

S03E26 - Is Space Trying to Kill Us? (Radiation)

The Multiverse Employee Handbook - Season 3

The Multiverse Employee Handbook has this to say about Space Radiation:

It is the part of space that most clearly demonstrates that the environment was not prepared for visitors.

Beyond Earth's atmosphere, there is very little in the way of protection. The magnetic field, which on Earth quietly deflects a steady stream of high-energy particles, is no longer present in any meaningful sense.

There is Solar radiation, which varies depending on the Sun's current level of activity, and galactic cosmic rays, which originate from distant astrophysical events and arrive having crossed the galaxy without interruption. They pass through shielding, electronics, and occasionally people, leaving small but measurable changes that accumulate over time.

The Handbook notes that the difficulty here is not usually dramatic. Most radiation exposure produces no immediate sensation—no sound, no flash, no indication that anything has happened at all. The problem is statistical. Given enough time, the numbers become unfavorable.

There are exceptions. The Sun occasionally produces unfortunate events that require immediate attention, at which point "background radiation" becomes a matter of scheduling and shelter.

As a result, human spaceflight beyond low Earth orbit is less a question of whether radiation can be avoided, and more a question of how much can be tolerated. Shielding helps, trajectory planning helps, and time helps, in the sense that less of it is preferable.

In summary, space does not object to human presence. It simply makes no adjustments for it.

You're tuned into The Multiverse Employee Handbook.

Today, we're talking about space radiation — specifically, what it is, where it comes from, what it does to the squishy biological systems we've been using to run human civilisation, and what happens when we take those systems somewhere the universe has made absolutely no effort to accommodate them.

Now. Before we go any further, I want to draw your attention to a sentence in that excerpt that I think deserves a moment of quiet appreciation.

Space does not object to human presence. It simply makes no adjustments for it.

That is, without question, the politest possible way of saying that the cosmos will happily watch you dissolve at the subatomic level and feel absolutely nothing about it. Not hostility. Not indifference, exactly. More like the particular serenity of a system that predates the concept of concern by approximately thirteen and a half billion years.

The universe is not trying to irradiate you. It simply has other priorities. You happen to be in the way.

And here's the thing — most of us have no idea how well-protected we are, right now, simply by virtue of existing on this planet. Earth's magnetic field and atmosphere between them deflect and absorb a truly extraordinary quantity of high-energy particles every single day. We built agriculture on top of this protection. We built cities on top of it. We built the entirety of recorded human history on top of it, and not once — not once — did we put up a sign saying Thank You to Our Magnetic Field for its Continued Service.

Step outside that protection, however — head up past the atmosphere, out beyond the magnetosphere, into the open expanse of deep space — and you will discover, in the precise and merciless language of statistics, that the numbers begin trending in a direction you would rather they didn't.

Not immediately. That's the unsettling part. There's no alarm. No warning light. Just a quiet, relentless accumulation — a steady drizzle of particles from the Sun, and a constant background hail from exploded stars in distant galaxies, arriving at near-light speed, passing straight through your spacecraft walls and, if you're in the way, straight through you.

Today, we're going to explore all of it. And what future technology might — might — one day make deep space survivable in a way that doesn't rely quite so heavily on hoping for the best.

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But first, gather 'round the quantum dosimeter, my radiation-adjacent listeners, for a tale that would make even Victor Hess — the man who rode a balloon into the stratosphere specifically to prove the cosmos was pelting us with particles — question his life choices.

In the fluorescent-lit realm of Quantum Improbability Solutions, specifically in the Department of Spatial Expansion Initiatives — which existed in a superposition of “bold strategic vision” and “nobody thought this through” — Gerald from Compliance was having what could charitably be called a documentation crisis.

It had started, as these things often do, with a memo.

The subject line read: Lunar Branch Office — Approved. Proceed.

Gerald read it three times. Then he opened the attached risk assessment — four hundred and twelve pages, produced by the Health and Safety Interdimensional Subcommittee — and read the executive summary, which used the phrase “statistically inadvisable” eleven times in four paragraphs.

He brought his concerns to the square-haired boss the following morning.

“The galactic cosmic rays alone,” Gerald said, setting a highlighted printout on the desk, “pass through standard spacecraft materials almost entirely unimpeded. They originate from supernovae. Exploded stars, essentially. And they arrive continuously, from every direction, at close to the speed of light.”

The square-haired boss looked at the printout. Then at Gerald. Then back at the printout.

“European problem?” he said.

“No,” said Gerald.

“Right.” The square-haired boss nodded slowly. “Well. We’ll pack light. That should help.”

Gerald requested a shielding materials budget. Procurement approved SPF 50 sunscreen and, after some internal negotiation, a novelty parasol in the company colours.

The storm shelter — a small, heavily reinforced area where crew could take cover during solar particle events — had its budget quietly redirected toward a breakroom with panoramic lunar views and a subscription coffee machine. The square-haired boss felt the views would compensate for a great deal.

“What about the Van Allen belts?” Gerald asked at the following Tuesday’s planning meeting. “We pass through them on the way out and again on the way back. Twice. Both times.”

There was a long pause.

“I thought those were a band,” said someone from Marketing.

Gerald returned to his desk and began researching radioprotective pharmaceuticals. These were, he noted, experimental, early-stage, not yet approved for human use, and almost certainly not coverable under the current staff benefits package.

He wrote this in his risk summary. He submitted the risk summary. It came back the following afternoon with a single comment in red: Can we make this more positive?

Gerald stared at the comment for a long time.

Then he wrote, in the summary’s conclusion: Space does not object to human presence. It simply makes no adjustments for it. Recommended action: adjust accordingly.

He filed the document. He noted, for the record, that he had filed the document. He then noted, separately, that no one would read the document.

The lunar office remained approved. The coffee machine was delivered on schedule.

Gerald updated his personal risk register, purchased a very good water bottle — hydrogen-rich, as it turned out — and said nothing further.

He had done what he could.

The universe, as ever, remained unaware of the meeting.

And that brings us to the genuinely fascinating — and genuinely alarming — science behind all of it. Unlike Star Trek’s conveniently adjustable deflector shields, the real problem with space radiation doesn’t come with a technobabble solution and a confident ensign at a console. It comes with statistics, physics, and the particular humility of realising Earth has been protecting us this entire time without asking for anything in return.

The discovery that space is lethally radioactive did not arrive all at once. It crept up on us — which is, if you think about it, entirely on-brand for radiation.

It began in 1896, in Paris, when a physicist named Henri Becquerel left a lump of uranium sitting on top of a photographic plate in a drawer. He'd intended to run an experiment involving sunlight. The sunlight didn't cooperate. But when he developed the plate anyway, he found it had been exposed — fogged, in the precise language of the era — by the uranium alone, in complete darkness, without anyone asking it to do anything.

The universe had sent its first unsolicited communication. Becquerel had accidentally opened it.

Marie and Pierre Curie took it from there. They established that this wasn't a surface effect or a chemical reaction — it was something coming from inside the atom itself. Marie called it radioactivité. She spent decades working with it directly, without meaningful protection, because nobody yet understood what it was. Her laboratory notebooks remain so thoroughly contaminated that researchers today must sign a waiver before handling them. She is, in a very literal sense, still radioactive. It is, in a very literal sense, a remarkable legacy.

By 1910, scientists understood radioactivity reasonably well. What they didn't understand was where the background radiation at Earth's surface was actually coming from. The assumption was the ground — rocks, soil, the planet itself. Sensible enough. Logical, even. Then Victor Hess ruined that entirely.

In 1912, Hess took a balloon to five thousand metres, carrying electroscopes to measure ionising radiation at altitude. The expectation was straightforward: the further from the ground, the less radiation. Simple.

The radiation increased.

It increased significantly. At altitude, Hess was measuring roughly twice the radiation he'd recorded at the surface. Whatever was causing it wasn't coming up from the Earth. It was coming down from above.

He concluded, correctly, that highly penetrating radiation was arriving from outside the atmosphere. From space. Constantly. In all directions.

He called them cosmic rays. He was awarded the Nobel Prize in 1936. The universe filed no objection.

Then, in 1958, physicist James Van Allen launched instruments aboard Explorer 1 — America's first satellite — and discovered that Earth is surrounded by vast doughnut-shaped belts of trapped charged particles, held in place by the planet's

own magnetic field. Beautiful, in a deeply inconvenient way. A natural radiation trap, circling the planet at altitude, through which any spacecraft heading to the Moon must pass.

Twice.

Gerald would have found this deeply familiar.

The picture that emerged from all of this was not reassuring: space is not merely the absence of air. It is an active radiation environment. And Earth, quietly, magnificently, has been shielding us from it the entire time.

When we return from this brief interlude we'll explore further what exactly is out there, what it does when it finds you, and what we're currently doing about it aboard the International Space Station and beyond.

Welcome back, my statistically exposed listeners.

Right. Let's talk about what's actually out there.

Space radiation is ionising radiation. What that means in practice is this: particles moving with sufficient force to knock electrons clean off atoms. Which sounds abstract until you consider that your DNA is made of atoms, and DNA functions considerably better when its electrons are where they're supposed to be. This is, admittedly, a low bar for a molecule responsible for all known life. But it is the bar we have.

There are three main sources. The Sun produces a continuous outflow of charged particles — the solar wind — plus occasional dramatic bursts called solar flares and coronal mass ejections, which can reach a spacecraft within hours and represent the acute, scheduling-dependent end of the problem. Then there are galactic cosmic rays — originating from supernovae, black holes, and colliding galaxies, travelling for millions of years before arriving, unannounced, at your hull. Constant, omnidirectional, extraordinarily energetic. And finally, the Van Allen belts — those trapped particle regions circling Earth — through which any mission heading to the Moon must pass. Twice.

The particles worth lingering on are the heavy ions — iron nuclei, for instance, moving at a substantial fraction of the speed of light. When one passes through biological tissue, it doesn't clip a single strand of DNA. It tears through, depositing energy in a dense track, causing clustered damage that the body's repair mechanisms genuinely struggle to address. Your cells are well-equipped for the

kind of radiation damage you accumulate on Earth. They are considerably less prepared for a subatomic projectile from an exploded star. The comparison to a dental X-ray, sometimes offered for reassurance, is not especially reassuring once you understand the distinction. Your dentist, to their credit, leaves the room.

The numbers are clarifying. Average annual exposure on Earth's surface: two to three millisieverts. Six months on the International Space Station: fifty to a hundred and sixty. A Mars round trip: somewhere between six hundred and over a thousand. NASA calibrates its lifetime limits around roughly a three percent increased cancer risk threshold. A Mars mission pushes hard against that before the crew has landed. This is the sort of detail that appears on page 340 of the risk assessment. Gerald had flagged it in yellow.

Long-term effects include elevated cancer risk, central nervous system changes — cognitive disruption, attention and memory effects — cardiovascular disease, and cataracts. The whole body, across virtually every system, affected in some degree.

So. What are we doing about it.

Shielding helps, with caveats. Aluminium — the standard spacecraft material — is not particularly effective against high-energy cosmic rays, and can actually produce secondary particles on impact, which is the radiation equivalent of a ricochet. Hydrogen-rich materials do better: water, polyethylene. On planetary surfaces, regolith — loose soil — is an excellent shield. Bury the habitat, cover it with dirt, or move into a naturally occurring lava tube. The most sophisticated radiation protection strategy currently available is, in certain respects, a cave. Humanity spent roughly forty thousand years living in caves, emerged blinking into the sunlight, built civilisation, invented rocketry, and has now concluded that caves were, on reflection, onto something.

Storm shelters — small, heavily shielded compartments — handle the solar event problem. Mission timing helps at the margins, though the solar cycle presents a genuine trade-off: high solar activity means more storms but fewer galactic cosmic rays; low activity means fewer storms but more cosmic rays. The universe declines to offer a clearly preferable option. It rarely does.

Biological countermeasures — radioprotective drugs, DNA repair enhancers, antioxidants — are under active research and not yet mature solutions.

The honest summary: galactic cosmic rays cannot currently be fully blocked by anything we can practically carry. The shielding required to stop them entirely would be too heavy to launch. We are managing exposure, not preventing it — keeping the numbers as favourable as possible, in an environment that is making no effort to cooperate.

Which is precisely why what NASA is doing with the Artemis programme matters as much as it does. For the first time in fifty years, humans are heading back into deep space — and this time, we're bringing considerably better instruments, considerably more questions, and, in one genuinely memorable case, two human-shaped dummies designed to measure exactly what the lunar environment does to a person.

Their names are Helga and Zohar. They were not consulted on the mission parameters.

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Helga and Zohar were, to be precise, human-shaped phantoms — mannequins constructed from materials that mimic human tissue density — flown aboard Artemis I in 2022. One wore a radiation protection vest. One did not.

Both were instrumented with hundreds of sensors measuring radiation exposure at the organ level. The experiment was called MARE — the Matroshka AstroRad Radiation Experiment — and its purpose was straightforward: find out exactly what deep space does to a human body, using something shaped like one, before committing an actual one to the experience.

The results confirmed that the vest made a meaningful difference, particularly for radiation-sensitive organs. They also confirmed that deep space is doing precisely what the physics predicted it would be doing. The universe, at least, is consistent.

Artemis I was uncrewed. Artemis II — the first crewed lunar flyby since Apollo 17 in 1972 — will carry astronauts back into deep space for the first time in half a century, with real-time dosimetry running throughout. Estimated exposure for the mission: twenty to forty millisieverts.

Manageable. Informative. The kind of data that page 340 of Gerald's risk assessment was specifically waiting for.

Beyond Artemis II, longer lunar surface stays are planned, and exposure scales accordingly with duration and solar conditions. The radiation environment on the lunar surface is not gentle. There is no global magnetic field. There is no atmosphere to speak of. What there is, is regolith — and future habitat designs take this seriously. Structures buried under lunar soil, or built into the walls of lava tubes, would reduce surface radiation exposure substantially.

The Moon, it turns out, is quite willing to help protect you. It simply requires that you live underground and never complain about the commute.

The Artemis programme is also advancing solar event warning systems — improving the window between a solar particle event and its arrival at the lunar surface.

Currently, warnings can come hours in advance. The goal is to extend that to days. This matters because the difference between adequate shelter time and inadequate shelter time is not, in this context, a minor scheduling inconvenience.

Looking further ahead, the technologies under development are genuinely interesting. Hydrogenated boron nitride nanotubes — HydroBNNTs, a name that sounds invented and is not — are a lightweight material with promising shielding properties against galactic cosmic rays, currently in development. Active magnetic shielding — essentially a miniaturised version of Earth's own magnetosphere wrapped around a spacecraft — is theoretically sound and practically very difficult, requiring substantial power and engineering solutions that don't yet exist at useful scale. It is the sort of idea that makes perfect sense and is extremely annoying to build.

Pharmaceutical research continues into compounds that help cells repair radiation damage more efficiently. Some individuals, it turns out, are simply better at this than others — there is natural variation in how effectively the human body responds to radiation-induced DNA damage.

The universe is, as ever, deeply unfair about who gets which biology.

None of these solutions are complete. Most are partial.

Several are still theoretical. The problem of galactic cosmic rays, in particular, remains genuinely unsolved — one of the central engineering challenges standing between humans and any serious long-term presence beyond Earth.

We are, in other words, going back to the Moon equipped with considerably better science than we had in 1972, a clearer understanding of what we're up against, and the quiet, determined ingenuity of people who have read the full risk assessment.

Unlike some people we could mention.

Well, my radiation-hardened listeners, we've reached the end of another quantum expedition into the genuinely alarming nature of existence.

Today we've learned that space radiation is constant, omnidirectional, qualitatively unlike anything you encounter on Earth's surface, and largely unbothered by our feelings about it. We've learned that Earth's magnetic field and atmosphere have been performing an extraordinary, unacknowledged service for the entirety of human history, and that the moment you step outside their coverage, the numbers begin moving in a direction that requires careful management by people with advanced physics degrees and a high tolerance for sobering spreadsheets.

We've learned that Victor Hess rode a balloon into the stratosphere in 1912, watched the radiation increase with altitude, and correctly concluded that the universe was the source — a discovery that won him a Nobel Prize and has been mildly worrying space agencies ever since.

We've learned that aluminium is trying its best. That caves are making a comeback. That Helga and Zohar endured the deep space radiation environment with the stoicism unique to those who have no central nervous system to disrupt. And that somewhere in the Artemis programme, scientists are developing materials, drugs, and miniaturised magnetic fields to give future astronauts a fighting chance against particles that originated in exploding stars and have been travelling, unimpeded, for millions of years specifically to arrive at this problem.

We've also learned that Gerald flagged all of this on page 340. In yellow. For the record.

The lunar branch office remains, as far as anyone can confirm, approved. The coffee machine has been delivered. The storm shelter budget has not been reinstated. Gerald has said nothing further, which those who know Gerald understand to be its own form of communication.

Space does not object to human presence. It simply makes no adjustments for it. And yet, with characteristic and slightly baffling determination, we keep going anyway — better instrumented, better informed, and only marginally better shielded than the last time.

That is, when you think about it, a fairly accurate description of the human project in general.

Want to explore more of the universe's least hospitable properties? Visit us at multiverseemployeehandbook.com, where you'll find science deep dives, episode extras, and our latest blog series: Van Allen's Doughnuts: A Radiation Belt Retrospective.

And if you've enjoyed today's subatomically eventful adventure, share it with

someone who deserves to know what's out there. Spread our signal like a coronal mass ejection — sudden, energetic, and impossible to fully prepare for.

This is your quantum-coherent correspondent, reminding you that in the multiverse of space radiation, we are all just biological systems in a largely unshielded environment, doing our best with the electrons we have.

The universe wishes you luck.

It has not, however, made any adjustments.