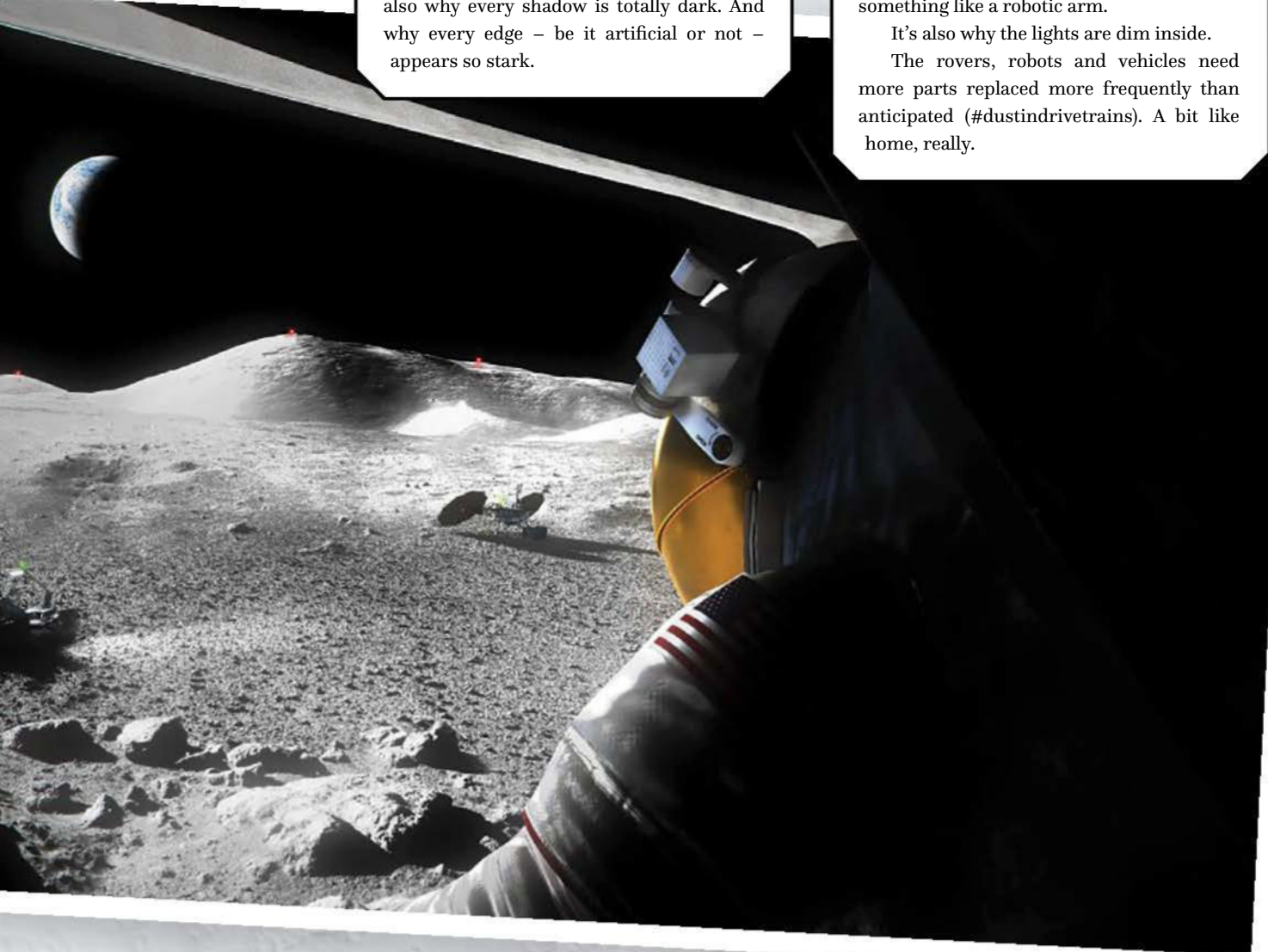


The last functional golf buggy is parked next to the heart and soul of the lunar cabin: a 3D printer. Actually, several different types of printer, all bundled into the same transportable unit. It's alongside the van-sized nuclear reactor.

Which makes sense. Do you have any idea how many ergs go into making a plastic fork? Think a lot, then scale that up to mixing and matching the materials needed for something like a robotic arm.

It's also why the lights are dim inside.

The rovers, robots and vehicles need more parts replaced more frequently than anticipated (#dustindrivetrains). A bit like home, really.



Day 42: 15:44

While you call yourself a brickie, you know A.R.N.I.E. and his fellow tradies do all the work.

Rovers come in all shapes and sizes. There are a few monsters. But, mostly, they are Tonka trucks that (try) to do all the odd jobs you'd normally expect a human to do back home.

Except think.



Your fleshy fingers program the size, number and pattern of geometric bricks A.R.N.I.E... excretes.

The bots then slot the interlocking blocks (which look disturbingly like bone sockets) in place.

Until they don't. And that's where you come in.

It seems the definition of human has narrowed to the ability to make workable inferences based on sparse data.

God of the gaps! Oorah!

A.R.N.I.E.'s dirty. We're talking Victorian-era-coalminer dirty. Every exposed surface is smeared and grimy. All those gizmos and gadgets incorporated into the design to prevent dust problems have been overwhelmed.

And that's your cue, Sherlock.

You unlatch a few pieces of fairing and remove some insulation. It all takes far too long. They still haven't invented practical pressurised gloves.

But, at last, it's out with the magnifying glass.



Yep, you knew it. Dust. Where there's a seam, dust will find a way. A flush-fitting radiator and actuator motor housing have worked apart just enough to allow in a few 0.07mm grains. From there, it was all downhill. Eventually, enough had forced its way in to separate the two parts entirely.

Heat with nowhere to go equals too much heat.

The fix? Pull it apart. Very slowly so as not to stir up more dust. An intense blast with your pencil-sized air jet. A quick wipe with a microfibre rag... and contact is made.

The solution? Obvious! Cover the actuator with a plastic bag. And duct tape (it still holds the universe together). This time, though, you're thankful you didn't have to resort to fencing wire. You're running low.

"Still waiting for that raise," you quip to those voices in your head.



NASA X2



Robots won't be enough on the Moon: human problem-solving and ingenuity will be central to the Lunar Cabin's success.

Day 42: 17:07

It's been a long afternoon. And you forgot to pack a snack. You wince. There's certain to be an OHS form to fill out about that one once you get back inside.

But that'll have to wait. There's a problem. And since you're already outside, you've been volunteered!

Your buggy labours its way up a lunar mound. Deep ruts mar the once-pristine moonscape and make for a rough, dirty ride. The Road-E bots still have a long way to go.

You crest the ridge to a dazzling sight. It's an enormous glowing dust cloud. With occasional sparkles.

Plasma discharge. Yep, moon lightning.

All made possible by the annoying way the Sun gives the dust it shines upon a positive glow. But the regolith in the ultra-dark permanent shadows has a somewhat more negative attitude.

Close the circuit between light and dark with a few stirred-up particles, and the result is shocking. Literally. You can imagine what that does to the sensitive miniaturised sensors and communications equipment on any nearby autonomous rover.

Mostly, they get amnesia. They forget where they are. And sometimes they're not able to make sense of all the strategic landmarks put in place for that exact reason.

Have you tried turning it off and on?
That's your job.

A Boss-E bot is the latest victim. It's a mobile sensor and communications platform designed to double-check the quality of construction work.

Under the glowing cloud is the future Moon Base One. At the moment it's just a hole in the ground (a partially graded and compacted field). And the rovers are busily building their own bomb shelters before tackling anything serious.

They're slotting pre-shaped bricks into tilted arches. It's an idea ripped straight out of ancient Mesopotamia – gravity helps hold everything in place. And the arches can be extended into tubular enclosures.

Usually, you get about two to three days' notice of an impending solar storm.

But it could be less than 12 hours.

So you need something to protect any static equipment. And somewhere for the rovers to scurry for shelter.

This Boss-E bot was supposed to be double-checking the fit of the bricks. One unwanted gap could potentially let in enough rays to fry an unsuspecting machine. Or person.

There it is: with derelict Brick-E bot alongside it.

You jump off the golf buggy a little too quickly. The resulting faceplant isn't at all embarrassing. But the alienesque dust angel you left behind is well worth the memory.

Your suit is caked with regolith. But you mentally brush it aside.

What's a little more dust anyway?

Less play! More work! That promotion is at stake!

You detach a screwdriver-thing from your belt and lean over the rovers.

"You got a lot of carbon scoring. Looks like you boys have seen a lot of action," you breathe into your mic. Would those cardboard-cutout mission control types even get the Star Wars R2D2 reference, you wonder?

You lean forward. A spark leaps from the lifeless Boss-E bot towards your regolith-caked glove. Then another. And another.

You smell smoke. In a spacesuit.

"Houston, we have a problem ..."



JAMIE SEIDEL is a freelance journalist based in Adelaide. His most recent story for *Cosmos* appeared in Issue 97.