Episode Book

EPISODE #5794

Starfish Prime: When the US Nuked Space

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SYNOPSIS

On July 9, 1962, the United States launched a Thor rocket from Johnston Atoll and detonated a 1.4-megaton thermonuclear warhead 400 kilometers above the Pacific Ocean. The blast turned the sky green across the southern hemisphere, lit Royal New Zealand Air Force night patrols from 2,000 miles away, and knocked out streetlights in Honolulu. It also created artificial radiation belts that slowly destroyed satellites over the following months. This episode traces why the US decided to bomb the Van Allen belts — the same belts James Van Allen had discovered just four years earlier — what the instruments actually recorded, and why some of the most important data doesn't exist because the explosion was too large for the equipment designed to measure it.

TRANSCRIPT



Corn

Here's the version of Starfish Prime you've heard. A nuclear weapon goes off in space, and the sky over the Pacific turns green, and every electronic device within a thousand miles dies, and it's proof that one bomb up there could end civilization.



Herman

And here's the version nobody puts in the thumbnail. The bomb that was supposed to end civilization knocked out a few hundred streetlights and set off some burglar alarms in Honolulu.



Corn

Both of those are wrong, and both of them are sort of right, which is what makes it worth an hour.



Corn

Daniel sent us a prompt. We've done Tsar Bomba, we've done Project Sundial, we did Hiroshima — this is the next entry in the series. The weapon here isn't aimed at a city. It's aimed at the sky. About four hundred kilometers of it.



Herman

The largest nuclear test ever conducted in space.



Corn

And Daniel wants three things. Why the United States decided to detonate a thermonuclear warhead in orbit. What actually happened when it went off — the launch, the flash, the effects that reached Hawaii and the things it did to the satellites already up there. And then what it taught us. Electromagnetic pulse, artificial radiation belts, satellite vulnerability, and how the whole thing fed into the test ban.



Corn

He also asked us to keep the documented effects separate from the sensational claims. That's going to be the thread, I think.



Herman

It's the whole spine of the episode, honestly. The popular image collides with the data, and the data, if you look at the right latitude, is scarier than the popular image was.



Corn

So let's start with the question that sounds like a bad joke. Why would you deliberately detonate a thermonuclear weapon in space?



Herman

Because you're worried somebody else will. That's the short answer.



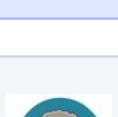
Corn

Say more.



Herman

Nineteen sixty-two, the Soviets had just walked away from a three-year testing moratorium. And the American fear wasn't cities — it was intercontinental ballistic missiles. A Soviet warhead detonated high above the atmosphere could, in theory, do something to a missile in flight. Nobody knew exactly what, because nobody had measured it properly.



Corn

So this is weapons-effects research, not a physics experiment with a bomb attached.



Herman

It's weapons-effects research. The project officer's own interim report says earlier high-altitude tests — Yucca, Teak, Orange, and the three Argus shots — were poorly instrumented and hastily executed. The models coming out of them were, and I'm quoting the report, too uncertain to permit extrapolation to other altitudes and yields with any confidence.



Corn

Which is a very polite way of saying we don't actually know what we're looking at.



Herman

Very polite. So you build a proper test. Operation Fishbowl, inside the larger Operation Dominic series. Joint effort between the Atomic Energy Commission and the Defense Atomic Support Agency.



Corn

And here's the part I want to sit on for a second, because it's the strongest detail in the whole story. James Van Allen.



Herman

Go on.



Corn

The man the belts are named after. Science historian James Fleming went through the records and found that Van Allen agreed to help bomb the Van Allen belts on the same day he announced their discovery.



Herman

Nineteen fifty-eight.



Corn

Same day. And Fleming's line about it is, this is the first occasion I've ever discovered where someone discovered something and immediately decided to blow it up.



Herman

It's a perfect sentence. You find a new structure in the space around the Earth, and your first instinct is to put a warhead in it and see what happens.



Corn

What were they even hoping for?



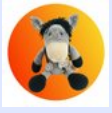
Herman

Disrupting enemy radar. Damaging missiles in flight. Damaging objects nearby in orbit. And then the one that always gets quoted, which is the half-baked idea that you could somehow move a blast down the belt — detonate it in one place and have the effect travel along the radiation belt until it reached Moscow.



Corn

That is not a mechanism. That is a wish.



Herman

It's a wish with a budget line, which is how a lot of this era worked.



Corn

I want to stay on that for one more beat, because the wish list tells you something about how they were thinking. They weren't testing one hypothesis. They were throwing a bomb at a system they barely understood and hoping the results would sort themselves into categories.



Herman

And to be fair to them, that's sometimes the only move available. When your models are too uncertain to extrapolate, you don't have a better option than to go measure. The problem is the thing you're measuring is a one-point-four-megaton warhead, and you only get a handful of tries.



Corn

And you can't repeat the experiment.



Herman

You can't repeat it. Not at that scale, not in that environment, and not after 1963. Which is why the data from this single shot is still being mined sixty years later. There's no second data point.



Corn

Walk us through the shot itself.



Herman

July ninth, 1962. Nine seconds past nine in the morning, UTC. A Thor rocket lifts off from Johnston Atoll. It's carrying a W49 thermonuclear warhead inside a Mk. 2 reentry vehicle. Thirteen minutes and forty-one seconds later, four hundred kilometers above the Pacific, thirty-one kilometers southwest of the atoll, it detonates.



Corn

Yield.



Herman

Roughly one point four megatons. About a hundred times Hiroshima. And there's a detail there that I love — the missile didn't go straight up and pop. It arced. It peaked at about eleven hundred kilometers before it detonated on the way back down.



Corn

So the warhead went up a third farther than the detonation altitude and came back to it.



Herman

That's the profile. And that first attempt isn't the one that flew. There was a launch on June twentieth that aborted when the Thor failed, and the debris came back down on Johnston Atoll. Radioactive debris. On the island the people were standing on.



Corn

Right.



Herman

They tried again three weeks later.



Corn

I want to make sure people understand how unusual that is. A failed launch that scatters plutonium across your own launch site, and the response is to reload and try again in three weeks.



Herman

The response is to reload and try again in three weeks. And that tells you how much institutional weight was behind getting this shot off. The window mattered. The Soviets were testing. The moratorium was dead. They were not going to let a Thor failure stop the program.



Corn

Okay. It goes off. What do people see?



Herman

Start fourteen hundred nautical miles away. Kwajalein. The Quick Look report is the primary document here, and the language in it is better than anything I could write. A brilliant white flash burned through the clouds rapidly changing to an expanding green ball of irradiance.



Corn

Green ball of irradiance.



Herman

Then white fingers rising to forty degrees above the horizon. Then what the report calls spectacular concentric cirrus like rings. And then, over a hundred degrees of arc, north to south, a dull burning red semicircle that persisted no less than ninety minutes.



Corn

Ninety minutes.



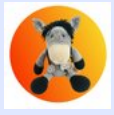
Herman

It's not a flash. It's a feature of the sky for an hour and a half.



Corn

And it's not just the Pacific. There's the New Zealand measurement.



Herman

Christchurch. A photometer measured the six hundred thirty nanometer oxygen emission — that's the red line of the aurora — at one point eight times ten to the fifth rayleighs. That's twenty-four hundred times the normal airglow value. The report calls it equivalent to a class three aurora.



Corn

A class three aurora over New Zealand. Which is not a place that gets auroras.



Herman

Not at all. And here's the line I would put on a poster. The Royal New Zealand Air Force was aided in anti-submarine maneuvers by the light from the bomb.



Corn

They were flying night patrols by the light of an American thermonuclear weapon on the other side of the planet.



Herman

Two thousand miles away, effectively.



Corn

That's the scale I don't think people absorb from the thumbnails. It's not Hawaii. It's the whole southern hemisphere sky.



Corn

There's an eyewitness account I want to read, because it's the one that actually lands for me.



Herman

Coale.



Corn

Cecil Coale. He's one of the scientists measuring the shot. And he says the whole Pacific lit up like a flash bulb. Night turning into mid-day for just a split second. And then the sky turned green for about a second.



Herman

And then the second half of the quote, which is the part I find eerie. It wasn't shimmering. It was just glowing red like a neon sign. There was no bang or thunder or anything. It was just visual.



Corn

No sound.



Herman

You can't hear it. Four hundred kilometers up, and sound doesn't get to you. So the largest explosion anyone had ever set off, and it arrives as pure light. No shock, no rumble. The sky just changes color and stays that way.



Corn

And Coale's addendum. He quit over it.



Herman

He said, I realized when I saw that thing go off that there really wasn't any safe place on Earth to test those things.



Corn

That's a man watching his own field's biggest experiment and deciding he doesn't want to be part of it anymore.



Herman

It's the most honest sentence in the entire source record, I think. He's not making a political argument. He's reporting a conclusion.



Corn

So that's the sky. Tell me about Hawaii, because that's where the myth lives.



Herman

Nine hundred miles away. The electromagnetic pulse — the EMP — did three things that we can document. It knocked out roughly three hundred streetlights. It set off burglar alarms. And it damaged a telephone company microwave link, which shut down calls from Kauai to the other islands.



Corn

Three hundred streetlights.



Herman

And the reason we only have three things is the interesting part. The pulse was far larger than expected. So much larger that it drove much of the instrumentation off scale.



Corn

The measuring equipment couldn't measure it.



Herman

The instrument was designed for what they predicted. What happened went past the top of the dial. So the most important data from the most important shot partly doesn't exist, because the shot was too big to record.



Corn

That's a specific kind of tragedy. You build the experiment for the answer you expect.



Herman

You do. And then there's the physics underneath it, which is the part that was a genuine surprise. The blast blew out a plasma bubble in the magnetosphere. The planet's magnetic field was completely expelled for nearly half a minute. Half a minute with no magnetic field in that region.



Corn

Expelled.



Herman

Pushed out. Replaced by the plasma from the explosion. And the shot released on the order of ten to the twenty-ninth electrons into the magnetosphere — that's a one followed by twenty-nine zeros — which boosted the electron intensity in the inner belt by several orders of magnitude.



Corn

Which is where the satellites come in. Let's do the numbers carefully, because they don't agree.



Herman

They don't, and I want to be honest about that. There were twenty-four satellites in orbit in 1962. One account — the APS writeup on the modeling work — says Starfish damaged at least a third of them. Wikipedia says the man-made belts eventually caused six or more to fail, naming Telstar 1 and Ariel 1. The Space Review gives a figure of nine lost out of twenty-five, seven of them American.



Corn

So somewhere between a third and nearly all.



Herman

That's the honest range. What's not disputed is that the belts did it, and that they did it over months, not seconds. This isn't a bomb blowing up a satellite. It's a bomb creating a radiation environment that slowly cooks the electronics.



Corn

The Ariel case has the best documentation.



Herman

Ariel 1 was a British satellite. It failed on July thirteenth, four days after the shot. And the UK science minister, Lord Hailsham, wrote a secret memo to Harold Macmillan about it that is one of the strangest documents of the Cold War. He says, although badly wounded in his solar paddles, he is not quite dead. He still utters intermittently, sometimes intelligibly.



Corn

He's writing about a satellite like it's a wounded soldier.



Herman

With more affection than most governments manage for their own employees, frankly.



Corn

And Telstar.



Herman

Telstar 1 launched the day after Starfish. It lasted a few months and then went. And then the Soviets ran their own high-altitude tests over Kazakhstan in October — Operation K — and that finished it off.



Corn

So the satellite damage is real, it's documented, and it's spread across the source record with numbers that don't match.



Herman

Which is the correct way to present it. I don't think anyone has a settled figure, and anyone who tells you they do is picking a source and pretending it's the only one.



Corn

And then the prediction failure. This is the part that I find most interesting as a piece of science.



Herman

Glenn Seaborg, chairman of the AEC, wrote in his memoirs — and this is a man who was not easily surprised — to our great surprise and dismay, it developed that Starfish added significantly to the electrons in the Van Allen belts. This result contravened all our predictions.



Corn

Contravened all our predictions.



Herman

They went in expecting to make a small, temporary disturbance in a natural structure. They came out having created a new, persistent, artificial radiation belt around the Earth.



Corn

Which is still a strange sentence to say out loud. We built a belt.



Herman

We built a belt, and it took years to decay.



Corn

Let's take the EMP question head on, because this is where Daniel's prompt asks us to be careful.



Herman

I'm glad he asked, because the popular version is doing damage.



Corn

The popular version is that Starfish lit up Hawaii and proved that a single high-altitude burst could take down a continent. What does the record actually say?



Herman

The record says the Hawaii pulse was about five thousand six hundred volts per meter. And that it extinguished, by the most careful accounting, between one and three percent of the streetlights on the island. Oahu had more than ten thousand streetlights. Three hundred is a real number and it's a small fraction.



Corn

And there's a paper that goes further.



Herman

Mario Rabinowitz, first published in the late eighties and reissued later. He argues that EMP is no more harmful to the power grid than its counterparts in nature, and that many reports have incorrectly stated that EMP produced a major electrical disturbance in Hawaii. And Sandia's Charles Vittitoe did a dedicated analysis of the streetlight incident in 1989 and didn't find a clean causal story either.



Corn

So the famous streetlight blackout is contested. Not invented, but contested, and probably overstated in the retelling.



Herman

Considerably overstated in the retelling. Five thousand six hundred volts per meter, a couple of hundred lights, some alarms, one microwave link. That's the actual event.



Corn

And now the part that makes that not reassuring.



Herman

The same physics that gives you a modest pulse over Hawaii gives you a catastrophic one over the northern United States. And it's the magnetic field that decides which.



Corn

Explain the mechanism, because this is the thing I want the listener to actually take away.



Herman

A high-altitude burst produces a prompt gamma ray flash. Those gammas travel down into the atmosphere and collide with air molecules, and that collision knocks electrons loose and sends them flying — mostly sideways, radially outward from the burst point. Those electrons are moving. The Earth's magnetic field is there. And a moving charge in a magnetic field experiences a force, which curves it. So the electrons get bent into a



Herman (continued)

coherent, circular, coherent current — a Compton current — and a huge, fast-moving current in the upper atmosphere radiates. That's the EMP.



Corn

It's the magnetic field that turns an expanding shell of electrons into a coherent antenna.



Herman

It's the field that does it. And that's why the geometry of the field matters enormously. Over Hawaii, the field lines are shallow — they're close to horizontal relative to the ground, and the interaction is weak. Over the northern continental United States, the field lines dive into the Earth at a steep angle, and the coupling is much stronger.



Corn

How much stronger.



Herman

Projections for a burst over the northern US run twenty-two to thirty kilovolts per meter. That's roughly four to five times the Hawaii field. And because EMP damage isn't linear — it's about what couples into a conductor, and coupling is sensitive to geometry and length — a fourfold field increase can be far more than a fourfold increase in damage.



Corn

So the number that everyone quotes for the streetlights is a low-latitude number.



Herman

It's a low-latitude number. It's the wrong number to plan a continental defense against, and it's worth saying that clearly.



Corn

And that's the sentence I want the listener to leave with. One bomb. Same bomb. Different latitude. One puts out some lights, the other is a serious national problem.



Herman

Both of those are documented. Neither one is the myth.



Corn

Now, the lessons. Start with the prediction failure on the pulse itself, because it's astonishing.



Herman

Hans Bethe had done the classified theoretical work on high-altitude EMP in 1957. And by the accounting that came out later, his estimate was off by a factor of more than a thousand.



Corn

A thousand.



Herman

Which tells you how thin the physics was at that point. This is not a small correction. This is a theory that gives you the right shape and the wrong magnitude by three orders of magnitude. And the correct mechanism wasn't worked out until 1963, when Conrad Longmire at Los Alamos deduced it properly.



Corn

So the experiment taught the physics, and the physics had to be rebuilt from the experiment.



Herman

That's exactly the order of events. Starfish demonstrated that the magnitude and the effects of a high-altitude burst were much larger than anybody had calculated. The theory came after.



Corn

And there's a detail about the data itself that I find almost funny.



Herman

The magnetic field tapes.



Corn

The tapes.



Herman

Palmer Dyal collected the magnetic field data from the shot. And because it was classified, the tapes were shelved. They sat in his garage. For four decades.



Corn

In a garage.



Herman

And the first magnetic field data from a once-classified high-altitude nuclear explosion was finally published in 2006, forty years after the shot.



Corn

That's a real physical object that spent forty years in a garage holding the answer to a question people were still arguing about.



Herman

And it eventually got used. Lawrence Livermore built a code called TOPANGA — Belyaev, Cohen, Clark, and Larson, developed between 2017 and 2021. It's the first model to reproduce Starfish Prime's EMP from first principles, validated against the declassified data, and presented at the American Physical Society's plasma physics meeting in Spokane in November 2022.



Corn

Sixty years.



Herman

Sixty years from the shot to a model that actually reproduces it from scratch. That's the timescale of this kind of physics.



Corn

And the satellites. What's the actual lesson there, given we now have thousands.



Herman

Two lessons that pull in opposite directions, which I think is the honest framing. The first is what happens when satellites aren't hardened. Starfish showed that. Ariel, Telstar, the others — unshielded electronics in a radiation environment that got much worse than anyone planned for.



Corn

And now?



Herman

Now there are roughly nine thousand nine hundred operational satellites in orbit. More than sixty-two hundred of them are Starlink. In 1962 there were twenty-four. So the exposed surface area of the global economy to a bad radiation environment is up by two orders of magnitude.



Corn

But.



Herman

But the second lesson is that modern satellites are already built for this. Elizabeth Quintana at RUSI makes the point that EMP in space is a largely overblown threat today precisely because radiation hardening is now standard practice. The commercial satellite industry learned the lesson in the worst possible way in 1962 and then designed around it.



Corn

So the vulnerability is real but it's been priced in.



Herman

Priced in for the radiation part. And that's the honest position. It's not a soft target the way people assume. It's a target that was hardened by an accident sixty years ago.



Corn

The test ban next. Hailsham's memo again — he goes from wounded satellites to the actual conclusion.



Herman

He wrote to Macmillan that the real moral about their high level explosion was the need for a test ban treaty. And that's the throughline. The Partial Test Ban Treaty was signed on July twenty-fifth, 1963 — atmospheric and exoatmospheric testing banned.



Corn

Less than a year after the shot.



Herman

Under a year. And then the Outer Space Treaty in 1967 banned weapons of mass destruction in orbit outright. So the political structure that keeps space usable traces directly back to a test that went off over the Pacific in July of 1962.



Corn

There's a detail about the timing I want to put in, because it's almost too neat.



Herman

November first, 1962.



Corn

Both the United States and the Soviet Union conducted their last high-altitude nuclear explosions. On the same day.



Herman

And it's also the day the Soviets began dismantling the missiles in Cuba.



Corn

So the end of high-altitude nuclear testing and the end of the Cuban Missile Crisis happen on the same calendar day. Whoever is writing this timeline has a heavy hand.



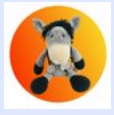
Herman

History does that sometimes.



Corn

Give me the reaction from the outside, because not everyone was having rooftop parties.



Herman

Canon L. John Collins, who'd been pushing against the test for years, called it an evil thing. And Izvestia, the Soviet state paper, ran a headline: Crime of American Atom-mongers.



Corn

Which is rich, given the Soviets did their own.



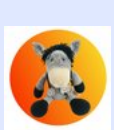
Herman

The Soviets ran Operation K over Kazakhstan in October of 1962. And they were observing Starfish too — they had scientific ships stationed near Johnston Atoll and down in the southern conjugate region, watching what came out the other end of the magnetic field.



Corn

So both sides were watching the same experiment, both hated it in public, and both were taking notes.



Herman

Notes they took and used. That's the Cold War in one sentence.



Corn

Before we wrap the discussion, I want to leave one door open, because there's a genuine gap in the record and I think it's worth naming.



Herman

Go on.



Corn

The precise details of the Soviet tests. We have the American side in tremendous depth — the Quick Look report, the magnetic tapes, the modeling six decades later. The Soviet high-altitude program is much less well documented. We know the name, Operation K, we know roughly when, we know they damaged Telstar further. But the yields, the altitudes, the measured effects — that record is thin.



Herman

It's thin internationally and it's thin in the literature. If anyone listening has spent time in that archive, we'd like to hear from them.



Corn

The satellite count stays disputed, which we should leave disputed rather than resolve.



Herman

Agreed. At least a third of twenty-four, six or more, nine out of twenty-five. All three are in the record and none of them is obviously wrong.



Corn

I've been thinking about the sky.



Herman

Okay.



Corn

Everyone's instinct with Starfish Prime is to talk about the weapons and the pulse and the satellites. But the thing that actually happened — the thing that a human being watching from a ship would have seen — is that the sky over a third of the planet changed color and stayed that way for ninety minutes. And nobody had ever seen anything like it, because nothing like it had ever occurred on this planet.



Herman

That's the part I can't get past either. From the standpoint of the upper atmosphere, this was a new event in the Earth's history. The magnetosphere is a system. It had a state. And we reached up and put it into a different state for a while.



Corn

And it recovered.



Herman

It recovered. Slowly, because of the belt. But it recovered.



Corn

The system is more resilient than we assumed and less studied than we assumed. Both of those are true at once, and both came out of the same four hundred kilometers.



Corn

Alright.



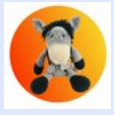
Herman

Sorry, one thing.



Herman

Somebody at the desk is going to have a view on this.



Herman

The word I'd push back on.

SOURCES

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