Episode 5

Fission Founders, Part 2: Designing Advanced Nuclear Reactor Startups

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Katherine Boyle

Energy is the hardest sector because it combines multiple challenges. You're dealing with commodities at pennies on the dollar. You have to be exceptionally good at math and deep technology if you're building a new type of energy company.

You also have to be able to paint the story to attract the one-in-a-million physicist or engineer you need to build something new. Looking at sectors that have emerged in the last ten years, like aerospace and defense, there are robust categories. But energy is harder.

Building the SpaceX of energy or nuclear requires excelling at all aspects, including regulatory. There's nothing you can skimp on or simply hire someone to cover your weaknesses.

Packy

Hello, and welcome back to Age of Miracles. This is our fifth episode and the last one on nuclear fission alone. In episode two, we went through nuclear's history to uncover lessons for today's nuclear renaissance in order to reignite the industry's growth. In episode three, we tried to apply those lessons to figure out how to get back to building large reactors more often, more cheaply, and more predictably.

Last episode, we heard from founders manufacturing small modular reactors (SMRs), scaling down existing pressurized water reactor designs and making them in factories and shipyards to bring them down the experience curve.

Julia

Today we're speaking with a different crop of founders, those building advanced reactors using new designs, selling to new markets, and forging new regulatory pathways. Katherine Boyle, a general partner at a16z's American Dynamism practice, is no stranger to hard startups. She's backed companies like Anduril, Flexport, Flock Safety, Hadrian, and the advanced nuclear startup Radiant. She told us that energy is the hardest of all the hard categories. To build a successful energy startup, you have to excel at math, deep technology, storytelling, recruiting, and regulatory.

On the last episode you heard from Bret Kugelmass and Matt Slotkin about manufacturing SMRs. Nothing they described sounds easy. Advanced reactors up the difficulty a couple more notches. Instead of tried-and-true pressurized water reactor designs and existing nuclear fuel supply chains, they're designing new reactors and using newer, harder-to-source fuel types like TRISO. And instead of selling to customers used to buying nuclear reactors like utilities, they're cracking new markets.

Packy

Advanced reactors are hard. But if we're doing a podcast on how to build an age of miracles, figuring out how to bring back innovation to nuclear is critical. To advance, we need to advance. A good place to start is with the question of what is an advanced reactor?

I like Nick Touran's definition on whatisnuclear.com: "The term 'advanced' in nuclear is used loosely to mean reactors that are better than the ones that you're worried about." Then he goes on to explain why it's not quite that simple in practice. We'll link to his excellent page on advanced reactors in our resource guide if you want to dive into the definitions debate.

Fortunately for us, the US government defines advanced nuclear reactors in the Nuclear Energy Innovation and Modernization Act. The term "advanced nuclear reactor" means a nuclear fission or fusion reactor with significant improvements compared to commercial nuclear reactors under construction today, including improvements such as additional inherent safety features, significantly lower levelized cost of electricity, lower waste yields, greater fuel utilization, enhanced reliability, increased proliferation resistance, increased thermal efficiency, or the ability to integrate into electric and non-electric applications.

Julia

Perhaps one of the most defining characteristics of advanced reactors is that they're not live yet. While Nick told us in episode two that a number of these more exotic reactors were tested in the '50s and '60s, they're currently not operating, not licensed, and many are still theoretical. In a legendary 1953 memo, Admiral Rickover, who built the nuclear navy, warned of "paper reactors" by distinguishing between academic and practical reactors. An academic reactor almost always has the following basic characteristics: it is 1) simple, 2) small, 3) cheap, 4) light, 5) can be built very quickly, 6) very flexible in purpose, 7) very little development is required and will use mostly off-the-shelf components, and 8) the reactor is in the study phase, but is not being built right now.

Packy

Rickover compared those idealized paper reactors with practical reactors which have the following: it is 1) being built now, 2) behind schedule, 3) requiring an immense amount of development on apparently trivial items (corrosion in particular is a problem).

4) very expensive, 5) takes a long time to build because of engineering development problems, 6) large, 7) heavy, and 8) complicated.

Julia

But what's the difference? Practical reactors, the ones we've talked about in episode three - large, hard to build, over budget, behind schedule - are somehow the ones getting built. So today we're heading into this world of paper reactors. We'll caveat up front that while a lot of what you'll hear from founders sounds great on paper, the true test will come when the reactors are actually built.

That said, there's a lot to be excited about. After all, today's practical reactors were once paper reactors too. Admittedly, I'm biased. I've co-founded one of the startups you'll hear about today: Antares. We're working on an advanced rector. And Packy and I both invested personally in another one: Aalo, who you'll also hear from.

Packy

70 years have passed since Admiral Rickover wrote the paper reactors memo. The founders building advanced reactor startups are aware of the risks. They've read the paper. They know the challenges and the skepticism, much of which comes from inside the industry. Last time we talked about the diagnosis component of a good strategy, and the challenges in bringing a new reactor design to market are certainly part of the diagnosis.

These are people who have self-selected into playing entrepreneurship on insane mode. But to them, the investors who back them, and the geniuses who work with them, so are the opportunities to make reactors passively safe, cheaper to build, more fuel efficient, and to serve new markets beyond utilities.

If they can pull it off, advanced reactor startups have the opportunity to solve big problems that go beyond even powering the grid by "offering something fundamentally different", as Union Square Ventures investor Albert

Wenger put it. USV has invested in two advanced reactor startups, Transmutex and Radiant.

When I asked how they underwrite nuclear investments, given their unique characteristics, he told me that they're looking for "different" instead of "a little bit better."

Albert Wenger

This isn't a "We think this particular approach is 10% cheaper." There's dozens of electrolyzer companies, for example, and everybody's like, "My electrolyzer is 5% more efficient." I just don't know how to evaluate that. I don't know how to invest on the basis of that, because that may or may not be the case. But that seems like a tough way to go through.

Whereas saying "No, we're doing something that's pretty fundamentally different and it'll either work or won't work." tends to be more our MO.

Julia

Over the past five years, venture capitalists have invested millions in several advanced nuclear startups, with a peak in 2022. But what are they funding exactly? Nick Touran comes through with an excellent reactor design flowchart, which we'll link to.

There are eight main categories of choices that reactor designers can make, each with multiple options, resulting in millions of potential reactor designs. Where to draw the line for advanced reactors is subjective, so we asked Nick to break it down.

Nick Touran

I put together a flowchart that steps you through the different options or choices you can make as you're choosing your own adventure in reactor design. At the top, I have a reminder that depending on your path, you're either going to be high, medium, or low technology readiness level, which really matters. Then you choose your construction style: modular construction with some components built in factories, the whole thing built in a factory, or stick-built. You choose an overall size, usually measured by the reactor's power level, from micro (less than a megawatt) to small, medium, large, or even gargantuan. People have proposed thousands of reactors combined together in certain wild scenarios.

You then choose a power cycle - how you convert heat into typically electricity, but sometimes propulsion or something else. Options include Rankine, Brayton, Stirling, piston chemical, thermionic ion capture. Next, you choose a moderator, with complex choices covering the whole field of reactor design. Then you choose the physical form of your fuel. Oxide is by far the most common, with uranium oxide as the workhorse developed over decades. There are metal fuels, mostly for fast neutron reactors, and some development in higher density, more stable fuels like nitrides and carbides. TRISO fuel has been the workhorse for gas-cooled, high-temperature reactors. You can also choose a fluid fuel, like molten salt or liquid metal.

Besides the physical form, you'll choose which isotopes are in the fuel to determine the fuel cycle type. Maybe you're just regular enrichment uranium to low enrichment and you're just burning it away. Maybe you're a natural uranium reactor using one of the really good moderators, like heavy water. Finally, you choose a coolant, where most of the diversity and complexity comes in. There's some overlap with moderator, as in some cases they're the same thing. Gas options are typically used for high-temperature reactors. We learned early on not to use air because it can catch fire. Water is the most common, either boiling or pressurized.

Liquid metals are fantastic reactor coolants with high thermal conductivity and heat capacities. Molten salt coolants can be used as fuels or kept separate from the fuel in a fuel rod and just pump a molten salt past it as a coolant. Other options include organic coolants, sulfur-cooled reactors, and heat pipes for some microreactors. So those are some of the options and trade-offs that people talk about.

Packy

There's a hearteningly dizzying number of startups in the space, so let's talk to the founders solving those problems in the real world. Today we'll be hearing from Jake DeWitte of Oklo, whose company is going public

via a SPAC with Sam Altman and is building fast reactors for use in remote communities.

Isaiah Taylor of Valor Atomics, who plans to use the heat from fission to produce hydrocarbons, aka the stuff of oil and gas. Tyler Bernstein of Zeno Power, who's using radioisotopes to power machines from the seabed to the moon.

Jordan Bramble and our own Julia DeWahl of Antares, who are making kilowatt-scale microreactors for defense applications. And Matt Loszak of Aallo, which is using the MARVEL design from Idaho National Labs to build research reactors.

We'll introduce you to each so you can hear in their words what they're building and why. Then we'll unpack all that goes into building an advanced nuclear startup. We'll discuss their varied customers, how they finance their businesses and build teams, supply chain challenges, engineering, and how they're dealing with the regulatory environment.

We'll give you more details behind the actual science and engineering ideas for these reactors, as well as their business models. Of course, each of these founders deserves a whole episode on their own, but we want to give you a taste of the crazy variety and imagination in this part of the nuclear world.

Julia

Why? Ultimately, if the startups you heard from in episode four are trying to bring nuclear down the experience curve by manufacturing reactors, this batch of advanced reactor startups are redesigning reactors from the ground up. They're taking advantage of nuclear physics to make reactors that could be cheaper, more efficient, and safer. But they won't start cheaper.

So each is starting off by tapping into new, underserved markets that are willing to pay more and which might offer slightly easier regulatory pathways. Then over time, they might compete directly to power the grid or reduce our reliance on it. Building an advanced reactor startup means challenging the conventional wisdom in nuclear and being willing to push on things to see what's really necessary and what can be improved, as Oklo's Jake DeWitte explains.

Jake DeWitte

All of a sudden I started to realize there's all these boulders on the hill that we have to push up to realize some of the future that I think we all see as potential with what nuclear offers. We're all taught that those are all really difficult to move boulders, and what I learned pretty quickly was actually a lot of them are made of foam, so they're pretty easy to push and move. Some are not. So some are harder, but you got to try.

And so that sort of set the stage for then us thinking about what it would look like to actually build a company around doing that. It wasn't something I came in like, "I want to be a founder. I want to start a company." That wasn't at all my view. I just kept getting increasingly anxious that there seemed to be some low-hanging fruit opportunities to at least explore. And that's what we set out to do. We said, "Well, let's try them."

The question we wanted to take was, what's a technology-agnostic approach to build off of a mature technology to reduce the total costs to go from zero to first power? That was a big one for us, as well as something that had fundamental economic advantages baked into it based on sort of core underlying what I call "cost physics."

Packy

We've talked about this idea of cost physics before. If you strip every energy source down to their fundamental components, nuclear power should be the cheapest. Nuclear fuels like uranium and plutonium are the most energy-dense fuel we have. Nuclear plants can provide constant power output and can run for months or even years before needing a refuel.

The question is, how do you get as close to the true cost physics as possible? Or as Elon Musk would put it, how do you decrease nuclear's idiot index? One potential outcome of advanced reactor startups like Oklo is that they can get much closer to the true cost physics of nuclear with new designs than traditional large-scale reactor designs ever could.

Jake continues by telling us a little bit about the design they're working on at Oklo.

Jake DeWitte

Technology that builds off the legacy on the sodium fast reactor side and the down-select we went through in that analysis was really built around the benefits that sodium gives you. It's a wonderful high heat transfer fluid, much better than water, that allows you to keep things pretty simple, small, and compact. It's also really good at operating at fairly high temperatures without being pressurized, which reduces costs, and it's compatible with commonly available materials.

So I don't need bespoke, complex, or specialized metallurgical capabilities to support an exotic supply chain that has cool potential on paper, but from a cost perspective, will give you nightmares. We wanted to tap into existing supply chains as much as possible, build off of what they were, and then be very smart about what we needed to do.

Julia

Oklo is building small sodium fast reactors, which use liquid sodium instead of water as its coolant and moderator, which slows down the neutron activity in the fission reaction. In fast reactors, though, the moderator does less slowing down of the reaction than most reactors. Enrico Fermi himself worked on sodium fast reactors as part of the Manhattan project.

Demonstration reactors, the experimental breeder reactor one, fast flux test facility, and experimental breeder reactor two showed that sodium fast reactors could operate reliably and effectively. But a commercial market around sodium fast reactors hasn't developed, at least yet.

Oklo is the furthest along of the companies we spoke to. It's ten years old and on the verge of entering the public markets, and as we discussed last time, an example that newer founders can point investors to to show that nuclear startups can get to liquidity within a fund's lifetime.

It's also the most similar to more conventional nuclear companies and the startups we covered last episode, with the twist that they're using sodium fast reactors and have had to work closely with the NRC to approve its new design, which we'll hear more from Jake on later in the episode.

Packy

Other founders, though, are doing things that look nothing like what you think of when you think of nuclear. To introduce our next founder, Isaiah Taylor at Valor Atomics, we're actually going to pull in some help.

On a recent episode of Invest Like the Best with Patrick O'Shaughnessy, Anduril co-founder Palmer Luckey described what Valor is building and why it's important, without naming the company.

Palmer Luckey

If you can make synthetic long-chain hydrocarbon fuels - in other words, synthetic gasoline, synthetic diesel, synthetic jet fuel - using carbon from the atmosphere, there's a lot of ways to do it. Boiling it down is one way. You take water, crack it into hydrogen and oxygen using some kind of energy source like a nuclear power plant, and then bond it with carbon to make hydrocarbons. Now you've got artificial gasoline coming out the other end.

If someone can figure out how to do that cheaply enough, first, it's an incredible carbon capture mechanism. Second, if you can do it cheaply enough, let's say at a dollar per gallon, then all of these trillions of dollars in investment into battery electric vehicles and hydrogen electric vehicles become a waste of money and time.

Packy

Here's the idea. Hydrocarbon fuels like gasoline, diesel and jet fuel are valuable and good. They store their own energy, with a worldwide supply chain in place. They can fuel things like planes and ships that batteries can't, at least not yet. As Isaiah put it, the magical thing about hydrocarbons is that they're so transferable through time and space. Unlike electricity, which is basically use it or lose it, you can store natural gas and oil, send it around

the world and use it whenever and wherever it's needed. The stuff is magical.

They do have a few problems, though. One, burning hydrocarbon fuels releases carbon dioxide into the atmosphere and speeds up climate change. Two, we have a finite amount of them. And three, getting more of them requires expensive and uncertain exploration. What if we could pull carbon dioxide out of the atmosphere, use electrolysis to pull hydrogen (H2) out of water (H2O), and combine the CO2 and H2 to synthetically produce fuels? It would be carbon neutral. You're just using the CO2 that you pulled from the air, and you could manufacture practically limitless fuel on demand instead of exploring and digging it up.

It's possible; you just need a lot of clean electricity to make it work. That's what Valor is working on.

Isaiah Taylor

What I want to do is actually move into the existing hydrocarbon supply chain, but fuel it with nuclear fission. We already have a massive hydrocarbon supply chain throughout the United States. Rather than stop shipping oil and natural gas into power stations, I would like to continue doing that, but actually synthesize those hydrocarbons using nuclear fission.

There are two big reasons to do that. One is you can do it much cheaper on a unit economics basis. If you're comparing how much uranium costs to how much it costs to pump, pressurize, and refine gas, I think we can get it to be much cheaper. The other thing is we can get it to be higher volume and higher stability.

Our hydrocarbon industries are highly dependent on exploration today. We're constantly exploring new places to drill. That means there are big price fluctuations and swings. You have entire segments of that market go bankrupt all the time. I think we can both get our hydrocarbons to be much cheaper and far steadier.

In fact, we are manufacturing the capacity for hydrocarbon production, which is something we've never seen before. Today, there's no sense of just adding capacity of hydrocarbon production to your economy.

Packy

Isaiah wouldn't give up the secrets of his reactor designs just yet. He even said that they might start out buying from somebody else in the beginning to get to market more quickly. But over time, he's exploring "fast spectrum reactions with live isotope management in an autonomous setting."

Let's break that down. Fast spectrum reactors (FSRs) operate without a moderator like water or graphite to slow down neutrons, relying instead on passive safety systems. The experimental breeder reactors in the fast flux test facility that Julia mentioned are examples of FSRs. Now, what's a passive safety system? Passive safety systems automatically stabilize reactors without the need for human intervention or external power sources. The safety comes from the inherent physical properties of the reactor materials themselves. That's about the extent of my knowledge here.

Julia, what's actually happening in the reactor that makes them passively safe?

Julia

Well, you have liquid metal coolants, like sodium, that come with some built-in safety features. They don't require as much pressurization, which simplifies the reactor design and reduces the risk of pressure-related accidents. They're also self-regulating. As the reactor core heats up, a wider range of neutron energies becomes more likely to be absorbed by the fuel, rather than causing further fissions, slowing down the chain reaction and causing the reactor to produce less power.

So, basically, if the reactor starts to overheat for some reason, it will naturally slow down its own reaction rate and reduce the heat being generated. This acts as a built-in safety mechanism, preventing runaway reactions. Certain fuel types are also designed to support additional safety features, such as TRISO fuel, which is short for tristructural isotropic.

In TRISO fuel, each fuel particle is essentially its own containment system. They're about the size of a poppy seed, typically embedded in a graphite matrix with multiple layers that encapsulate the fission products and prevent their release. They can withstand extremely high temperatures without breaking down.

So between the reactor design and modern fuels, you have systems that are inherently safe in their design.

Packy

It's so cool. Study your physics, kids. I wish that I had. I wish that I could be working on this, but here I am podcasting instead.

In addition to those passive safety features, FSRs have some other major benefits. They can pull more energy from fuel than a thermal reactor, minimize waste by burning more of the fuel, and can use a wider range of fuels, including nuclear waste. That said, they're more technically complex and can be more expensive upfront, thanks to that complexity.

Then there are the two other pieces that Isaiah mentioned: live isotope management and autonomy. Live isotope management is very challenging and has not been done at commercial scale. This is a paper reactor squared, but its promise is to supercharge the FSR's advantages by separating and controlling isotopes in real time. It would make fuel usage even more efficient, reduce waste even more, and improve safety.

Finally, an autonomous FSR might use sensors, AI, and robotics to do some of the work currently done by human operators more responsively and reliably. This is particularly intriguing because while the risk of radiation exposure to a civilian who lives near a plant is minimal, one of the reasons we have the linear no-threshold framework is to reduce the risk to humans operating the plants. With robots, we have one less reason for LNT.

Julia

More technical complexity in exchange for better safety and efficiency sums up the various approaches that advanced nuclear startups are taking. I'd also add more regulatory complexity, but we'll get to that. As we discussed in episodes three and four, for nuclear to win, ultimately everything needs to translate into better economics. That's how Matt Loszak described the approach they're taking at Aalo: better safety and efficiency built in to unlock better economics for the company and its customers.

Matt Loszak

At Aalo, we're exploring more advanced reactors that use liquid metal as coolant to achieve potentially better economics. With these liquid metal reactors, you can have greater power density, which means using less material to produce more energy. That screams good economics.

You have this great safety characteristic: the hotter our fuel gets, the less reactive it gets. Because of the physics, it's safer as opposed to trying to engineer safety systems into and around it.

Packy

Building safety into the physics itself means less money and manpower spent on safety systems, and greater power density means more output from every unit of fuel. That should translate into better economics, on paper at least, and ultimately into cheaper, more competitive nuclear power.

There are some areas, though, where economics matter less for now. What matters most is delivering capabilities that nuclear is uniquely suited to serve. Zeno Power is building in one of those areas, as its founder Tyler Bernstein explains.

Tyler Bernstein

We started on two hypotheses: a) there was a need for reliable, long-endurance power, as we see growing activity in off-grid environments, from the moon's surface to the seabed to the Arctic, and b) if we could build an affordable but lightweight radioisotope power system, that key combination would open up much broader usability.

Our approach uses strontium-90, an available abundant fuel form, with a novel design that allows us to use far less heavy shielding material. This results in a more lightweight heat source, enabling for the first time a

commercially built radioisotope power system using an available abundant fuel in a lightweight form factor, opening up much broader usability in various environments.

Packy

Did he say the moon?

Julia

He said the moon. We'll get to that, but I want to focus on something else he said: radioisotope power system. Every other company we've discussed is based on the fission reaction, splitting heavy metals, typically uranium, apart. But with radioisotope power, there is no fission reaction. Instead, you're taking advantage of naturally occurring decay because they store energy and release it over time. Radioisotope power systems are sometimes called nuclear batteries. These systems are simpler and smaller, but can be perfect for remote locations like the moon.

Tyler Bernstein

Radioisotope power systems are hot rocks in a box. You have isotopes that are decaying over decades because they're unstable, and they produce heat as they decay. So you have rocks generating heat over decades as they decay based on the half-life of the isotope.

For example, the isotope we're primarily using is called strontium-90, with a half-life of roughly 30 years. Over 30 years, you're getting relatively constant heat generated. You can then convert that heat into electricity and have a small box the size of a microwave oven that generates electricity for decades.

Now, this is small power. We're talking tens or hundreds of watts of electricity.

Packy

Thanks for listening so far. Hang on. We'll be right back after a quick word from our sponsors.

Julia

Zeno is a great example of the variety of approaches advanced nuclear startups are taking to serve diverse end markets, often ones where there's no workable alternative. Antares, the company I recently co-founded with Jordan Bramble, is another example of this.

Here's Jordan to explain more.

Jordan Bramble

We are building microreactors for military applications. I think one thing that differentiates us from other players in the microreactor space is that we really lean into the DoD-first approach, whereas others are more dual-use, focusing on commercial and military simultaneously.

Julia

As Jordan mentioned, we are building microreactors, which are a subgroup under SMRs that are anything less than roughly 15 MW. We're going smaller than just about anyone else, targeting the low hundreds of kilowatts in size, similar to a large diesel generator in output, or enough power for about 300 households. This size matches the power needs of the most remote installations, such as radar systems in the Arctic. But they can also be scaled up into microgrids for slightly larger power needs. We love this size because it's more nimble, making it much easier to rapidly deploy in cases of escalation or changing needs.

Jordan and I got excited about a military-first approach because the military has already demonstrated interest in nuclear, and we think the overall opportunity is really large. There's a demonstration project called Project Pele, the first microreactor demonstration DoD has had in decades, which should go live around 2027. The

Department of Defense doesn't have to go through the NRC since they have their own regulatory jurisdiction that oversees the Navy's nuclear-powered submarine and aircraft carrier fleets. This should help on the cost and timeline front, but I have no delusions that any regulatory process is a cakewalk.

Finally, the DoD has made it clear they need power that can untether them from vulnerable and burdensome fossil fuel supply chains. Almost 50% of the casualties in Iraq were from supply lines. Weapons systems are also increasing in ability and quantity, with increasing power needs. The DoD is focused on deterrence of China in the Pacific, where power and logistics are critical. Just think about how massive the geography is. They call it the tyranny of distance. Getting power to the right places is really critical to the ability to win in case there is conflict.

We want to provide rapidly deployable, resilient power with a five-year lifespan for our military and allies, and believe that microreactors are the best way to get there.

Packy

It feels like people have had to think more about war over the past couple of years than they have for a while, probably since the beginning of the Iraq war. But it's not something I had ever thought about, and it makes so much sense that with the supply chain, you know the starting and end point, so you're kind of a sitting duck along that route.

Being able to bring your power with you seems like a huge advantage that whoever capitalizes on first becomes a more flexible and nimble fighting force.

Julia

Absolutely. Every war looks a little bit different. Circumstances, geography, players, and their weapons and capabilities are different. When thinking about China as a near-peer adversary, this is a country that has been developing their capabilities for a couple of decades and has proven they can build warships, drones, and planes.

They're flying right past our own planes today in a very provocative manner. So the military wants to be ready in case of escalation. Obviously, the primary goal is always deterrence, but deterrence usually means having a lot of fancy weapons that you can show off and say, "Hey, we have these and we're ready to use them."

Packy

Yeah. Not to make light of it, but I think when it's a matter of life and death, a lot of the niceties around not wanting nuclear and the environmental movement kind of fall away. You want the best possible solution for your force.

It's heartening to see that the military is receptive and even inviting to nuclear.

Julia

That's absolutely right. What's going to be interesting, though, is if you think about the Pacific, there were nuclear weapons tests back in the '50s that harmed people. Think about Bikini Atoll. There's legacy distrust in that region that I think will be a much higher hurdle than even nuclear in the US.

So it will be very interesting to see how this politics and conversation goes there. But if people feel things are escalated enough, it does change their perception of how important some concerns are versus what could be an adversary right in their backyard.

Packy

Yeah, to your point, I think everything that's coming out now is like China beats us in all of the war games run at the Pentagon. They have a 200:1 shipbuilding advantage. So at some point you just need whatever advantage you can get.

I didn't realize that Japan now has the third highest defense budget in the world because of their proximity to China and preparation for a potential conflict. So if nuclear is actually safe in the form you're delivering it, and it can give an advantage to the US and our allies, at some point that becomes the highest priority.

Julia

Japan is pretty aware that as an island nation, they rely on other countries for their energy and fossil fuels. They have slowly turned their direction on nuclear. They are no longer shutting down plants they thought they would, and they're moving to bring some additional plants back online, which I think is very promising.

Packy

I love having you in this conversation as someone who's actually doing this. I think even just that conversation shows that behind everything we talk about, there's so much that goes on beneath the surface. Why different buyers want nuclear, why startups are taking different approaches to design, the various regulatory issues - there's so much we can't get to.

But I want to use you to show that there really is so much beneath the surface on what we're going to talk about. And that's true across all of the startups we'll discuss.

Julia

What's really fun about this episode is that myself and Jordan with Antares, but also the other four different founders we talked to, each have a unique approach, technology stack, path to market or customer base. It shows that people don't think you can just do the same old playbook, because that doesn't seem to be working. We've had such a hard time getting any new nuclear online that people are saying we've got to try something else.

You'll see that all the founders we're talking to now are doing something much smaller. Why? Because you can do that for less money. You don't need to blow $30 billion to try to build a plant. You can spend a lot less money and basically prove that we can do this again. Finally, there are these underserved pockets out there that are quite different. Matt with Aalo is thinking about going to market via research reactors, which just got funding via the CHIPS Act - super creative angle.

And while we're at it, let's use the MARVEL design that's already being worked on at the INL to move as quickly as we can. Tyler at Zeno saying there's probably less bureaucracy and red tape in doing nuclear in space because we haven't done that much. So, new territory here, and let's try this new approach. Everyone's doing something different.

Packy

One thing we maybe miss when we talk about the speed angle is that it's not just about being slow. There are knock-on effects of iteration cycles. A software startup can iterate a thousand times a day. OpenAI, as we're recording this, is doing its Dev Day, and it's like the 9000th iteration since it released ChatGPT. Iteration is really important. You have to try something, see what works, see what doesn't. Obviously, with a nuclear reactor, you're never going to iterate as fast as a software company, but having ten years before you can tweak your design a little bit, and once it's locked in, you can't do anything else - it's a real bottleneck to innovation. We'll talk about what that means for safety in a bit.

But I love seeing founders say, "All right, we know the market's bad, we know regulatory is bad, we know nuclear hasn't really worked in 50 years and we need it. So we're going to figure out different approaches to solve the problem. We're going to get creative with all those pieces in order to move faster." We talked to five companies today, including you. Besides these, there are so many companies innovating in the space. I want to give a shout out to some of them upfront to give a sense of the breadth of approaches and the size of the market. It's really exciting that we're seeing about 30 different approaches to solving this problem, similar to what we're seeing on the fusion side.

Let's go over a few of them: TerraPower, backed by Bill Gates, is developing a traveling wave reactor that can run on depleted uranium and is currently working on its first demonstration reactor. Terrestrial Energy, a Canadian company, is going with integral molten salt reactors and has partnerships with national labs in the US and Canada. Kairos Power is working on a low-pressure reactor with a fluoride salt coolant. X-Energy is designing a gas-cooled pebble bed modular reactor. Thorcon is building a molten salt fission reactor using fuel in a liquid form. They're also putting it on ships and it has natural cooling baked in. The "Thor" in the name comes from using a thorium fuel cycle, a process that converts the more abundant thorium into uranium-233 and -235, meaning the company needs to use about half as much natural uranium. I know there are people who are worried that at some point we'll deplete our uranium reserves or that supply chain can be challenging. So using a more abundant fuel source and turning it into uranium is an interesting approach.

Transmutex, too, is working on enabling a thorium fuel cycle and on using spent fuel or nuclear waste to power its reactors. One company's nuclear waste storage headache is another company's treasure.

Julia

Then there's Elysium Industries, developing molten chloride fast reactors for hydrogen production. Ultrasafe Nuclear is working on a graphite-moderated molten salt reactor. BWXT is partnering with Argonne National Lab on a microreactor design. They won the contract for the Project Pele Department of Defense project mentioned earlier. Black Mesa is building a nano reactor in the tens of kilowatt scale to replace the average mobile diesel generator.

Another compelling advanced nuclear startup is Radiant Nuclear. They raised a $40 million Series B led by the American Dynamism team in April of this year. Recall that Katherine sees nuclear as a market with a small number of very big winners. So her investment here as the only nuclear startup in the portfolio is definitely her vote of confidence. Radiant CEO Doug Bernard declined our interview request because he's focused on building, which you've got to respect. Isaiah at Valor sung Radiant's praises.

Isaiah Taylor

Love what Radiant's doing. The cojones to say we are going to put this nuclear reactor on the back of a semi-truck is just mind-bending for so many people. Engineers have been dreaming about that for a long time, but to actually go out and do it...

I was talking to somebody very high up at an existing old-school nuclear construction company and trying to explain the concept of Valor Atomics, and it was just not connecting. Like, "Wait, you're going to manufacture this? Doesn't make any sense." Even just being able to point to Radiant is like, "No, look, you can put a reactor in the back of a semi-truck." It's a complete conversation changer. You absolutely change the perspective on what nuclear could be.

Packy

Narratives and examples that the impossible is actually possible are vital to nuclear's progress. Entrepreneurs seeing Radiant put reactors on the back of a truck, and investors seeing NuScale or Oklo going public mean that more entrepreneurs will try new ideas and investors will be more likely to fund them. The dozen different advanced nuclear startups we've spoken about prove Isaiah's point. These startups each offer their own fresh perspective on what nuclear could be.

Coming to the season, I had no idea that there were so many nuclear startups pursuing so many novel reactor designs. I just pictured the big plants with the big hourglass-shaped cooling towers like we have on the podcast cover art. The reality is richer than that.

But given the timelines and complexity in nuclear, success for any particular advanced reactor startup is anything but guaranteed. Many in the industry believe that advanced reactors are cute and good for attracting talent to the industry, but that they aren't going to have a particularly big impact compared to simply building more large reactors.

Julia

The burden of proof is on the startups. They'll need to go from paper reactors to practical reactors. And to do that, they'll not only need to make the technology work, but build real businesses that serve real customers and eventually earn real profits.

So let's dive deeper into the most important pieces of building an advanced nuclear startup. Assuming that the tech works, how do you build a business around it? We have to think about the business in terms of use cases, customers, and economics.

Then there's operations. How do you fundraise the capital you need? How do you recruit the team to build the product? And the rest of your government affairs team, your legal team, everything else.

The design: How do you make design choices along the way? Vendors and your supply chain: who are you going to buy your parts from? And then of course there's navigating the regulatory landscape.

Packy

I am not jealous, by the way, that you have to go through that process.

Julia

Man, it's tough. It's very different from working in consumer tech with Opendoor to SpaceX, which has cleared its way and was able to move forward on building, to just being at the very beginning where you're looking at a mountain of red tape. It's rough when you're not able to build directly for your customer the way you are with software.

You have to navigate this morass of government layers, different regulations, and gatekeepers along the way. It can definitely be disheartening and is going to require tenacity over years.

Packy

I'm glad we have people like you pursuing it, and I salute you on behalf of all of our listeners.

Julia

Oh, man. It's going to be a fight. Obviously, I deeply believe it's completely worth taking on, and I'm glad I'm in good company. I'm hopeful that Congress and the DoD see that there are multiple companies out there trying to make a difference and build great technology. Doors eventually will open and progress will be made.

As we think about what kind of progress we need to make here, let's talk about those end use cases and customers. You have incumbents and the SMR manufacturing companies we met last episode typically building in the tens or hundreds of megawatts to a gigawatt reactor size and connecting them to the grid. These buyers are typically utilities and governments, but they might also include companies with very large energy or industrial heat needs, like AI data centers and chemical producers.

But this class of company we're talking about in this episode, these advanced reactors, are basically always smaller. They focus on establishing footholds in markets that are currently underserved, whether remote communities, the military, or the moon. You have the whole range here.

Packy

To start talking about powering off-grid use cases with advanced SMRs, we need to start with the OG in space: Oklo. Nuclear has powered off-grid uses before. Small nuclear reactors have been powering our submarines in the Navy since the days of Admiral Rickover.

And Russia deployed a floating SMR, Akademik Lomonosov - I'm sorry to our Russian listeners for my pronunciation - in 2018.

Julia

Packy, did you know that Russia is also the only country right now with an existing breeder reactor, one of those fast spectrum reactors we talked about?

It just makes me think, hey, can we get into some kind of nuclear energy cold war with Russia where we all try to outbuild each other?

Because that would certainly be a positive outcome for all of humanity if we did.

Packy

This is Josh Wolfe's point from before. Part of getting people excited about nuclear again is greed - these are huge markets - and part of it is fear. While we don't need to worry about them using a breeder reactor in war, because that's not how it works, there should be some kind of national pride and competitiveness.

We can't let the Russians out-innovate us on reactor designs. "Innovate" is a funny word in this context because as we've talked about, these are all old designs finally being brought to market. We should be able to get these things to market as quickly or more quickly than the Russians are. So let's go, people.

Julia

Totally. It makes me want to write up leaflets and drop them around congressional offices like, "Hey, did you know Russia has these types of reactors? Let's go.

We are dragging our feet on this.

Packy

The number of reactors in China makes sense. If you're going to go top-down, it's easy to say we're going to do all of these reactors cheaply. Labor is probably not working in the best conditions, and there's a lot you can do to build the old thing faster. But the fact that we're also getting out-innovated - I think you do need to drop those pamphlets next time you're in Washington, DC.

We do, however, as this episode shows, have this spirit of entrepreneurship and innovation here. Oklo, founded in 2013, is the first modern US company to attempt to power off-grid use cases with an advanced reactor. Its co-founder and CEO, Jake DeWitte, spent his career in traditional nuclear, and he recognized that to sell advanced reactors, he'd need to start with customers who most needed cheap, reliable energy, like data centers, factories, industrial sites, remote communities, and defense facilities.

He had an idea of a really small reactor in mind. Then as he talked to customers, they determined the size of the plants they would build based on those conversations.

Jake DeWitte

We wanted to be at the smallest reasonable size that still had a large growth market, not necessarily playing on niche edges, but being big enough to find that. We initially started at about a megawatt and a half. We found that was interesting, but as we got further along, we learned the market was more interested in more than that.

We found people asking us for ten of these. Then we learned pretty quickly they were more interested in 15 MW. Our roadmap was always that multiple plants would come off of this. We found the minimum size to be about 15MW, which could support quite a bit of growth in that market. We found a lot of traction in several different segments in that space.

Julia

Jake has got it completely right. It's so important to listen to who you think your end user is going to be and what they actually want. You don't want to be building a science experiment in a garage by yourself and create something kind of cool, but that doesn't serve anyone's needs or that people won't pay for.

From day one and throughout the multiple years you're working on building this, being in constant communication with your end user and customer is crucial. Going back to Jordan, my co-founder at Antares, when we're setting out to work with the Department of Defense, we spent a lot of time talking with them to deeply understand their needs down to the specifics.

How exactly will they deploy this? What would it look like for their troops to operationally work on these reactors as the maintenance crew? Getting into those details early on is vital to ensure you're building to the right specifications.

Jordan Bramble

We really lean into the DoD-first approach, whereas others focus on dual use, commercial and military simultaneously. I believe in this approach because the writing is on the wall: the military will be the first and largest at-scale adopter of microreactors. This is motivated by a shift in our military's focus to the Indo-Pacific region.

We have a great power conflict, and many of our most important technologies' ability to scale their deployment comes down to energy capacity. It's forcing people to think creatively about how to get what the military calls "operational energy" into the field where and when we need it. The military and commercial markets are very different in how the end buyer thinks about energy.

When the military talks about operational energy - getting energy into tactical environments with no grid or existing supply chains - the purpose is to unlock capabilities that would otherwise not be possible. They sometimes pay up to $10 a kilowatt hour or $400 a gallon for diesel fuel. In more common scenarios, it's still around $7 a gallon. You see prices as high as $1 a kilowatt hour. It's very much a non-commodity market, whereas in the commercial sector, energy is effectively a commodity. You just try to get it as cheap as possible. For something capital intensive like nuclear, it's a really hard place to start building a product in my view.

Packy

This continues to be fun one because I could just directly ask you the follow ups. I know you've been flying all over to the most remote places in America to talk to potential customers at the DoD. What's it been like selling to them?

What have those conversations been like? How do they think about nuclear?

Julia

It's been really eye-opening for me. It's my first time stepping onto a military base or into congressional offices. I've found that the vast majority of people I talk to are quite open-minded about nuclear, even excited about it. I'm not facing the staunch anti-nuclear environmentalist crew that does exist out there. Generally, people are open-minded about it.

I've found the DoD to actually be very informed on nuclear. They come to the table with really good questions about deploying microreactors in the field, like managing heat signatures so enemies can't easily spot them, unloading from cargo planes, and using earth and other found materials as shielding to minimize bringing in heavy metal shielding. The conversations can go pretty deep quickly.

That said, the DoD is a massive organization and everyone has their own interests and agendas. If someone has other priorities, it can make progress painfully slow for us. People are slow to respond to emails - they're busy and we're just one of many things on their plate. So sales here is critical: how do you get someone excited about you, what you're building, and where you're headed, so that they want to champion your work?

The incentives aren't as aligned as in a consumer startup where everyone has equity and is aligned around efficient problem-solving to bring something to market quickly. These are people working within a very bureaucratic organization. They frankly just have less skin in the game, and you see that sometimes with the pace of movement.

Packy

Yeah, it reminds me of Anduril. Talking to their team, it was almost the same vibe - very complimentary of the individual people involved. Really impressed with the level of detail that the DoD people can get into quickly. They talked about making sure you're actually building what they want to buy because you could have the best thing in the world, but if it's not on their priorities list, they're just not going to buy it.

But also, it's one of the biggest organizations with the biggest budget in the world. So it's just really slow to move inside the DoD.

Julia

I think it's something where you can either look at it and think, "Oh, what a morass. This is awful, so slow, so painful." Or you can say, "I am playing in the biggest of the big leagues." In terms of sales jobs, it's about as big as it gets. You need to sell to 100 different people, have them wield influence in 100 different directions, constantly doing that over a multi-year horizon to finally get the sale or get them to work with you on buying your product and having that become a program of record.

If you listen to the Anduril founders, which you've obviously extensively studied, they talk a lot about how they went to DC on day one of starting the company and building relationships there. Lobbying and figuring out how to exert influence in all these different ways was priority zero for the company. There's almost more required there from a skillset perspective than building some of the technology, though I certainly don't want to belittle how hard it is to build a microreactor. But there is an equal amount of tenacity and skill required on the overarching sales effort, too.

Packy

It's interesting, and it makes sense why an advanced reactor is a nice wedge. Other than the fact that you're not going to bring a large reactor around the world with you. They were talking about building to what the military has already said they want to buy, and partly towards capabilities they've hinted they might want.

Once you get that advanced technology in your portfolio, it gives you the right to set the conversation in DC. Have you found with microreactors that if you're going with a first-of-a-kind product, everything that was a wall maybe becomes a moat as you write the RFPs and get to do all of those types of things?

Julia

Yeah, that's exactly right. It's super hard to break into. But once you become a program of record, it's hard for others to break into your little fiefdom. It's always easier to add to a budget than take away from it. That's the ultimate goal. I don't love that it works that way. I'd love to think that over time, companies working in defense tech with the government and military can help change that because it's better for the country. But yeah, that's the game we're playing, at least right now.

Packy

This is a bigger overarching point for all defense startups and nuclear startups: I really want this current batch to be the one that wins and then doesn't try to use regulatory capture or lock-in to extend that lead, but really lets competition bloom. We'll see if that happens. All that said, it sounds like a bear, but kind of a cool thing to experience.

There's also maybe an easier way, and this sounds crazy, but maybe it just takes a moon mission to cut through all that red tape. We promised we'd take you back to the moon, and now it's the right time to do that.

Here's Tyler at Zeno Power to explain why his company is taking a literal moonshot.

Tyler Bernstein

As part of the Artemis program, NASA and our international partners are going back to the moon, not just to visit, but to stay this time. There's also huge commercial activity in this area, following the trend of commercial

industry working in the space and nuclear industry. On the moon, you're generally in light for 14 days, in darkness for 14 days. If you're only using solar power and batteries, it can be very challenging, if not impossible, to operate in the 14-day lunar night.

For example, the US is going to land two landers on the moon later this year, built by commercial companies, that are likely going to operate for 14 days and then freeze to death. With a radioisotope power system or other nuclear sources, you can have heat and power that enables these assets to operate for years instead of 14 days. This is critical as we look to have a sustainable presence on the lunar surface and future settlements.

Nuclear reactors are a great source of power given the dark and shadowed regions on the lunar surface. I'll add that there's only one asset on the surface of the moon operating 24/7/365, and that's a Chinese rover powered by a radioisotope power system using plutonium from Russia. A lot of what we're doing and contracts we just won from NASA are to build American-made assets that can have that same presence on the lunar surface.

Packy

Aside from being spectacularly cool, powering the moon has economic benefits. As we touched on in episode two, there's a long tradition of the government being the first buyer for promising new technologies that aren't yet commercially competitive in terms of cost.

When it goes right, the government gets valuable new capabilities and private companies get to begin their journey down the experience curve to competitive prices. Tyler explained how he sees that dynamic playing out in the space nuclear market.

Tyler Bernstein

I'll start with cost and economics because it's a big distinction compared to terrestrial markets. When you look at nuclear terrestrially, what matters most is the dollar per kilowatt hour. These are primarily competitive energy markets. You're starting to see this change a little bit. Look at X Energy, for example, who is now looking to use heat for the chemical industry. But generally, you want to get your energy cost as low as possible or else you could get out-competed by other energy sources.

In space, it's a very different paradigm. It's not about the cost of the energy produced from nuclear. It's about the capability that is enabled. It's enabling brand new capabilities, from taking a lander that currently operates for 14 days and enabling it to survive for five years on the lunar surface. This is taking satellites in static orbits and increasing their maneuverability for more dynamic operations as space becomes a contested environment.

This is about cutting the transit time to Mars to reduce the radiation astronauts receive, increasing the likelihood they can safely visit and return. So again, it's not about the cost, it's about the capability that is enabled.

Julia

If you thought energy was a hard problem on Earth, it's even harder in space. On the moon, you're in light for 14 days and darkness for 14 days. If you rely on solar and batteries, you're dead half the time.

Tyler told us that two lunar landers the US plans to set up later this year are going to operate for 14 days and then freeze to death. And you just can't bring up more diesel.

Getting satellites to low Earth orbit is cheaper than it used to be thanks to SpaceX. But sending a payload to the moon is still much more expensive.

Tyler Bernstein

I'll give another example to put some newer numbers on this. Right now, the rule of thumb price to land 1 kg on the surface of the moon is $1 million. So you have a lot of companies commercially landing payloads on the lunar surface for around $1 million. And that $1 million will result in 14 days of operations.

Now if we can tell someone who wants a scientific or commercial payload on the lunar surface that it can operate for 5 years instead of 14 days, then that completely blows up the economics. It's a brand new capability and we're still working through what this business model is going to look like with a lot of these providers.

But again, it's a very different paradigm than terrestrially, where the cost of energy is extremely competitive and one of the primary drivers.

Packy

In addition to the benefit of finding less cost-sensitive buyers, another reason advanced nuclear founders are avoiding traditional markets to start is that many communities that would ultimately buy nuclear power from utilities don't want nuclear reactors. Isaiah at Valor said that choosing the right customers, ones who actually want the product, is the most important thing.

And that's what so many previous nuclear companies have gotten wrong.

Isaiah Taylor

There's a second problem, and that is that individual communities don't necessarily want that reactor. So you've got a cheap reactor. Fantastic. But do people want to buy it? And that's still a massive problem. That's a public perception problem.

So that's the second place that I landed was like, "all right, so we can mass manufacture these. We could get them through the regulatory approval processes. But would communities buy those reactors?"

Packy

So what's Valor doing instead? We mentioned that they're using fission to make synthetic hydrocarbons. They can produce those anywhere and send them around the world.

Isaiah Taylor

One of the big benefits here, and this is intentionally chosen, is if you're producing a hydrocarbon, an energy commodity, you get to pick a lot of things because hydrocarbons are so transferable through time and space. Transferable through time means you can store them. You could put them in a tank, and they'll stay there. They won't dissipate nearly at the rate that, for instance, an electrical capacitor will.

You can translate them through space. You can put them in a pipeline, liquefy them, put them on a ship. That's something we do all the time. You can compress them. So that gives us a lot of flexibility. We are currently shipping massive tankers of LNG across the sea to Europe.

So there's a good example of producing a hydrocarbon in one corner of the world, liquefying it, and shipping it across the entire planet. That gives us a lot of flexibility in where this plant goes.

Julia

If you're producing electricity, you need to be connected to your end customer's grid or to their facility itself. If you're producing industrial heat, you need to produce it at the facility where it will be used.

But if you're producing something that is already piped and shipped around the world, that's transferable through time and space, like hydrocarbons, you can separate the decision. You can put your plant where it makes the most sense and transport the product to wherever customers are willing to pay the most for it.

Packy

There's not one right answer here. At Antares, you're building something specifically designed to replace the need to transport hydrocarbons to austere locations not connected to pipelines. So you need to make something that moves with them. Same with Radiant and Zeno Power. Valor wouldn't make sense for those customers. You can't bring hydrocarbons to the moon. And bringing hydrocarbons to the front lines of war is a dangerous endeavor.

But cheaper carbon-neutral hydrocarbons make sense for a lot of people around the world. If Valor can produce them, they'll find buyers. The energy markets are so huge and the needs for energy so varied that there's room for every approach. It's not large versus small, or traditional versus advanced, but a mix of all of it. If you can deliver energy more cheaply or reliably, or deliver it where it's not currently possible, there will always be a buyer.

There's Jevons paradox, where the cheaper something like energy gets, the more demand there is for it. The overall market expands even as the cost approaches zero over time. So if you can make cheap energy, there will be buyers for it, and people will find new uses for that energy. Customer selection then is just a matter of sequencing. Who's willing to buy first when the product is more expensive than it will be once you scale?

Julia

It's also a matter of regulation, the second leg of the advanced nuclear startup playbook. Whether working with the NRC as it stands, trying to get ways to work around it, or both, what matters to entrepreneurs is getting their product to the right market as quickly, safely, and cost-effectively as possible. They'll shape the company's strategy in part around minimizing regulatory roadblocks. No advanced or Gen IV reactor design has ever achieved regulatory approval in the United States yet. Regulators are more comfortable with designs they've already approved and are familiar with. They're not incentivized to take risks on new reactors, although, as Jake told us, they're increasingly willing to try. They're working on regulation to accommodate new designs.

The NRC's Part 53, which Alex Epstein talked about in episode three, is a new set of regulations being developed to modernize and streamline the licensing process for advanced nuclear reactors. It aims to provide a more risk-informed, performance-based approach for licensing advanced non-light water reactor designs, including SMRs and other advanced reactors. Part 53 was mandated by Congress because there wasn't a framework geared towards non-water-based reactors, making it hard for advanced reactor companies to navigate the regulation process when there was no framework geared towards the technology they were building. They were given until 2027 to enact it, but pressure to do it sooner has resulted in a draft. Some people are not fans, thinking it's still quite complex, but entrepreneurs are not waiting around. People are starting to build.

I think we'll see people working directly with the NRC as this new framework comes together, co-creating along the way. You have to be hopeful that the NRC has enough pressure to help advance the nuclear reactor space overall. People often are citing stats that there have been no new advanced reactor designs license since the NRC has been developed, and we need to change that. The more public and congressional support we have for the NRC moving more efficiently, the better. I'm hopeful that we will see that.

Packy

This feels like one of those specific areas where we can say, if you have to direct your attention somewhere - and this is self-serving for my friend and co-host Julia - it's call your congressperson about Part 53.

What should we tell people to do?

Julia

I think it's maintaining pressure on the NRC to move more efficiently. It's not saying cut corners, because they have set up a very robust regulatory framework. It's the fact that we are having the opposite problem. There's no new nuclear getting built. We've got to change this.

Let's look at Russia. They're doing this. We can do this, too. We're basically shooting ourselves in the foot here with this burdensome regulatory framework we have.

Packy

Despite that, thank God for the entrepreneurs, because they're not waiting around. Isaiah actually thinks it's on the entrepreneurs to prove to the NRC and the country that what they're doing is worth moving faster for.

Isaiah Taylor

The thing that has to catalyze change here is entrepreneurs who are coming to the table with better ideas and are willing to push them forward over decades. That's what this comes down to. People have to be in this fight for decades.

That's what actually creates change over time.

Packy

No one that we've spoken to embodies that more than Jake at Oklo. He's been working with the NRC for a decade to get Oklo's design approved.

Jake DeWitte

On the regulatory side, our view was everyone can play footsie about regulatory shortcuts - going to another country, building a test reactor from the NRC, doing it at DoE, or getting DoD to do something. All those things have been looked at, tested, explored before. At the end of the day, for anything commercial, you're still going to have to get through the commercial licensing process in the NRC unless you want to play on a very niche side of things. So we just said, engage early and often. We went in and that was a big focus of ours because so many people waited and were wringing their hands about the daunting regulatory process. Look, it is daunting, but the way you do it is you do it. So we leaned into that pretty hard from very early on in the company's history. Obviously, you have your bumps and bruises on the path, but that's what happens when you're trying to blaze a new trail.

Packy

When Jake says bumps and bruises, he's most specifically referring to the company's 2020 application that ended up getting denied. We're going to let Jake tell the story. It's a bit longer because it provides an inside look into the process at the NRC, an organization we've talked about a ton on the series and one that every US nuclear company will need to work with in some form or another.

It shows the persistence that Isaiah spoke about on Oklo's part. It shows a regulator that is at least trying to streamline its processes even if there are bumps en route to improvements and that there is a whole lot of work left to be done if we want to bring more nuclear online in a reasonable timeframe.

Jake DeWitte

The denial we had to go through sucked because they never gave us a heads up that it was happening. Shame on them for that. They should have done that by their own procedures and policies. They should have called us and said, "Hey, we're doing this." But that's water under the bridge. You just get right back in with them. They gave us some good feedback about what they wanted to see. We took a very forward-leaning approach based on our feedback with the NRC.

To go back in time and give the playbook of what happened: We started meeting with them in 2016. A bunch of things happened through until 2018, when we submitted a pilot application. They performed audits on it between 2018 and early 2019, resulting in feedback saying they could review an application that looks like this. Awesome. So we said, okay, we'll work on submitting that. We spent a year developing that, familiarizing them with what it would look like as we went through it. They proposed that some of the methodologies we piloted might not make sense for us because we're so small, changing the risk profile. So we agreed to go back to some old-school ways of doing things, like straight engineering analyses.

We submitted an application in March, literally March 11, 2020. This was built in parallel with the NRC developing a novel, in-person audit review process for us. They wanted to be more agile, lean, and focused with a cohesive, cross-functional team that would meet dynamically. The audits are very rigorous and different from their normal approach of sending questions and waiting for responses. You get through more ground quickly, so it's valuable. We were eager to try this approach. But when you submit something on March 11, 2020, the day the pandemic's declared, everything went out the window.

We thought we could try something innovative, knowing there would be challenges. We figured we could adapt, change, or resolve issues depending on how discussions went. But that process became really hard in a fully remote review environment. Sadly, they kicked it back to us, but it clearly identified our obstacles and where they were having a hard time with what we were doing.

Starting in spring 2022, we began engaging in person again, focusing on resolving these issues and mapping out the process. Now we're on track to close those items by the end of this year or early next year, transitioning us into a pre-application readiness assessment - a dress rehearsal before submitting an updated application.

Packy

So have you had to engage with the NRC yet or has it mostly just been with the DoD?

Julia

We haven't yet engaged with the NRC, but we certainly will pretty soon. We believe people have the right intentions. The incentive has always been to keep things safe, and if you don't change much, you'll probably succeed in keeping things safe.

We have that great image of the FAA's chart showing that if you do too little, you'll have accidents and aviation deaths. But if you don't allow any new safety innovation, you're also missing out on saving lives. You need to be in that Pareto optimal spot.

Packy

This whole episode is a testament to that, where all these entrepreneurs are saying these are reactor designs where the physics themselves make these safer than the current ones online. We haven't had a disaster in twelve years anywhere in the world since Fukushima, and really no big disaster since Chernobyl. Everything's safe and getting safer in the physics if we just allow these designs to come to market, but they can't. There's a chicken and egg problem.

I'd be curious to hear how the Navy does it, because I've never heard of an incident with our nuclear navy. They have submarines going around the world powered by nuclear reactors 24/7 in hostile environments. It seems really safe, with people living inside submarines underwater for weeks and months at a time with no incident.

Julia

It's absolutely a well-oiled machine. It's very much like the terrestrial civilian grid plants. This is a group of extremely well-trained operators whose lifelong livelihood is to take care of these reactors and make sure they're running properly. They've done it really well. I also think the NRC's oversight of the civilian grid has done it really well. I have no doubt that we're going to be able to continue that trend here.

I just think we've gone too far at this point that we're not even enabling anyone to try anything new or proceed with a design. The risk you run here is that companies are going to start designing and building, then they're not going to get regulatory approval, and then run out of money. How can you stick around for ten years, just hoping that you'll get more funding? Realistically, that's hard. We've talked about fund timelines. You can't really go much more than ten years without any sort of return. I worry that's one of the biggest challenges facing all nuclear startups.

Packy

This is just a fun fact aside, but there was a kid I went to high school with who ended up going to Naval Academy. He was smart, but he wasn't the math genius in our class. Then I heard he was going to be working on submarines, and he said he was studying nuclear physics.

I thought nuclear physics was reserved for the top 0.1% of geniuses. It's cool that they have a whole program set up where if you're going to be working on submarines, you need to be trained on nuclear physics up front.

Julia

There's actually been a decline in people studying nuclear engineering in universities, and we need to reverse that, too. You need a workforce that knows about this, and the Navy does it phenomenally well. I wouldn't be surprised if a lot of these startups we're talking to end up hiring out of the Navy, although I'm sure the cultures are quite different.

In terms of "move fast and break things" versus "do not move too fast, nor definitely don't break anything." But it is definitely respected as a group of people who have really been trained in this better than probably anyone else.

Packy

I'm going to keep going back to Anduril. They seem so appropriate here, where they've hired so much ex-military talent, because you want to move fast and break things, but you don't want to break too many things in defense or nuclear. I think Tyler said it's "move fast and bend things" in the nuclear industry, which I really like.

So I would love to see my buddy from high school end up working at Antares or somewhere else. It shouldn't come as a surprise that other advanced nuclear startups have learned from Oklo's experience and have built a big part of their plan specifically around going through faster regulatory pathways. It reminds me a little of what Tyler told us about regulation for space nuclear. It's not regulated by the NRC, but by the FAA as the result of a 2019 presidential memorandum.

Tyler Bernstein

Regulatory is in a very exciting area for space nuclear right now. In 2019, a presidential memorandum overhauled the launch approval process for spacecraft with nuclear power systems. Prior to this memorandum, any spacecraft with a nuclear power system, whether it had a gram or 1000 grams of material, had to go through the same multi-year, multi-agency safety review that ended in the president's signature. Notably, only the government could launch nuclear power systems into space.

This presidential memorandum did two things. First, it broke down the launch approval process into three tiers based on the risk level of the launch. Tier three being the highest risk launch, primarily a highly enriched uranium reactor; tier one being the lowest risk launch, primarily a radioisotope source that meets certain safety standards. These tiered approaches have different levels of regulation. Tier one, for example, can be regulated and authorized for launch by a single agency, whether NASA or the Department of the Air Force. It broke this down into a potentially more streamlined process.

Second, for the first time, this memorandum opened up a commercial pathway to launching a spacecraft with a nuclear power system under the jurisdiction of the Department of Transportation and the FAA. In many ways, this presidential memorandum has unleashed this wave of commercial space nuclear companies and opportunities. Right now, with our contract with the Space Force, we're working diligently to meet these guidelines.

We're engaged with the FAA and the Department of Defense. We've developed an approach and submitted it to the FAA in January of this year, and our payload review application was accepted, which means the FAA believes there could be a chance of actually approving a launch. We're targeting an approval for launch in early 2025 to enable our launch in late 2025 or early 2026, which could be the first commercial nuclear power system ever launched into space.

Packy

A few things made my ears perk up in Tyler's response. First, Elon has been battling the FAA over SpaceX launches. So it's by no means a rubber stamp organization, but they do at least approve launches.

Second, getting approval to launch by 2025 or 2026 would be a much faster timeline than terrestrial nuclear companies we've spoken to can hope for.

Third, and importantly, a clear and hopefully efficient regulatory framework "unleashed this wave of commercial nuclear space companies." Good regulation can be a huge unlock for companies innovating responsibly, not just because the path gets clearer, but because faster timelines can mean faster iteration and better safety. Isaiah pointed out that poorly designed regulation can actually make things less safe.

Isaiah Taylor

This is a huge problem in governance: when you add a strict regulatory framework around something, you actually get local minima of safety. For instance, we've got self-driving cars finally hitting the market, creating a massive new category of safety where human error is slowly removed. But a huge part of what's taken so long to get there has been regulations added to cars to make them safer. So there's always this catch-22 with regulation.

A good example is molten salt, where we have this incredible negative reactive coefficient of salt, which can slow reactions down as they begin to overheat automatically. That's incredible. Passive control is something we should have had for the last 50 years. But it's a little harder to implement because things that have been done before are easier to do again in a regulatory framework.

Julia

The FAA has a great graph titled "Applying the Safety Continuum," showing that too little rigor is unsafe due to inadequate safety programs, but too much rigor is also unsafe due to lack of safety innovation. Eli Dourado wrote about it in a piece on the FAA's new MOSAIC rulemaking initiative, which we'll link to.

We talked about the built-in safety features in many advanced reactor designs, these passive safety systems, but despite their potential for increased safety, they're actually harder to bring to market. It's a catch-22. Isaiah thinks the only way out is through, and he's designing Valor's plants to minimize regulatory drag as much as possible relative to their size, by stacking reactors in one location far away from people.

Isaiah Taylor

Regulatory bodies given a mandate from Congress to protect the US people are automatically going to be extremely risk-averse. They'll tend towards slowness, bureaucracy, and absolute safety, even if it's not totally rational. They actually have to be catalyzed into action by entrepreneurs demonstrating extremely high value over time. Part of the issue with nuclear power so far is that there have been people with good reactor designs, but not the right customer yet.

When you're trying to generate electricity and telling the NRC you've got this reactor to put in Chicago, New York City, and all over the country, that's a very different safety profile and revenue profile. That individual reactor now has its own revenue stream, and might not produce quite enough power to justify changing the rules. What I want to do here is catalyze some movement. We're doing this on very different ground than nuclear power has ever been done before.

We're talking about remote offsite generation of chemical fuel, which goes into the existing supply chain. We can take these things off a mass-manufactured supply chain but house them in a secure facility. We can check all the NRC's boxes for containment, radiation, and surviving a 747 attack. But the actual units can be mass-manufactured and deployed centrally in this offsite location.

This threads the needle on many different ways, both regulatory and delivering energy to the end consumer. It's been a five-year process of trying to answer this question: how can we get the benefits of nuclear power to the American people in the existing framework, which has a million problems? Let's hack this thing. Let's find a way to do it and provide that energy.

Packy

There's one final pathway here which we think is really smart. Aalo is taking a design that's being tested at the Idaho National Lab called MARVEL, scaling it down and selling it to universities that have research reactors and funding for new research reactors.

Matt Loszak

What that team has done is really impressive. In a world where nuclear projects often take 5-20 years, they've gone from an idea to essentially getting approval to start building, along with all the funding, in just three years.

Julia

There's a chicken and egg problem in advanced reactor regulation. The NRC wants to see real data from operational reactors to approve new reactors. But if those designs haven't been allowed to be built yet, where do you get the data?

This is why I think Aalo has a clever approach. They're taking a design that was implemented within a national lab, so it already has that test data that can be used with the NRC, allowing them to beat that chicken and egg cycle.

Packy

It's amazing to see the lengths these startups have gone to just to be allowed to operate, and even more amazing to see the creativity and grit with which the entrepreneurs have approached the problem. We've heard a few different approaches to dealing with burdensome regulation as an advanced nuclear startup: 1) Deal with the NRC process for your design upfront, like Oklo has been for the past decade, and then on the construction side each time you want to put a new reactor somewhere.

2) Go through the NRC process on your design, but on the construction side, build a big, secure facility with room to expand in one location. This way, each time you want to add more capacity, you just add it to that one spot that already has construction approval. It might still take a long time in the beginning, but it speeds up over time. This reminds me of Matt's approach at Blue Energy, where the first one might take six or seven years, but then you're just printing the same thing over and over. That's how Isaiah is thinking about doing it at Valor.

3) Get regulated by somebody else, like the FAA, the DoE, or the DoD. This is what Antares, Zeno Power, and Aalo are doing. Once the designs have run in the wild and generated data, it might be easier to build commercial versions with NRC approval.

The attitude seems to be that there are roadblocks, but the opportunity and potential for impact are so huge that they're worth figuring out. You hear a lot about mission-driven founders, but it's hard to imagine going through advanced nuclear regulation without being particularly deeply mission-driven.

Julia

The regulatory aspect of nuclear is especially burdensome, but not entirely unique. Biotech founders ultimately need FDA approval to bring a new drug to market, which is also onerous and expensive. But new drugs are approved all the time, and there's some degree of confidence in that process. There's a whole ecosystem supporting those companies: investors, lawyers, large pharma companies who know how to finance and bring those drugs to market.

We're still building that muscle in the advanced nuclear space. And then there are all the other things you have to do to run and grow any startup: raise money, build a team, create a brand, do sales and marketing, set up a supply chain. You need to operate the business.

Packy

I think each of the founders we've spoken to has something to say about each of those aspects. But to kick off the section on operations, we have not only an advanced nuclear founder, but somebody who's done operations for her whole career at these big, complex companies.

So I'm going to turn the mic on you again, Julia. Antares just raised an $8 million seed round. Congratulations, first of all. And second, what was that process like?

Julia

I think it was helpful that Jordan and I had some operating experience. This is the second company I've worked in a couple of big operating roles, and having a track record can be helpful. The big thing about raising in the nuclear space right now is that people believe in the "why now" moment. There's enough turning of the tide, whether it's public sentiment, what you're seeing out of Congress with bipartisan support for nuclear, or what you're seeing in the DoD with things like Project Pele to demonstrate microreactors.

Generally, what we heard was that now seems to be the time people are focused on clean energy. They're trying to move away from fossil fuels, and you just have to believe that you're going to be able to get through the regulatory environment and building things. We've now developed a hard tech ecosystem that will also be a tailwind to building nuclear. You have engineers who have worked at SpaceX or other big companies that are ready to take on the challenge of building complex projects from scratch and actually completing them.

So it was a hard process, but people believed that we have what it takes to do this. The round came together within a month or so, and we're now back to the races, heads down. Once you have money in the bank, it's time to recruit and start building.

Packy

Amazing. Clock is ticking. It sounds, if not easy, a month is pretty good. It's easier than I would have expected for a nuclear startup. I think that's a testament to you and Jordan and, to your point, to the moment we're in right now.

Matt at Aalo and your co-founder Jordan told us something similar when we talked to them - that now feels like the right moment for nuclear and that investors are starting to look at nuclear as the next big thing.

Matt Loszak

I think there are a lot of VCs who made good money in the software world in the past 10-15 years and many of them are now looking for the next big thing. In my opinion, quite rightly, a lot of them are identifying energy as this insane opportunity.

Jordan Bramble

It's certainly an area of interest for even generalist VC funds. We found a lot of the larger brand name funds have actually invested in developing a thesis in this space. When we did our most recent fundraise, we were able to narrow down who we spoke to, to people who have already spent time thinking about this, which is awesome.

Learning from scratch or going through that education process can take a long time. But we had the benefit of being able to talk to a lot of investors that have already spent time thinking about this and the market opportunity.

Packy

That reminds me of what Jake at Oklo told us on the last episode, that investors even in the public markets are coming to meetings more educated on and excited about nuclear. It kind of makes sense for public market investors, many of whom are used to investing in energy companies and manufacturing companies, companies that spend enormous amounts on capex to unlock massive markets. Still, the excitement among VCs is somewhat of a surprising positive development.

Investing in nuclear energy is very different from investing in software. Matt told us that a lot of the milestones for a seed stage company are around regulatory approval, then design milestones, then commercial milestones. Versus in software, it's looking at team and early traction, did you get to a million dollars in ARR, what does your retention look like, how's your marketing efficiency... Deep tech in general but specifically nuclear, given the regulatory landscape, feels a lot more like whether you're able to pass through a series of very particular gates as opposed to where you are on some continuous growth curve.

What do you think has changed more broadly that's made investors more comfortable investing in advanced nuclear?

Julia

I think one reason investors are feeling more comfortable investing in capital-intensive businesses like advanced nuclear startups is that other companies have come before us and been successful. Anduril and Varda, for example, whether in space, hard tech, or defense tech ecosystems, companies like these have been able to get non-dilutive capital from government grants and military contracts. This enables them to build with less dilution and without VCs being the only funding source.

Because of these examples and market demand for new products from government and space industry, venture capital now sees the potential for healthy businesses here. Yes, it's more capital-intensive upfront and there's risk of going to zero versus becoming a massive revenue company. But you see that power law in other venture investing, so that's not anything new. The comfort around good outcomes in this burgeoning hard tech/defense tech ecosystem means more investors are interested in this space.

Packy

It's fascinating because I'm seeing on my side too, I'm just more drawn to this type of company now. I think SaaS might struggle with defensibility over the next decade. As we're recording this, OpenAI is doing their developer day, and who knows what companies they've killed on the software side? Whereas if you can navigate the regulatory challenges and build an advanced reactor, you're more protected. If you make it through, the outcome is potentially more protected and bigger.

David Ulevitch at a16z did tell us that if you don't, there's no pivot or easy way out. You don't sell this company to someone else or restart with a new product - it's all or nothing. But if you succeed, Anduril is now worth $10 billion, SpaceX $150 billion. Josh Wolfe told us there are two motivators: fear and greed. This is also in Morgan Housel's new book too.

It's hard to look at these massive potential markets with practically unlimited demand and not get a little greedy. So while funding is still challenging, it's not as big an obstacle as before. Now that you've raised capital, what's the next thing to think about?

Julia

It's really company building. There are a few areas to focus on. One is starting the reactor design and moving to build a prototype as quickly as possible. One failure mode in hard tech and nuclear reactor companies is spending too much time on the computer simulating rather than building. You learn so much when you do it in the real world. It's capital intensive, so being well-funded is important.

Then there's team building. You want to recruit a diverse team of engineering disciplines. Some nuclear background is great, but there's limited talent there. So pulling from other engineering disciplines like mechanical engineering, systems engineering, and eventually software engineering, who can learn about nuclear is key. You're also building out other functions like government affairs, legal, accounting, etc.

Then it's building your go-to-market strategy. Who are you engaging with as customers, and what are their requirements and specs? Then developing your government affairs team to engage with Congress, regulatory bodies, and the DOE. You want to set all these things in motion simultaneously, not sequentially. You don't want to build your prototype and then talk to customers or regulators. You want to do all of that in parallel.

Packy

It's cool to see. You've been knee deep in nuclear for a couple of years, but before that were new to the industry. Now you're starting an advanced nuclear company. Many founders we've spoken to say they're looking for fresh talent, partly due to limited homegrown talent in the nuclear industry, and partly because fresh perspectives matter.

Given the limited progress, a fresh perspective is needed. That's what David at a16z told us.

David Ulevitch

When you go to the incumbents or experts in the field, they'll just say, "Oh yeah, we should just do what we've been doing forever because obviously it's worked."

But anyone who can look at the nuclear industry can actually be a non-expert and should be a non-expert to look at the nuclear industry and say, "Obviously this has not worked at all."

Packy

It takes a mix. Your co-founder Jordan grew up in the nuclear industry, but he mentioned that in Antares, you're looking to bring in people from all backgrounds.

Jordan Bramble

I think it's really important that we find ways to bring people from other backgrounds into the nuclear industry. My message would be it's totally something that people can pick up. If you have an interest in it, you can go from hobby to practice.

Packy

So you have a team, you have a design that's being worked on and tested.

What's the next big thing that you need to focus on?

Julia

Supply chain is critical and it's one of those things that takes a while to develop. So like everything else, you want to start that at the very beginning. The supply chain is basically where you get all the different components you're going to use to make your reactor, and those can be really expensive. We know that if you're working in the nuclear industry, you need to work with supply chain vendors who are complying with specific regulatory compliance. These can run up to 100 times more expensive than the same part used in another industry.

There's also the fuel supply chain. Many advanced nuclear startups are using non-traditional fuels, like TRISO or HALEU. We'll get to those in a second. Because there hasn't been consistent demand for these fuels yet, the supply chain just isn't there. People have demonstrated the ability to produce these fuels, but they certainly aren't something you can buy off the shelf or just place an order for to arrive next week.

The thing about nascent supply chains is that you can't get everything you want. There are trade-offs to be made. You might have to trade off between fuel efficiency and the realities of whether you can procure this more efficient fuel at a timeline and cost that works for your business. Matt at Aalo told us that while supply chains build back up, they're making trade-offs between fuel efficiency and supply chain realities.

Matt Loszak

It's a big concern and question. But I think it's getting better. We're doing our best to make decisions today that can help us get something done in the near term. As supply chains improve, we can make bolder decisions. One example is that many reactor vendors are planning to use HALEU (20% enriched fuel), while we're looking at using LEU+ (around 10%). This is more readily available and should help in getting something done practically and near-term.

You're right that many nuclear supply chains have atrophied from where they were decades ago. An interesting anecdote is Ontario's process of finishing refurbishments for their Bruce Power plant. By doing these upgrades to the existing system, scheduled years ago, they've maintained a supply chain that will be helpful for their subsequent deployment of new generation capacity. In some cases, things are hanging on by a thin line. But as more nuclear developments happen, that muscle will naturally build back up.

It's like the buzzing bees analogy - the more interest in nuclear, the more things happen, the more the supply chain gets built out. It's a positive snowball effect. In summary, we're trying to make the right choices given today's atrophied supply chain constraints. We'll do our part in bolstering nuclear's image and strengthening the supply chain by spreading the good word and hoping for more deployments.

Packy

Supply chains seem like another strand in this gordian knot that we talked about in episode three. If reactors aren't being built, if there's regulatory uncertainty surrounding the approval of certain advanced reactor designs, it makes rational economic sense for potential suppliers to stay offline. They don't want to spend the capex and go through all the pain of producing a product for which there might not ultimately be buyers. But if the fuel isn't available, it slows down the companies that would become the buyers.

Julia

This is an interesting place for government to step in and play a role in standing up a supply chain that isn't yet healthy on its own. When you have a brand new industry, there's that chicken and egg problem.

Earlier this year, the Senate voted 96-3, almost unanimously, in favor of a bill to accelerate the availability of domestically produced HALEU for advanced reactors. This is a big step in saying that the government and Congress would like to support this advanced reactor industry getting off the ground, and here's what we're doing to support from the fuel side.

Packy

We've talked about HALEU fuel a couple of times. What's special about it?

Why are advanced reactor startups looking to use that versus regular uranium?

Julia

HALEU (High-Assay Low-Enriched Uranium) is enriched to a level between 5% and 20%. That's higher than existing fuels, which are in the 2-5% range, and lower than highly enriched uranium used for atomic weapons. People like this middle ground as it's better fit for smaller designs.

You want more enrichment than purely low-enriched uranium, but people don't want HEU (highly enriched uranium) in the hands of just anyone due to proliferation concerns. So this is a nice middle ground. That said, it hasn't been extensively used yet, so there's not much of a supply chain yet.

Packy

It's cool to see the government not just saying they support nuclear, but providing very specific, important support for the advanced nuclear industry. 96-3 is amazing. This takes us back to our conversation on the role of popular support, from fundraising to getting legislation passed. A big part of these entrepreneurs' job is making nuclear sexy enough that people demand it.

When Isaiah announced Valor on X recently, there was a snarky reply about these companies doing a service to the rendering industry by keeping rendering artists in business. They do have beautiful renderings. If you look at the websites, there's a split between very basic sites with just the company name and not much detail, and completely over-the-top beautiful sites full of animations and renderings.

You should check out Radiant's site at radiantnuclear.com. As you scroll down, there's a truck with the Kaleidos reactor on the back that drives from the factory to the customer site and back for refueling. On Oklo's site, the renderings are particularly beautiful. They collaborated with renowned architecture firm Gensler to design their Aurora Powerhouse. You can check out an animation at oklo.com, showing one being built in a tree-lined area. We'll link to it in the show notes. I kind of want to live in an Aurora Powerhouse.

We asked Jake about the importance of building a visual brand while doing this really hard thing, and his answer was illuminating.

Jake DeWitte

From a visualization and branding perspective, we want to reflect what we do and why we come to work every day. It's cool to work on nuclear, but it's really cool because of what it can afford humankind going forward - a clean, sustainable future that's full of affordable, reliable, and clean energy. We didn't want to look stodgy like what's out there before. We wanted to take an architectural approach that was functional and beautiful, working with great firms to support that. That's a core thing for how we want to approach what we're trying to do with respect to the imagery and the visualization of what these things can bring to bear. So that's just kind of core to how we think about this.

And I think it kind of reflects for how we do things, not just exterior wise, but internal wise. I really like reactor art and how they look. The performance of the system dictates the design, but you can bring elegance to that. They're not often visible from the outside, but I think they're cool to show. Next-generation plants and reactors are inherently quite simple because we as an industry have energy density on our side. That elegance and simplicity is beautiful, and it's great to highlight that. As people start to see and understand that, it can get more exciting.

Julia

One beautiful thing about entrepreneurship is that each generation of startups learns from and builds on the previous generation's work. Tesla taught deep tech entrepreneurs that making something sexy that people clamor for is half the battle. When you need to change hearts and minds to move people from internal combustion engines to electric vehicles, or in this case fossil fuels to nuclear, the brand can be as important as the technology itself.

A community will be more willing to accept a beautiful, small-footprint nuclear plant like Oklo's, rather than those big hourglass-shaped structures that come with mental baggage. Putting a Radiant Kaleidos on the back of an 18-wheeler is valuable logistically, but it's also an important shift in perspective - nuclear reactors can be safe and simple enough to drive around.

Lux Capital's Josh Wolfe, while an outspoken critic of some of Elon's actions, believes that what the nuclear industry needs is its own Elon.

Josh Wolfe

It probably requires an Elon-type character. Despite all the misgivings I have about his relationship with the truth, particularly around Tesla, what he did was not wait for batteries to get better and for government regulation. He just plowed forward with irreverence and, in some cases, disregard for national highway safety, full self-driving, or any number of regulatory authorities from capital markets on down. But he advanced the field in doing that. So you can absolutely say that was a virtue among the vices of his behavior.

I think you need an entrepreneur who is absolutely dead set, who galvanizes with belief and conviction. That, in turn, creates the flood of capital behind them. Of course, the root of the word 'credit' is 'credere,' to believe. And that's what you need. You need people believing. So it starts with belief, and that usually starts with an entrepreneur that is so dead set that at first people have that Gandhi like view, where they at first laugh at him, then they join him, and then he wins or she wins.

Packy

While Josh's plan sounds like a risky path that would require a particularly brave founder, there is recent precedent. It's exactly what Anduril's doing in defense. When Palmer Luckey started Anduril in 2017, defense was the black sheep of the tech industry. Outside of Palantir, big tech companies and their employees wanted nothing to do with defense or the DoD. Palmer was a pariah in Silicon Valley for starting the company, especially for working with Customs and Border Patrol.

But in the meantime, while people were ignoring the defense industry, Anduril built something that leveraged tech's unique advantages: a suite of defense products built on an AI-powered operating system. They hired

mission-aligned talent and chipped away. When Russia invaded Ukraine, defense suddenly became sexy. Luckey is like an Elon-like character in a space that needed one. But instead of flaunting regulators, Anduril has worked closely with the DoD since day one.

Of course, there's still some disregard for capital markets. Luckey called public market investors "Wall Street weenies" in a recent interview, which I absolutely loved. But the company is exhibiting a balance of brashness and seriousness that might become the new playbook for deep tech companies, especially ones in an industry as highly regulated as nuclear.

Julia

In that playbook, there are a few lessons that advanced nuclear startups can take away: 1) Leverage the technical advantage. Large, established companies build tried-and-true large reactors, and it's hard for startups to compete with that. So compete on innovation and speed, which is where startups shine. Hire the best technical talent you can.

2) Balance public marketing with behind-the-scenes sales. Anduril's public brand, for example, is excellent, well-executed, sexy, and exciting. But behind the scenes, teams of serious people, including ex-military folks, are engaging with the system as it is and working to change it from within.

3) Make it exciting. Cheap, abundant energy is exciting. Advanced reactors that leverage physics for safety are exciting. Powering areas not touched by the grid, including the moon, and replacing dirty diesel fuel is exciting. Lean into that movement.

4) Understand where to work around the status quo. Bend, but don't break the rules. If the path through the NRC is too slow, find a faster path. You can't put an unlicensed reactor on the grid, but you can find a faster way to get licensed.

Packy

All right, so there's a bit of a playbook, which is awesome. It's been so cool for me getting to talk to so many of these founders and work with you on this, seeing so many smart people who have a million other options. They could go work at SpaceX or Anduril or start something in a slightly easier space, like space, for example. But they're going after this really hard thing.

I'd love to hear from you. You've had a successful career so far, and now you're jumping into this thing that we said was entrepreneurship on insane mode. Obviously, you're excited about nuclear, you've been digging in, you've been an advocate, but were there cons that you were weighing? Were there reasons that you thought maybe this wouldn't work or that this isn't something worth dedicating the next decade of your life to?

Julia

Well, I'll start by framing it. The mission of energy abundance is just too important to not work on. I feel personally drawn to it. I think a lot of other people working in the nuclear energy space or any other hard industry like this probably feel some pull to do it, because the deck is stacked against you in so many ways to be a small nuclear reactor company.

We've gone through a lot of these already, but the regulatory environment is no joke. It's extremely expensive and time-consuming. Unfortunately, it's just one of the things that puts companies out of business. Lasting through that long of a process is really difficult. The same goes for your sales cycle. Whether you're selling to the military, space companies, or commercial, where you actually need to go through the NRC first. Any way you slice it, you're working with national labs or other national testing facilities. There's bureaucracy everywhere you turn.

What I find challenging about that is that it's somewhat out of your control, not completely. You do your best to influence, ingratiate yourself, whatever you can do to move through that process quickly. But it's not one of these things where you can just stay up all night coding to ship your product. It's a completely different paradigm, and I think that can be very tiring. It's also a multi-year endeavor. When you're building in the real world with atoms and in hard tech, you have a much longer timeline. So your tenacity level needs to be even

higher than shipping something on the software side.

There are so many challenges here, but I think anyone working on this probably believes, like me, that the world will be a better place with more nuclear energy. So give it your all, give it a go, and get as many people to be supporters and influencers around you to change the narrative and collectively say, we have this moment, we have this opportunity now, we need to unblock this technology and allow it to flourish.

Packy

Hell yeah. One of the things we touched on that I generally like is this idea that entrepreneurs get to learn from what's happened in the past. It's been 70 years since Admiral Rickover wrote about paper reactors versus practical reactors. How does that play into the way you're thinking about product development and building the reactor, knowing that things are going to look good on paper, and you won't know until you get down the line?

I'm sure we have better software now. I'm sure there are better ways of doing it. What has the industry learned on that front over the past 70 years?

Julia

You're right to say we do have much better simulation software now. But like anything else, you don't want to get bogged down in the design phase. You don't want to just be sitting on your computer simulating all day. You still have to get to cutting metal as quickly as possible.

The way we're thinking about it, at least, is how can you build something subscale as quickly as possible and get that to testing as fast as you can to validate that a lot of your assumptions and your online computer modeling are actually valid in the real world. Most of the time, that's not actually the way things work. When you test things in the real world, they don't actually go quite as expected. So you need to go back, make your tweaks, try it again.

We're going to mention Elon one more time here, but he's done this so well with Tesla and SpaceX, as have many other entrepreneurs, which is to say you must constantly be iterating, trying things, being with the hardware. So the goal here is to move away from being a paper reactor to an actual functioning reactor as quickly as you can.

Packy

Bret Kugelmass said we should have more nuclear meltdowns. A difference with SpaceX is that we don't want full explosions of the products, which is physically kind of impossible now. In a normal industry, you're racing against your competitors, but you're almost all gated by the same thing now.

If the NRC passes a Part 53 that is clear and easy with a sensible path to market, you all win. Is it a more collaborative environment? Are you working with others on the regulatory side, or is it still really competitive where whoever gets to their initial use case first can build up to larger scale?

Julia

There's so much opportunity for collaboration between startups. There's already been some discussion about what we want to see from the Department of Energy or the national labs to better support this nascent microreactor or SMR industry. Working in collaboration with other startups to improve the regulatory framework or the testing environment is going to be a win for everyone.

There's still going to be competition in terms of how you get through that regulatory framework, how the testing goes, and how you sell to customers. But in terms of opening up opportunities for multiple players, we all should be in favor of that and working together towards it.

Packy

It sounds like such a fun environment. What does success look like for Antares and for your career in nuclear?

Julia

I think it's shipping your first reactor. That's the day I'm looking forward to - when you've actually sold and brought a reactor online. That in itself would be huge success in my book. But bigger than that, we're aiming to build a company that can proliferate these reactors. We want to bring abundant energy to all corners of the earth and hopefully have reactors of different sizes for different use cases.

I'd love to see the entire industry flourish. In a success case, there will be multiple very successful companies because we're going to need so much more energy. If we want to replace fossil fuels, we're going to need even more energy. So there's room for so much here, and there can be many winners.

Packy

I'm rooting for all of you, you in particular, but rooting for all of you. It's such a cool thing to be working on. If I were a little bit smarter, I'd probably be working in the nuclear industry.

Julia

I think this is the job here, to say "Hey, get the word out about what nuclear is." Honestly, two years ago, I didn't know anything about it. It's just one of these great cases where the more people who show up, get involved, learn, and try their hand at working in this industry, the better the outcomes will be.

Packy

Amen. Well, this has been my favorite episode that we've done so far. It's been so cool getting to hear directly from you on it.

Before we get too excited, next episode on Age of Miracles, we're going to be talking to people like Noah Smith, Casey Handmer, Eli Dourado, and others who argue that there are other energy sources like solar, batteries, and geothermal that we should be even more excited about. I'm really excited to let people have their say.

My perspective is we want it all, but they make some really convincing arguments, and I'm excited to do that one.

Julia

Yeah, I'm super excited for that episode. So stay tuned for the next one.

Packy

Thank you for listening and watching to this episode of Age of Miracles. If you like what you hear, please rate, subscribe, and share. If you're feeling really generous, tell us what you think in the comments.

Plus, we have a ton of resources and references in our resource hub if you want to go deeper, and we've linked them all in the show notes below. See you next week.