The Rational Optimist Podcast

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Stephen McBride: So Isaiah, I was talking to a German guy here in Abu Dhabi a couple of days ago, and I said to him, "hey, you you want to turn back on those nuclear reactors." I said that it's the cleanest, safest, best source of energy in the world. He says, "yeah, but it's also the most expensive."

First off, is that even true? And if it is, why is it true? Because back in the 70s, nuclear was the cheapest power that humanity has ever produced.

Isaiah Taylor: Yeah, I think if you have a very non-fundamental view of things, then you'll always just take the price as it is. But the prices have reasons, and those reasons can be complicated. In the case of nuclear, there are some complicated reasons why it's been expensive in the last 20 years. But you can come to understand those reasons and then see why that should be different going forward.

So the first thing I'll say is like, just look at the historical figures, which is exactly what you said before. If nuclear used to be 10 times cheaper, then clearly we're doing something wrong.

When we say we need to do nuclear again, we're obviously not talking about like, copy-pasting the 10 failed projects in the Western world that ended up eating tons of money, we're talking about the fundamentals of nuclear, which is that splitting uranium apart makes an enormous amount of heat at a very low cost. Doing that correctly is going to produce a huge amount of very cheap energy.

So, okay, so that's just setting the table of like, we're not talking about copy-pasting failed projects. We're talking about very fundamental stuff.

Now I happen to agree that nuclear as it is, is very expensive. It's not the most expensive, but it's very expensive. And there's a few reasons for that. The biggest reason is that we're trying to sort of reboot an industry that was suited for 1960s-style methods of construction.

So in the 1960s, it made a lot of sense to build large civil works projects. And the reason for that is we had a lot of cheap labor and we had the supply chain to do mass-scale civil construction. This is when we were really good at making bridges, making roads, making dams. We were good at the large-scale civil works. And nuclear became essentially like a large-scale civil works thing. Because that's how we built stuff, right? Like we were good at building stuff.

Nuclear as a matter of physics and design looks really nice the bigger you make it. I would argue actually that even— so I wouldn't make it big. Even if we were really good at doing civil works, I would actually still make it small, but we can talk about why in a second.

But anyway, we're trying to build nuclear the same way that we did back when we were really good at making some works projects. Now it turns out we're not good at that anymore, right? It's hard for us to make a bridge. It's hard for us to make a road. It's hard for us to make a dam.

What we are good at now is manufacturing. Right? If you're going to turn nuclear back on, you're going to like turn that switch back on. It will probably not look like the civil infrastructure projects of the sixties anymore. It will look like SpaceX, right? Or it'll look like Tesla, which is essentially manufacturing.

If we're going to turn nuclear back on, if we're going to harness the power of the atom to make cheap energy, we're going to do it in a way that is essentially manufacturing-based rather than construction-based.

And if we do that, it will be very cheap because the fundamentals are there.

Stephen McBride: Do you think the part of those big, huge, traditional nuclear power plants is just gone? Maybe another way to ask this question is, you know, on a gigawatt scale, do you think SMRs or that category of manufacturable small reactors is just going to outpace—is it going to be 10 times more at the output than traditional reactors have today?

Isaiah Taylor: Yeah, it will. There's really no way around it. Again, think about the Falcon nine versus the SLS, right? So the only way that we sort of rebooted space was to make a smaller rocket that was capable of being manufactured and then just make tons of those. And then that ended up being like the only way to get massive amounts of payload to orbit.

I think that now, what's interesting is that now SpaceX has moved down to Starship, which is even bigger than the SLS. So that's kind of interesting. But you have to start back at that smaller scale because you have to do something that is fast and repeatable and it's iterative. And it's very hard to do something fast, repeatable and iterative when the actual physical thing is huge. Right? So you need those small sizes to fit into tooling and to keep the cost down and to keep the speed up.

And then once you sort of have the stature of this massive industry that builds hundreds of thousands of the thing, then you can make the size bigger. So I think, yeah, the old-style nuclear power plants is absolutely going away. If nuclear power plants do get bigger again, it will probably be from one of the small nuclear companies like Valar that gets into a larger form factor because we want to scale more.

I also think that there's a natural reason for reactors to be smaller. And that reason is safety. So smaller reactors are simply safer. And the reason for that is that the one I would say there's kind of two main safety challenges in a nuclear reactor, but one of the biggest ones—and the one that was the failure mode of both Fukushima and through Mile Island—is that in an emergency scenario, after you shut down the core, you still have a decay heat being produced in the isotopes. So the reaction has totally stopped. There's no more fission occurring. There's no more chain reaction occurring.

But you still have heat production. And the heat is being produced in these recently split atoms that are a bunch of different fission fragments. And they're all going down their decay chains. And they're producing heat. And you have to be able to get that heat out of the core.

So passive decay heat removal is what this is called. And in large plants, there's diminishing ways to get that heat out of the core passively. And you end up relying on forced cooling. So what that means is you end up relying on the engineering guarantee that coolant continues to move through the core and pull that decay heat out. And in both Fukushima and Three Mile Island, that engineering system failed.

So in Three Mile Island was because there was an explosion in the steam system, and the steam escaped. There's no more cooling in. In Fukushima…was that the backup generators got knocked out by the tsunami.

So there's just always reasons why an engineering system might fail. And so to go back to the beginning, why is it that making a larger and larger reactor pushes you toward forced cooling away from passive removal? It's a very simple reason.

The surface area of a cylinder scales with the square. The volume of a cylinder scales with the cube. So the bigger your cylinder, the more volume you have inside and less surface area, right? Proportionally. And what that means is at the end of the day, there's just a lot of heat production in that cylinder and you, have fewer and fewer ways to get the heat out. Right?

So if your plan was to essentially use black body radiation as the way to get the heat out, well, you just have so much less surface area now to deal with. If your idea was to use convection, right? So air contacting the surface of the vessel? You just have less surface area to deal with.

So I think there's a natural reason for reactors to be smaller. It makes them safer. And the other reason is just that it's easier to produce 10 small things than one big thing in general.

Stephen McBride: Talk to me about how something that can fit in your back garden can power, you know, 5,000, 10,000 homes or more for a year. How is that? Just get a little technical for a minute. How is that even possible?

Isaiah Taylor: Yeah. Well, first of all, I would say your garden is going to have to be pretty big to fit this guy back here. This is a real nuclear reactor behind this. It's not a background. I'm inside of my shipping container down here in the factory floor. That thing's about, I mean, it's exactly 20 feet tall actually, because that's an iso-frame. So it's a little bit bigger, but that's more about the machine itself.

I think what's more interesting is the uranium, right? So how is it possible for the uranium to power, you know, cities while being a very small size.

The stat that's interesting here is if you used uranium fission to power everything in your life—like your *entire* life. Every single time that you as a human use any power. And I'm not just talking about electricity. I'm talking about just energy in general, right? So getting in a car and driving somewhere, you're using energy. Getting in an airplane and flying to visit grandma, you're using energy. Obviously your lights. You open up your phone and you use chat GPT.

Every single thing in your life…if you use uranium fission to power that, at the end of your life, you will have used a volume of uranium approximately equal to this cup of coffee. Every single day of your life, every single thing that you did, you would use about this much uranium's worth of energy.

So uranium is just like this unbelievable cheat code. It's like an energy cheat code left in the world and all around the solar system. It's here, and you have to be careful how you use it. Using it carefully is essentially the discipline of making nuclear reactors. But it's there.

What's also crazy is that we've done this before, right? We did use uranium to power—and we still do—but at an incredibly low cost to power our world back in the 60s and 70s. And so I'm excited because we're going be going back there again.

Stephen McBride: I believe we tried nuclear-powered rockets at one point. I always remember the Palmer Lucky quote, what did we think when we were allowed to think what we wanted? And the fifties and sixties are just ripe with these crazy experiments. Is there one that stands out of like, hey, I wish some entrepreneur would try to bring that back.

Isaiah Taylor: Yeah, the nuclear power rockets is pretty cool. But I think that honestly, Nixon's vision for a nuclear-powered society was pretty awesome. And I do think we're heading back that way. You know, there are a bunch of these realizations about how much energy impacts all of human society and capital and technology.

What does cheaper energy mean? Well where does our food come from? Food comes from, you know, plants…there's solar power, but then there's also a lot of fertilizer, right? And the fertilizer is generally ammonia-based. And that comes from energy actually, because you have to get the nitrogen out of the air, and then you have to combine the nitrogen with methane, right? And so there's this highly energetic process for producing ammonia, and the ammonia then goes into the different fertilizer stacks. And so there's this interesting feature where cheap energy actually means cheap food. Right?

And we say cheap energy, we mostly mean natural gas, but it turns out that you can also make ammonia with electrolysis, right? So you electrolyze water, you get hydrogen. Combine the hydrogen with nitrogen, you get ammonia.

And so there's this idea of like, why don't we make like a ton of nuclear reactors? And they will make grid power, but they'll also make a bunch of other things. So they'll make hydrogen. The hydrogen can make ammonia. The ammonia can go to crops. The crops make cheap food. We can also make hydrogen—send it to direct steel reduction, right? Direct iron reduction, make primary steel. That steel is very cheap. Can make bridges. Right.

We can also electrolyze bauxite that bauxite gives us aluminum. The aluminum helps us make cheap cars and airplanes. We also get gallium out of that to help us make cheap microchips. So there's this sort of like cohesive…what if we made a bunch of reactors and just obliterated the price of energy, just like drop that thing so low that all of these industries start to become cheaper?

I think it was a very beautiful vision. And this is sort of the progenitor to our gigasite idea. The gigasite is very much this where you have many reactors laid out in a row.

Some of are making electricity, some of are making hydrogen, some of are making process heat. And you have this campus of things that are feeding off of that energy at a very low cost and are complimentary and are producing goods at a much lower price than anyone believes is possible today. So that's very exciting.

Stephen McBride: Just go a little bit deeper into that because you've called Valar Atomics the anti-SMR, SMR company. You take a very unique approach and the gigasite strategy and also producing hydrocarbons. Just go into the strategy and how you came to settle on that.

Isaiah Taylor: Yeah. I do call it the anti-SMR, SMR company, not because it, so to back up what, what is an SMR? An SMR is a small modular reactor. and the idea behind SMRs was that we've made reactors too large and that's made them very difficult to build. And so let's make them smaller.

The problem with SMRs is that there was sort of a reason that reactors were so big. And one of the big reasons is that there is a fixed cost of base cost that you're going to have to get over to do a nuclear project, right? To like do nuclear at all, there's some minimum floor costs.

And you want to like in economics, if you have a fixed cost, you want to start building lots of revenue on top of the fixed costs so that it becomes a proportionally smaller piece of the overall pie.

So let's say you have like an auto shop and your rent is $10,000 a month. That's a fixed cost. It's not going anywhere. And so you want to do like $100,000 of revenue or $150,000 of revenue to offset your base costs.

And nuclear—that base cost is huge because you have so much like environmental work and compliance work around doing nuclear at all. So you need to like clear the site and you need to get the community engaged. need to do environmental studies on it. You need to get the supply chain, the infrastructure set up. You need to do site security there. You have to figure out the fuel storage. You have to figure out the waste storage.

So all these different components that come together, now you're ready to do a nuclear reactor. And so that nuclear reactor better be enormous so that you can recoup all of that fixed cost. This is sort of like why the industry moved that direction. And it's why we keep designing gigantic reactors. It's one of the reasons why we can't keep designing gigantic reactors.

So even though the SMR movement was right, that you need to make the reactor smaller because it makes the reactor easier to make. It actually made that fixed cost problem worse, right? Where people were looking at like hundred megawatt sites and they're like, well, wait a minute, there's still like a billion dollars worth of developing costs and project costs before you can get to the reactor. And so you sort of made that problem worse.

So when I say that Valar is the anti-SMR, SMR company, the idea is basically you do make the reactor smaller, but you keep the sites big. And in fact, you make the sites even bigger, right? We want to see 10 gigawatt, 20 gigawatt, 30 gigawatt nuclear sites, but with the unit size very small. And so what you do is you still get to take care of that fixed cost, right? You can have the fixed cost and you get to amortize that. But...you're actually able to build a reactor as quickly and cheaply and combining these two things.

Now, why hydrocarbons? Hydrocarbons are sort of like how you do this and you hook the entire system into the largest power grid in the world. So when I talk about something like an energy grid, the first thing that people think of is electricity.

But what's interesting is that the electrical grid is one of the smaller grids that we have. We actually have much larger grids, and the biggest grid is the hydrocarbon grid. So imagine the pipes and the tanks and the pumping stations all around the world and the ships, right? That grid is enormous. That grid is probably seven times larger than the electrical grid.

And it's global, and it has lower losses over very long distances, and it has storage built in already. So it's a really, really phenomenal piece of energy movement equipment. Let's call it that way. So if you can make hydrocarbons from one of these gigasites, you open up terawatts of demand. There are terawatts of hydrocarbon demand, and they become available to you through hydrocarbon. So that's the reason.

Stephen McBride: Obviously bringing on all this new, you know, this new synthetic supply of basically hydrocarbons. What do you think happens to the oil price over the next 20 years?

Isaiah Taylor: I think it goes down and this is not something we've been able to do for like 30 years now. Oil has just capped out, started high, we worked our way down, we found better ways to drill, better ways to refine, better ways to transport more efficient uses…and then we tapered. And you could say like, well, that's OPEC restricting the supply or whatever. Yeah, you find ways to drop that for a time. And what you discover though is we've kind of tapped out how you drill and refine and transport hydrocarbon.

And one of the reasons for that is that the sources keep shifting. So like this source is the source today, but over here is the source tomorrow. And so the transportation side of that can't really scale that well. And you keep having to like pay for capex in multiple places to draw the supply from different spots. And then you have like a big refiner, which is a huge amount of capex, and then its utilization goes down because actually the oil can't get shipped there anymore because the source changed.

So there's all this inefficiency. And we sort of maxed it out, right? Like it's hard to imagine gas becoming five times cheaper than it is today. So we really need to switch to something that's fundamentally different than all those constraints. It's not buying oil. It's not shifting source, right?

There's like no reason for a gigasite model of hydrocarbon generation to have source shifting. Because you're just purchasing CO_2 from a nearby coal plant from the air, and your water, which is very abundant. So it's different in terms of…you can actually scale transportation capex source shifting, and then you're not purchasing oil.

So I think that for the first time in decades, we actually will see hydrocarbon prices trend down, which is very exciting.

Stephen McBride: Walk me through what these recent executive orders and regulatory changes mean in concrete terms for innovators like Valar. Because obviously this has been the big elephant in room for 50 years now. We've known nuclear was great and safe and all these things, but the roadblocks have been there. So what do these things mean in concrete terms?

Isaiah Taylor: Yeah, this is really exciting. I mean, this is like the most important thing that's happened for nuclear in 50 years. I've long believed that the NRC, with all the problems that it has, is actually not the core problem with the nuclear industry. It's a commercial regulator. It doesn't really know what to do with SMRs. It has a bunch of ideas, it has a bunch of thoughts, but it's like never actually been able to turn one on.

And the industry has never really been able to turn one on and there's a sort of like weird chicken and egg situation with it. But actually the problem is that the NRC is mostly concerned with big stuff, right? The NRC's job is maintain the existing nuclear fleet, which makes 20% of American electricity. And these are gigawatt reactors and they are high stakes.

The NRC deals with the highest stakes stuff in the world. And so when you come to it and say, I have a tiny test reactor, can I turn this on? You're kind of walking up to like a gigantic elephant, and you're like a mouse, right? So there's just sort of a mismatch there. Again, they're dealing with 20 % of American electricity generation in gigawatt-scale reactors. They honestly just don't really have time for this. And this is like the testing and the small-scale stuff.

What's interesting is that Congress actually knew this way back in the 60s and 70s. It actually afforded for this. And what they did is that they spun the test functions for nuclear into an agency called the ERDA. So it separated out the Atomic Energy Commission into two functions, the NRC, the Nuclear Regulatory Commission for commercial nuclear, and the ERDA for testing.

And the whole point of the ERDA was to do exactly what we just said, which is test the small-scale stuff. And you were supposed to be able to use that to get through this sort of early R&D. And then once you're there and you have something serious, then you can go to the NRC and the NRC can say like, all right, now here's how we do that 1,000 times all over the United States.

But I have always believed there's this natural mismatch going with your small reactor concept to the NRC. So what is the ERDA? You've probably never heard of that agency before. It's the Energy Research and Development Agency. And the reason you've never heard of it before is that in 1974, it was renamed to the Department of Energy.

So most people don't know this, but the Department of Energy is actually a nuclear reactor test agency. That's literally what it was created for. It was created to test nuclear reactors. And this is so exciting because basically what the executive orders did from the president a couple of months ago is that they sort of executively recommissioned the DOE into doing what Congress originally intended for it to do, which is to test nuclear reactors.

So the big headline there, there's a bunch of stuff in those orders, but the big headline is that the Trump administration has mandated that three advanced reactors turn on American soil by July 4th of next year. Incredibly fast timeline, but also incredibly exciting. And we're up for the challenge.

Stephen McBride: You were one of 10 companies, startups, selected for the DOE Reactor Pilot Program. Just tell me where, you know, it's September the 4th today. We're gonna switch one on by America's 250th birthday. Of course, Valar Atomics is gonna be one of the three selected. Tell me what's—

Isaiah Taylor: We'll be the first.

Stephen McBride: We'll be the first, I love it. Yeah, and you can quote me on that. Tell me the pathway from September 1st to July 4th next year. What, you know, what practically is going to have to happen?

Isaiah Taylor: Yeah, we're going to have to set up a nuclear test site out in Utah. So we're going to be out there in a few days. And we've been out there a bunch, but we're going to have a cool event there, which you'll see shortly. And yeah, we've got to build a nuclear test site. We've got to put a reactor on it. We've got to fuel it up. We've got to turn it on.

So I think the biggest thing right now is just the coordination of all those steps. We have it all laid out in front of us, what we need to do. And the biggest thing is like managing all of the tiny, mighty details and need to come together, right?

It's regulatory. It's, you know, all the little bits and pieces that have to show up on the site at the right time. It's the assembly process. It's making sure, you know, we don't drop it a sensitive instrument as we're installing it. There's all these sorts of little things that come together.

There's the security and operations, there's the procedures, there's the nuclear safety, there's the health physics. It's all detail work, but that's exciting, right? Because now we have the outlines, we have the plan, and now we just gotta go execute.

Stephen McBride: We have these big headlines of the executive orders and the reactor pilot program and so on and so forth. Are there things like LNT and ALARA and NEPA that can still get in the way or are these complete carve outs that kind of allow you to bypass those roadblocks?

Isaiah Taylor: Yeah, thankfully we've been able to swerve pretty much all of that for this project, right? So because it's under the DOE, and the DOE is just a very unique thing that's really purpose-built for this, we get to swerve all the way, know, swerve around most of these things.

I think the rest of what you just talked about will get resolved, right? So LNT, ALARA and NEPA will get worked out and those are NRC problems to get worked out in the next 18 months, essentially. And I think they will. And again, like one of the things I want people to like take away and understand is that regulators…it's very hard to reform a regulator in theory.

You have to regulate it and you have to reform it in fact and in practice with real projects. Because it's just too hard to theoretically tell somebody who's in charge of a regulator, like this rule is wrong. And it's hard for you to even know which rule is wrong. It has to be tested against real things in the real world.

And when you have a real project in the real world that's being held up, you can say like, "Hey, this reactor turned on under the DOE. How long would this have taken if it had to go through an NRC process? And what would the results had been?" And you can compare it, contrasting say "OK, like, yeah, clearly something's broken here. We need to, we need to fix it to be able to make that project run." You can really only regulate things that exist. You can't, can't regulate things in theory. can't regulate like principles of nature.

Regulators can regulate existing technology, but when you're innovating and you're moving fast, you have to have something that's very dynamic. And then once that thing exists, then you can kind of take it to a more stable regulatory regime.

All of these things will be worked out, but they will be worked out through building. They'll be worked out through these types of projects happening on the ground. The NRC can look at them and say, OK, well, clearly we need that piece of flexibility because look how fast this thing actually went, right? And we would be the bottleneck there. It's very exciting. It's going to be a great time.

Stephen McBride: You've said that engineering is now the bottleneck as opposed to regulation, which has been for 50 years. Of course, a good problem to have. What's the hardest technical nut that you still have to crack?

Isaiah Taylor: So for us, we made this a little bit easier for ourselves because we picked a really simple reactor. But I would actually say probably power conversion. The reactor architecture that we picked is so simple. It's a really, really bulletproof reactor, incredibly, incredibly high safety margin, very easy to build, really easy to construct, huge supply chain. And so really we're like sort of in the ancillary systems now in terms of where the engineering difficulty is.

Stephen McBride: You have this vision to make nuclear the cheapest power in the world. I've talked to some other, you know, small, small modular reactor, microreactor startups that kind of frame it as premium power. What do you know that they don't? Or what are you, what are you going to achieve that they, that they can't?

Isaiah Taylor: Production rate. We're just gonna make so many of these things. We're gonna, so there's like two things. One is if your reactor is too small, then production rate won't solve it. Like you have to have the right size, right? We're gonna make a 25 megawatt reactor. And a 25 megawatts mass production will make that the cheapest energy on earth. If your reactor is a lot smaller than that, yeah, production rate will help it a little bit, but you're probably not gonna get cheaper than that gas

So if you have like a one to five megawatt reactor, let's say, it's hard to see the production rate actually helping that. But at 25, like absolutely, we're just gonna make so many of these things and it's gonna be the cheapest energy on earth.

Stephen McBride: I've also heard you say it's either China, Russia or Valar. How do you size up, you don't have to mention names, but how do you size up a lot of the other US competitors? How do you…I was doing a dive into them. There's at least 15 or 16 of them that, you know, seemingly on the frontier working on real technology. Just how do you think about all the competitors?

Isaiah Taylor: Yeah, there's a lot of people—talking about competitors is really hard because they're all so different, right? And I can talk about any one of them and have something very specific to say, but talking about them as a field is very difficult.

The most general thing that I'll say is that let's just separate it into two classes: startups that have been around for a while and brand-new ones.

So on the brand-new ones, I'll say, we'll see, right? Like I have high confidence that Valar is going to win and it's going to take the whole market. There will be other pieces, but like we'll be the runaway winner, but we'll see, right? Like these guys are also, you know, taking a crack at it and moving quick. And we respect that.

The other bucket is the startups that have been around for awhile. And I would say that they missed something that's very important, which is you simply can't design a nuclear reactor on paper. Like, you just can't make technical progress in theory. The only way that genuinely hard technologies have ever come into the world is through building them.

You just have to build it. You have to turn it on. You have to test it. You have to figure out what's leaking. You have to figure out what won't tighten properly. You have to figure out which systems won't integrate. You have to figure out which protocols won't talk to each other. Like that is actually the hard part. And if you have gone for five or 10 or 15 years on paper without tackling any of those problems, you misunderstood what technology development is. And so. I hope you figure it out soon.

Stephen McBride: You mentioned about the protocols. We often think about nuclear as hardware. How much software goes into a modern nuclear microreactor?

Isaiah Taylor: Yeah, there's a ton of software. There's software all over this thing in. There's also like electronics. So there's analog systems and there's digital systems. And the digital systems have some software, but there's a huge amount of both electrical engineering and software engineering.

Now Valar in particular, I would say that we are cautious about overspending on software. We built this entire system behind us here without a single software engineer on the team. We have a lot of smart people, and those smart people happen to know software, right? I wrote a fair bit myself as I had to, but like we built pretty much all this and operated it under pressure without having a software team.

This is one of these things that scares VCs. And like VCs want to believe that everything they invest in is actually a software company. This is wrong. The most exciting companies in hard tech are not software companies. They're not like, you people have this insane idea, like genuinely insane idea. If you were a VC and this is in your head, please come like text me or call me and I will dispel you of this notion. Yeah, totally. But like, if you have this in your head, like—

Stephen McBride: You need the Men in Black pen.

Isaiah Taylor: —remove it or call me and I'll remove it for you. SpaceX is not a rocket company with software. That's not what it is. Like they have this crazy idea that like SpaceX is like this software company that happens to use rockets as a mode or something like that, but actually it's a software company. That is not true. Even a tiny bit true. Obviously software is involved in what they're doing, but that is not what's going on in SpaceX.

The reason that SpaceX is successful is similar to why certain software companies are successful. But the fundamentals is that they execute an incredibly hard technology in a way that produces a huge amount of leverage. And then they apply that leverage to massive margins on the market. Right. And how did they become masters at that, at that technology, the same way that all great technologists do, which is that they push forward toward the efficient edge of known information at a faster rate than anybody else. And then they operationalize that information.

So what I'm talking about is there is a theoretical way of how you produce a kerolox rocket motor and you have to push out to that efficient edge at all times, and then operationalize that knowledge. And if you are doing that slower, SpaceX will beat you.

That is exactly what has happened to everybody. And that's the same thing that's going on here at Valar. And of course, you use software, but I'd like to point out that the G-fold algorithm is from the 1950s, and it landed us on the moon. So we know how to land rockets with software, but it's the operationalization of that and the experimentation.

The actual launching and landing and launching and landing and launching and blowing up and then launching and landing. That's the process that pushes SpaceX forward. And that's really what hard tech is kind all about. And that's what we're all trying to do.

Stephen McBride: We talked about the DOE, know, testbed carve outs. How do you think about the DOD and all this? They've kind of emerged as another one of these, you know, kind of loopholes, let's say.

Isaiah Taylor: Yeah, so if you look, if you read the executive orders on the DOD part of this, you'll notice that it basically says that the DOE and the DOD will collaborate to figure out how to move forward here, which I think is an awesome start. Eventually, I believe that the DOD will sort of have more than the...

So right now, like the DOD does run its own reactors underneath naval nuclear. And I think that over time, DOD will figure out how to do that again in other places. It'll figure out how to do that for Army. It'll figure out how to do that for Marines. It'll figure out how to do that for Air Force. And they're currently trying to figure that out. And basically the executive orders tell DOD, have DOE help you do that by 2028, which is super exciting. So we're going to see a lot more of it. That's all I'll say for now.

Stephen McBride: I've heard you call nuclear waste the safest form of trash humanity has ever invented. Why is there such a disconnect between public perception and the actual reality? And how do we close that gap?

Isaiah Taylor: Part of it is the fact that, there's two things. One is I think that there were specific pieces of propaganda that were intentionally disseminated. I believe that our rivals throughout various times in history have tried to dissuade the American public from nuclear because it is such a powerful thing that we can make metal cheaper and we can make power cheaper and we can do AI cheaper and all these sorts of things.

So I think that we have sort of been intentionally misled away from it—exactly like Germany was in the last five to 10 years. Russia very explicitly convinced the German public and German politicians that nuclear was bad so that they would stop nuclear and they turn their plants off so they would become more dependent on Russian gas. This is a known fact that this happened. I think there's some of that.

There's also just the fact that the media pieces that portrayed nuclear have been very focused on atomic weapons. If you Google nuclear, there's two categories of things that come up. But nuclear bombs are always up there.

And so there's just sort of like some co-branding that's a problem there. It's very interesting that fusion didn't like catch this as much. I'm not sure why that is. And it's like worth considering like why fusion didn't really get coupled into that as much. People love fusion. If you talk about like, "fusion coming." Like people aren't like, "atomic bombs," even though atomic bombs are all basically fusion bombs at this point.

So that's kind of ironic that it just didn't really cross over psychologically. But yeah, it's a branding problem, but I think what's interesting is that the Information Age has like totally obliterated that. Like if you look at my generation, who like read stuff and reads or Googles things and watches podcasts about people talking about stuff and just…has a ton of information about this. They are extremely pro-nuclear.

So the generation that got all their information from, it's like a centralized source, like TV and newspapers, either don't like nuclear or like sort of against it. Our generation, which has democratized access to information, loves nuclear. Yeah, there's a huge irreversibility to that. You just can't put that cat back in the bag because everybody just knows about it now.

If you were to try to quickly spread an anti-nuclear narrative globally, it would be very difficult. The information is just very sticky. So that's exciting. I think it's a really fun time to be building nuclear.

Stephen McBride: It's almost like we've got the antibodies, we've got the antibodies to the anti-nuclear argument.

Isaiah Taylor: No, actually that's actually a great point. I think that Fukushima actually contains some of those antibodies. Basically there was this nuclear incident in Japan and the Japanese response to that was like, immediate and it was, I would say, massively overheated.

They evacuated, I think, 100,000 people. And it turned out that the evacuation effort killed more people than the event, which was zero. So the event didn't kill anybody. And the evacuation effort did kill people. And so there was this…our reaction to the thing was worse than the thing. And that actually created some antibodies of like, did we as a sort of as a society catch this weird bug about nuclear that kind of made us act irrationally.

And so I think it's exciting that we sort of seem to have moved beyond that. We're cautious in the other direction now. We're cautious about nuclear scares, which is great.

Stephen McBride: I'd love to get a little technical for a moment to just walk through how your reactors, Ward Zero and then Ward One, work. You mentioned passively cooled earlier. Why can't they melt down? And just talk me through the design of the reactor, the design choices, I guess. Like I believe that the fuel is TRISO, the moderator is graphite and the coolant is helium. Just walk through all those design choices, basically.

Isaiah Taylor: Yeah, yeah, you nailed it. So, so those three, design choices lead to a very, very safe nuclear reactor. So TRISO fuel, graphite moderation, helium coolant. This is an excellent safety stack for nuclear reactor. TRISO is kind of where it starts. TRISO is this incredibly strong form of nuclear fuel that is capable of reaching high accident temperatures. That's super important.

There are a couple of different features of a nuclear design when it comes to safety. And one of them is called containment. So containment is the barrier between the fission products, right, which are highly radioactive and toxic, and the outside world. So you have to have a physical barrier between fission products and the outside world.

In the traditional nuclear plant, that physical barrier is a big concrete dome. If you've ever driven by a nuclear plant, you've probably seen this big old concrete structure. That's called the containment dome. And it's literally just placing a ton of strong mass between the world and fission products. Now, this is generally a sphere because spheres are a very strong, materially efficient structure.

But the one problem with the containment dome is that they're huge and they're expensive and they're still not that strong. They're good, but you could get through them, right? Now the reason for that is that they're big. And it turns out that the bigger a sphere is, the worse it is. So I'll say this again: The larger a sphere is, the worse it is at being strong, right?

So that this strength of a sphere scales inversely with its diameter. If you have a very very tiny sphere, that sphere can be extremely strong per shell thickness. And so TRISO basically like takes that idea. So the idea is if you just kept making the containment dome smaller and smaller, it gets stronger and stronger. And TRISO basically takes that idea to its fundamental logical conclusion, which is that what if the containment dome is actually that big?

And that's what TRISO is. So TRISO is these tiny little beads of uranium, and they are wrapped in these layers of very, very hard ceramics. And those ceramics make up containment. And it turns out that once you scale it down to that tiny size, that ceramic sphere is actually hundreds of times stronger than a gigantic, nine-foot-thick concrete rebar reinforced high-density concrete dome, which is really awesome. So that's kind of where the safety starts.

Now, the other thing that's super important about this is because it's a ceramic, it has high temperature resistance. So in an accident scenario, the core can reach a very high temperature without releasing any fission products. And then try so that somewhere around 1600 degrees Celsius, which is really hot.

And the nice thing about that temperature is that if you allow the core to get very hot, you actually increase the ways that that heat can escape, or you increase the volumes at which that heat can escape. So for instance, black body radiation. So black body radiation is basically just hot things radiating heat. And black body radiation scales with the fourth power of temperature.

So if you double the temperature of an object, the amount of heat that it is emitting will actually go up by 16X. So it's not linear. It's to the fourth power. And so what that means is if your reactor is tolerant of higher and higher temperatures, it is actually able to emit more and more energy in an accident scenario.

The final one… Sorry, the next one is graphite. So the fact that you use graphite as a moderator is really great. Graphite is a very strong negative thermal feedback for reactivity. And so what that means is as the temperature of the core rises, the reactivity of the core tapers and eventually drops.

Right, what that means is it's incapable of nuclear runaway. Right, so it's incapable of a runaway state where you have criticality and then your criticality actually, your KF continues to increase and then you have sort of a neutron population that's out of control. It's actually incapable of this. And that's because you have this really tight feedback between temperature and reactivity. This is a nuclear physics concept. I can explain it, but it takes a while.

The other thing that's really interesting though about graphite is that it has high thermal inertia. And this goes back to what we talked about before, in the decay heat. So when you shut the reactor down, your TRISO is still producing heat, a lot lower than when it was, than the, the, nuclear reaction was active, but it's still producing heat.

That heat needs to go somewhere. And fundamentally, you want the heat to get outside of the core. But even before it gets outside of the core… Graphite has really high thermal inertia. So think about inertia. So imagine you have a big block of steel floating in space, and you hit it with a hammer. You whack it with a hammer. It doesn't move that much. It starts moving, but not that much.

So now apply that idea to heat, right? So if you have something with high thermal inertia, you can hit it with a ton of heat. It won't heat up that much, right? So it will absorb a lot of that thermal energy without increasing its temperature too much. So this is what graphite does. It just is like a giant heat battery. So post shutdown, that triso can transmit a ton of its heat to the graphite without the graphite reaching dangerous temperatures.

And then the last thing is that the graphite itself can also reach enormous temperatures without sublimating. It can get well beyond 20 to 100 degrees Celsius. The final thing, and sorry, I you asked me a 30-second question. I gave you a five-minute answer. I apologize. This is dangerous to ask me about the technical questions. The last thing is that we use helium as the coolant.

Stephen McBride: Well, I love it.

Isaiah Taylor: Helium is a great coolant. It's invisible to neutrons. What that means is that it will not capture neutrons and become radioactive. And this is unlike water, right? So water in a nuclear reactor will become radioactive. And so if you have a leak in the system, you have radioactive leakage. You have to treat the water as waste, right? So this is in working fluid.

Water in a reactor is nuclear waste. So helium is just a lot cleaner. It's a lot safer. Also, the biggest thing about it is that helium starts a gas and stays a gas. And so you don't have a phase change that you're worried about inside the nuclear system. So in a normal nuclear reactor, have water as the coolant. And you're always sort of like thinking about phase change, meaning what happens if all of that water suddenly becomes steam?

And when water goes from liquid to gas, the pressure of it increases by about 1,500 times. So water to gas is a 1,500X pressure spike. And that's a steam explosion. So that's what has happened in many steam-based systems.

Helium starts a gas, stays a gas. It's a noble gas, which means that temperature and pressure are directly related. So you're never going to have a 1500X pressure spike if the temperature doubles, your pressure doubles, and that's well within the bounds of like being able to engineer a system.

So anyway, there's like 70 years' worth of thinking into how to design a really safe nuclear reactor. I do believe HDGRs are kind of the best in the world at this. And that allows us to make many of them and operate them safely.

Stephen McBride: As we gear towards closing here, Isaiah, I we could play some devil's advocate. So I'm going to put out some things that someone listening to this conversation, some questions they might have, some pushbacks. So the first is, “hey, I'm so worried about these small modular reactors. What if a terrorist gets their hands on them? Can they turn it into a nuclear weapon?”

Isaiah Taylor: Yeah, totally.

So, TRISO is really the best defense against this. You can make other reactor architecture safe as well. I'm not saying that TRISO is the only type of safe small reactor, but TRISO gives you a ton of bang for your buck here. TRISO is incredibly difficult to reprocess.

There again, we talk about these like incredibly strong mini containment domes. Turns out they're like unbelievably hard to access. And this is one of the reasons that they were invented actually is to prevent, this is called non-proliferation. Basically, how do you prevent the wrong people from accessing nuclear material?

Actually, I was talking to a guy who works in nuclear reprocessing and I was like, "have you guys tried to reprocess any TRISO?" And he's like, "well, we ran it through the grinder machine and it broke our grinder machine." And I was like, "okay, nice. That's good to know."

Basically, it would be probably easier to try to steal any other type of reactor or like try to breed it yourself or something like that than to try to actually access the TRISO reactor. So there are things to think about, lots of security that we think about, but it's a really annoying form factor to try to do something bad with.

Stephen McBride: If SMRs are so great, why hasn't China built a hundred of them already?

Isaiah Taylor: They're getting there. Yeah. Give them a little bit of time. China's new at this. Like China's new at the nuclear game and they're currently figuring it out. But I mean, China has turned on two of the type of reactor standing behind me right here. The first one was five years ago. The second one was—sorry, five years ago, four years ago, two years ago. Yeah. I'm to get those dates wrong. Someone's going to correct me, but yeah, give them time. They're working on it. And we got it. We got to work faster.

Stephen McBride: You know, we, for sure, we wanna bring these learning curves to SMRs, we wanna pump out the reactors, make them faster, cheaper, safer, all those things. At what point do learning curves kick in? It's maybe not going from one to four. How many of these things do we need to produce to get those learning curves?

Isaiah Taylor: Yeah, I think the number is probably around five, like five. Um, but I would just point out, if you make your reactor really small, five is something you can do in a year. If you make your reactor gigantic, five is like decades. So this is, this is just one of the basic reasons that you make the reactor small. It's like, you want to make it small enough that you can, you can do it a lot and doing it a lot teaches you a lot. And you move that idiot index down closer to zero. Sorry, closer to one.

Stephen McBride: NuScale's project after costs ballooned. Why is Valar Atomics different?

Isaiah Taylor: Our reactor is a lot smaller and also we, you know, we build the reactor and test it and run it and like get to know it before we put uranium in it. But I think the biggest thing is just like our reactor is a lot smaller. It's a lot easier. We can move a lot faster and we, we don't try to skip all the steps.

I think one of the big failure modes that people have experienced in nuclear is that they really so badly want to get to commercialization and their investors want them to and everybody wants them to get to selling commercial reactors that they always try to skip everything that leads up to that.

But again, with SpaceX, they had to build the Falcon 1 first and they had to launch it and blew it up and blew it up and blew it up. And then it finally flew. Then they could fly the Falcon 9 and it blew up and then flew it again and it blew up and then they flew it. And then it had to figure out how to land itself in a crash and try to land itself in a crash.

You have to get through those things. No amount of design will get you there. You simply cannot do it. You could give Elon and SpaceX $50 billion and 50 years to try to build what they built and you wouldn't do it. It just doesn't work that way. You would have spent $50 billion in 50 years.

So the only way that you actually get to commercialization is you have to test the systems and you have to get to know the nuts and the bolts. And so that's what we're going to do.

Stephen McBride: Two closing questions for you. What truth do you believe about nuclear that most of your peers in the industry think is crazy?

Isaiah Taylor: It will be the cheapest source of energy in the world in the next couple of years.

Stephen McBride: And I think both of us are over the 2.1 threshold for kids. Leave us with a dose of optimism. Why should kids be optimistic about the next 10, 20 years? Give them some optimism, some agency.

Isaiah Taylor: I mean it's gonna be so exciting, dude. I love playing Minecraft.

Stephen McBride: Where do you find the time?

Isaiah Taylor: I don't play much yeah no I don't really play anymore I used to play with I used to there's really only two games that I like seriously played Minecraft and Counter-Strike and unfortunately you know I probably have like 3,500 hours in Counter-Strike. Since starting Valar Atomics, I probably have eight so that that's kind of fallen off.

One of the things that I noticed was when I was working on other companies and other things, I would always keep coming back and playing Minecraft. And since starting Valar, there have been a couple of times when I played it with friends, but like, I realized that I'm playing Minecraft in real life. And that is just so much better. It's harder and like, you have to wait longer for the reward, but, but like that's, that's what we're doing now.

We're playing Minecraft Alpha in real life right now. We're not really playing it. You have to wait a long time. There's, too much like nonsense you're dealing with. The supply chains aren't really there. I think one of the reasons that people love software and that software like sort of like snipes everybody who's smart into working on it is because software, really are playing Minecraft, right? What do I mean by that?

I mean that you're like creatively working in this open world where the tools and ingredients are there and they're composable. And you can like make compositions of things that have new functionality. And then you compose other things on top of that and compose other things on top of that. And you're like building this world. Software is like that today. And in Minecraft is this game where the physical world works in a software-like fashion and it's composable and it has components to it.

And you can quickly compose worlds, but we're going there, right? That's happening in the physical world. It's happening through advanced manufacturing. It's happening through energy being cheaper. It's happening through robotics. It's happening through like more and more precise engineering and nanotechnology and all of the things that people around the world are working on to make the physical world more addressable and more componentized and more composable is making the physical world more like Minecraft.

Stephen McBride: Besides nuclear and energy, what innovation, what breakthrough are you most excited about in that Minecraft future?

Isaiah Taylor: Yeah. So there's really only three things that I think are like extremely important to be working on. Energy, intelligence, and dexterity. Right? So these are the three things that make up everything. Energy is really obvious. Intelligence, you know, really obvious. Dexterity may be the least obvious right now. But we need the ability to physically manipulate the world with detail.

So examples of dexterity are like everything from a robot arm to a manufacturing line. Manufacturing line is actually an example of dexterity. It's like a set of machines that manipulate matter into a desired shape. So getting better at all three of those things, energy production, intelligence, and dexterity, are what are pushing those forward.

So I think the thing that I'm like very excited about right now is intelligence and dexterity starting to work together. It needs big improvements of all. Intelligence needs to get a lot better. Dexterity needs to get a lot more flexible. and I don't really think it's a humanoid, although we can talk about that. I actually think that humanoids would be a very large business, but not really for what people imagine they'll be for. I don't think you're going to see factory floors crawling with humanoids.

Isaiah Taylor: So there's something else that needs to be made, which is more generalizable. And it will probably not look like a human, but it is capable of manipulating matter and that intelligence can be applied to it. And it needs energy, and I'll provide the energy. And then we all play Minecraft, and it'll be super fun.

Stephen McBride: Isaiah, thank you so much for time. This has been fascinating. Where can people find more out about what you do, what Valar Atomics does?

Isaiah Taylor: You can follow me on Twitter or X @isaiah_p_taylor. You can also go to valaratomics.com.

Stephen McBride: And we will all be following along as Valar Atomics is the first startup to turn on a new nuclear reactor on US soil. Thanks so much for your time, we'll talk soon.

Isaiah Taylor: That's right. Thanks, man. Have a great one.