Stanford eCorner

Investing at the Cutting Edge [Entire Talk]

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Josh Wolfe co-founded Lux Capital to support scientists and entrepreneurs who pursue counter-conventional solutions to the most vexing puzzles of our time in order to lead us into a brighter future. The more ambitious the project, the better—like, say, creating matter from light. Wolfe is a director at Shapeways, Strateos, Lux Research, Kallyope, CTRL-labs, Variant, and Varda, and helped lead Lux Capital's investments in Anduril, Planet, Echodyne, Clarifai, Authorea, Resilience, and Hadrian. He is a founding investor and board member with Bill Gates in Kymeta, which makes cutting-edge antennas for high-speed global satellite and space communications. In this presentation, Wolfe shares the principles that guide his entrepreneurship and investments, giving examples from companies he has founded and funded.

Transcript

Announcer Who you are defines how you build. 00:00:06,360 (thrilling music) - Welcome, YouTube and the Stanford community, 00:00:12,720 to the Entrepreneurial Thought Leader series. And I am Mo Fong, the executive director for STVP, the Stanford Engineering Entrepreneurship Center. So the ETL series is brought to you by STVP and BASES, which is the Business Association of Stanford Entrepreneurial Students. And today I am so honored to welcome Josh Wolfe to the ETL stage. And I'm gonna read a little short bio; but his amazing accomplishments, you should really look it up because it is incredible. Josh co-founded Lux Capital to support scientists and entrepreneurs who pursue counter-conventional solutions to the most vexing problems and puzzles of our time in order to lead us into a brighter future. He is the director at Shapeways, Strateos, Lux Research, Kallyope, CTRL-labs, Variant, and Varda, and helped lead Lux Capital's investments in Anduril, Planet, Echodyne, Clarifai, Authorea, Resilience, and Hadrian. I don't know how you were able to do all those things. Wow, that's a lot.

But it keeps going. He is the founding investor and board member with Bill Gates in Kymeta, which makes cutting-edge antennas for high-speed global satellite and space communication. He is a Westinghouse semi-finalist and published scientist. He previously worked in investment banking at Solomon Smith Barney and in capital markets at Merrill Lynch. In 2008, he co-founded and funded Kurion, a contrarian bet in the unlikely business of using advanced robotics and state-of-the-art engineering and chemistry to clean up nuclear waste. Now, for those who are in the School of Engineering, that is awesome, right? But it is unlikely business because who thought that this unmet and inevitable need with no solution in sight would be one of the first responders to the Fukushima Daiichi disaster? That's incredible. So in February 2016, Veolia acquired Kurion for nearly $400 million, 34 times Lux's total investment. Josh is a columnist with "Forbes" and editor of the "Forbes/Wolfe Emerging Tech Report." And he has been invited to the White House in Capitol Hill to advise on nanotechnology and emerging technologies. He has lectured at MIT, Harvard, Yale, Cornell, Columbia, and NYU, and now here at Stanford University. He is a term member at the Council on Foreign Relations and chairman of Coney Island Prep charter school, where he grew up in Brooklyn.

He graduated from Cornell University with a B.S. in Economics and Finance. I understand you flew in all the way from New York to be here with us, so thank you for doing that. And, everyone, please join me in welcoming Josh. (applause drowns out Mo) Thank you so much. - So I'm gonna give you a quick moment here about Lux 00:03:15,293 just so you can get a flavor

of the kind of stuff we invest in. (lively music) (lively music continues) (lively music continues) All right. So the kinds of stuff that we fund, everything from robotics to high tech sensors, the intersection of biotech and artificial intelligence, novel foundation models that are touching pretty much every industry, all of this comes with backing entrepreneurs. And I know that that's the core content of what the class is about. And I'm gonna give you a whole bunch of principles about the kinds of things that we look for when we're either starting a company with some entrepreneurs or we're identifying founders, and the kind of attributes personality-wise that we like to back.

These are some of the people that we've been backing, and they came from illustrious places and founded Oculus, and we're heads of R&D Amgen, and we're key engineers at SpaceX and CTO of SpaceX. And then they go off and we say, "Okay, these are brilliant people, you know, they've done it before. They're gonna be able to attract incredible talent and lower the cost of capital and raise money and tell stories," and we like to back them. But we also like to back first-time entrepreneurs, and we like to say that we believe before others understand. So it's really an instinct that's honed over many years of what somebody might look like in their disposition and how they're going to pitch somebody that believes that what they're doing is absolutely impossible and we believe that it's inevitable. A few of the themes I touched on, and, again, I'm gonna fly through a whole bunch of this stuff. Principles. And I'm just gonna sort of stop and make a poignant point at some of these principles. This underlies everything we do, and what this is is about the cost of capital. Right now the cost of capital is rising.

But when the cost of capital is low, it is like a tractor beam for the future; it takes far out 20-year projects and turns them into 20-month frenzied projects. And so the further out that something is when the cost of capital is very low, money flows, lots of experiments get tried, the vast majority of them are gonna fail. We are now in a different era, an era that really we haven't seen in a generation or longer where the cost of capital is rising. And what that means is that only fewer things are gonna get funded, but arguably the necessity of those, the importance of them is gonna be much higher. You can make great companies and make fortunes, you know, in up and down markets and when the cost of capital is high or low, but right now it is rising. Another principle, 100%, and this is a truism, 100% of the information that we have right now is based on the past; everything you've learned, everything that you've read, everything that you've experienced. But 100% of the value, if you're an investor, an entrepreneur, is based on the future, which is inherently probabilistic. It's unknowable, it's uncertain, all you can do is think about probabilities. And the best definition of risk, which we hold at Lux, is that more things can happen than will. And so we're always trying to think about the good things that can happen and the bad things.

And you'll see in some of the dispositions around the founders at Lux how that plays out. One of the other principles is the directional arrow of progress. We don't know which technology, we don't know which entrepreneur, we don't often know which specific company, but we do know that there are these directional arrows of progress. And you're gonna see as I talk through some of the companies and the examples and the founders that we've backed, some of these directional arrows of progress. Everybody knows Moore's law. Moore's law has transcended semiconductors, it's been in memory, in compute, in transportation, in telephony, in film and TV. We had an insight going back during the first clean tech boom that there was another directional arrow of progress, and a lot of people were not focused on it. Most people were consensus looking at alternative energy, very few people were looking at nuclear. And all we did was look at the directional arrow of progress of mankind's use of energy. And we went from left to right, from carbohydrates to hydrocarbons to uranium.

And the unarguable trend was higher and higher density per unit of raw material. Why was nobody looking at nuclear? And there's a variety of reasons, some of them psychological, some of them political, some of them technological. But we said, "What's the one thing that really sucks about nuclear?" And that's the favorite question that we like to ask about any industry. I always joke that it's sophisticated, two-word PhD-level question: "What sucks?" You find something that sucks and it is waiting for a technology and an entrepreneur to go and solve that. So we looked around for entrepreneurs and couldn't find one. And so we ended up starting a company from scratch. We named it after Madame Curie, we called it Kurion. And we recruited people that were slightly under the age of 60 but were industry veterans. And we pulled together this team, we pulled together technology, and we decided that we were gonna go after the nuclear waste problem. And it turns out that there's 104 domestic reactors, there's 440 global reactors; you can make a market selling into those.

But there's this huge defense market that's in places that most people have never heard of like Hanford, and Savannah River, and Idaho National Labs, and Sellafield in the UK. And all of these places have hundreds of millions of gallons of radioactive waste, and that really sucks. That was a a big problem. And so we saw an opportunity for a big solution. Now, this is a company that would've been great, it would have been a phenomenal business over the course of a decade. We founded this company back in 2008 or 2009. March 11th, 2011, something terrible happened in Japan, it was a negative black swan, it was the Fukushima disaster: earthquake, tsunami, nuclear disaster. And that became a positive black swan for this little company. We had never predicted that this outsized negative event would become this outsized positive event for this company. We became the only US company picked for the cleanup of that nuclear disaster because we had assembled the team that had the know-how, the technology, the robots, the intel and the access for the relationships.

And I'll give you a quick video of what occurred here at Fukushima. (dramatic music) Reporter Tokyo Electric Power's Fukushima- 00:09:42,136 (reporters chattering) Speaker The water is so radioactive 00:09:49,320 that people don't even wanna go near it to even sample it. Speaker When I first got to Fukushima, 00:09:52,977 they said it was gonna be 30 years. And I thought that can't be possible till I got to the site. Speaker They didn't even know how to define the problem. 00:09:59,940 It was almost like a comet that hit their plant. We actually knew immediately what the answer was. Speaker And

we designed it in two and a half weeks, 00:10:08,130 filled three Russian filled Antonov military transports with 700 metric tons of equipment in five weeks and started it up three weeks later. Speaker We were just, you know, 00:10:17,117 shocked by the enormity of the whole thing. That a large company like TEPCO trusted a tiny little startup of six people with a critical part of what they needed to recover from the accident just was mind blowing.

Speaker The day we started 00:10:31,620 was a scale of about a hundred times bigger than what went on at Three Mile Island. Speaker And there's nothing more full scale 00:10:38,370 than Fukushima. Speaker To actually work on a project 00:10:42,540 where you went from a whiteboard sketch to an operating system in eight weeks and succeeding is the accomplishment of a lifetime. - Now, we really like to find entrepreneurs 00:10:53,910 and sectors where there's like one or two competitors; so not an area where there's 50 entrants and people are developing social media apps, something that is really hard, something that has a very high barrier to entry, something that is very technical. And if you are an entrepreneur and you can identify one of those spaces that is very technical, something that you can do or assert that you can do or a team can do that nobody else can do, your ability to raise capital is gonna be much higher, your ability to succeed is gonna be much higher because you're competing with far fewer people. So we like to find these weird, off-the-beaten-path technologies and problems that very few people are going after. Another philosophy: We like to say that failure comes from a failure to imagine failure. Now when I say we, it's mostly me because I'm very negative. It's a adaptive mechanism. Growing up, if I could expect all the bad stuff that can happen, psychologically I could cope with it better.

But I think that this is a great way to manage risk. There's this mythology around entrepreneurs that entrepreneurs are these great risk takers, but I actually think that most entrepreneurs are risk killers; they identify a risk and then they try to kill it. My co-founder of Lux, Peter Herbert. Peter Hebert and I met 25 years ago, we founded Lux nearly 20 years ago. Pete is an optimist. He's wearing bright colors, as he always is, typically pastels. He's thinking about: "How can things go right? How might this work? What if it's successful? How much money could we make? Who could we populate the board with? What's the right syndicate construction? How do we help these entrepreneurs?" And I am thinking, okay, "How is this all gonna fail? How is this all gonna go terribly wrong? And what can we do to prevent it going wrong?" So people like to joke that Pete invented the airplane and I the parachute. And this is a beautiful yin and yang in a partnership, but it's also something as entrepreneurs that you need. You need somebody that can believe and say we're gonna go do it, especially when you have down times, but you also need somebody who's a little bit of a realist that can put the brakes on. So this yin and yang, I think, in founder dynamics is actually really important.

Okay, another principle: Chips on shoulders. Chips on shoulders put chips in pockets. The favorite entrepreneur that we like to find is somebody that has a real chip on their shoulder. They might have come from a broken home. They might have been the obese kid that everybody made fun of in a Friday night's Texas town. They might have been a minority, they might have been gay, they might have been made fun of, they might have had a disability, but there's something, and a lot of immigrants have this as well, but there's something where they felt rejected by the system and they know that they are better, that they are more valuable than what the market is saying they are worth; and those are the best people. And the most interesting thing that we have seen through generations of these kinds of entrepreneurs is no matter how much money they make, no matter how much success or achievement they have, they still have that chip on their shoulder; it never goes away, and it is this beautiful force. So a lot of people, particularly out on the West Coast, 'cause I am based in New York, half our team's Menlo, half our team's New York City, a lot of people out here are about mindfulness and meditation. How many people try to meditate every day? Okay. That is a wonderful thing for you.

It is a terrible thing for society. You want troves of disaffected, miserable people that want to improve their lot in life or something else that they identify that sucks, and so we really like to try to find that. Another tip: When you go to pitch venture investors and you're starting a company or you're raising money for one, if you come in in and say, "I just wanna change the world," for most people I think that's BS. I think that most people have a chip on their shoulder and the best entrepreneurs have something to prove, and a byproduct of that is that they end up improving the world in a positive way. But a lot of people come in with a sort of vainglorious positivity that I'm just a little bit too cynical to believe in. But I do believe deeply that chips on shoulders put chips in pockets. And you pick many of the people whose buildings are named after them on this campus, they all had chips on their shoulder; they had something to prove, they had people that doubted them. I'll give you two great examples. One in science, this guy Peter Mitchell. Peter Mitchell had a a theory of chemiosmosis.

And everybody thought that this guy was a complete idiot, okay? So he ends up winning the Nobel Prize because he was right. But what was amazing about the Nobel Prize speech, and this is one of the best speeches ever given in all Nobel Prize history, is he put up a chart and he explained his work and how the technology came about, but he also put up a chart that showed every person that was a colleague or an enemy and when they finally changed their mind and agreed with him, okay? That is a chip on your shoulder. That is a motivating force when the haters and the doubters don't believe in you. And that should be for all of you, it will happen, it has happened in your lives, fuel your fire. You should never let that go. People are gonna tell you that you suck, that you can't do it, that you should go back to business school, that you should do something else. If you believe in yourself, you stick with it. It's one of the most important lessons from our great entrepreneurs. I'll give you another great person. And listen to the scouting report for this local hero.

(lively hip hop music) Announcer Stephen Curry, 6'3", 185 pounds. 00:15:14,456 Position, point guard. (lively hip hop music continues) Stephen's explosiveness and athleticism are below standard. He's not a great finisher around the basket. ♪

Needed something' quicker ♪ Announcer He needs to considerably improve 00:15:27,750 as a ball handler. - All right, you get the point. 00:15:32,040 When you are an entrepreneur, when you are an investor in venture, there are three sources of edge that you can have. And it's really important that you understand this because the third is the most important. You can have an informational edge, you can have an analytical edge, you can have a behavioral edge, okay? Informational edge means that you get information that other people don't have. In today's world, that's really hard because information is abundant, it wants to be free in the proverbial sense, it's flowing everywhere.

Analytical is that we get the same information. Maybe Deena my partner gets a piece of information, I get another piece of information, it's the same piece of information, but I analyze it differently than she does. Maybe she's closer to ground truth and I'm wrong, okay? Also really hard because there's brilliant people. And now we're all augmented by AI and it's really hard to have a better analysis than somebody else. But behavioral is the one source of lasting advantage, to identify where the herd is going, okay? Back then in that example with nuclear, everybody in the herd was going in clean technology for alternative energy and biofuels and solar and ethanol and we attacked the other way. So if you as an entrepreneur can identify, "What is everybody else doing? And what can I do differently and then be right?" it's really powerful, okay? This is a great example. It's the Simon Asch experiment. How many people have ever seen this before? Okay. The guy in the red sweater is the mark, everybody else is in on this. It's a psychological study about group think.

So watch what happens. They're gonna show a bunch of lines; and the lines, they're gonna lie about which one matches, okay? And he's gonna look at them and say, "You idiots, like, you got it completely wrong." Watch what happens. Narrator In the first test, the correct answer is 2. 00:16:56,430 Participant 1. 00:16:57,330 Participant 1. 00:16:59,183 - 1. 00:17:06,300 - It's 2. 00:17:07,200 Participant 1. 00:17:11,550 Narrator Once again, the correct answer is 2. 00:17:13,080 Participant It's 3.

00:17:13,980 Participant 3. 00:17:15,893 - 3. 00:17:22,470 - 3. 00:17:24,180 Narrator Now he knows it's not three, 00:17:26,640 but the social pressure is so strong. And you will encounter so many situations, and I'm sure you already have, where that social pressure to conform and go along with what other people are doing. And, again, have the belief and the conviction in your own ideas and stand away from the crowd. It's painful. It literally feels like pain to be socially ostracized; but if it's of your own choosing to separate, it's a really powerful thing. Okay, so those three lines, if you flip 'em horizontally, you get a different advantage which is time arbitrage: if you can think longer than other people. So many people are looking for the startup that is the quick fix, something that's gonna pay off in a year or two.

But all the deeply technical stuff takes a long time, it takes a lot of money, it's a lot harder, okay? It's like taking a shot and you don't know if you're gonna hit a three pointer for like six years. But sometimes the biggest payoffs are these longer term things. So we like to invest in things where there's time arbitrage, where we're going further out than other people are because there's just less traffic there to compete. I'm gonna skip the marshmallow test you guys know and the myth of Odysseus tying himself to the mast to resist the siren song, in this case the siren song of the temporal now. I'm gonna skip this as well. "The reading of good books is like a conversation with the best men of past centuries." This was a placard outside of our New York City office, our old office, and it went up to the New York Public Library. And I love this because there are three great men in literature that help define where you should focus, and each one has a famous quote associated with them. Fitzgerald's quote was that the test of a first-rate intellect is the ability to hold two opposing ideas in your head at the same time and still retain the ability to function. Okay? So a Fitzgerald's situation for us at Lux is the stuff that everybody's arguing about, the stuff that's on the front page, okay? And I actually say that this is not really valuable to focus on. Gold, gold is a shiny piece of metal.

Gold is a great store of value in an otherwise fiat currency world. China, China is an engine of growth or China's a giant bubble waiting to collapse and there's nothing but lies, damn lies, and government statistics. What you can predict in these Fitzgerald situations is that people are just gonna be battling it out online. Okay? A lot of volatility in something that is widely known. The next domain is Twain. And Twain's famous dictum was, "It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't." It's where there's certitude, where people are highly confident that something is going to happen and continue to happen, but they're wrong. The housing crisis was a great example of this, okay? Housing crisis could only go up until 2007, 2008, boom, massive crash. All of a sudden people are shocked. Huge leverage, huge disaster, great financial crisis.

Another example, we all experience this every year. Now, imagine you're a Turkey start of the year, you're an egg, you're growing, you're getting fatter, life is good. Every day is better, okay? All of a sudden comes Thanksgiving, you die. (audience laughing) Okay? So any presumption of linearity is a dangerous thing. Now, where we like to spend our time is in Schopenhauer domain. The Schopenhauer domain, his famous quote was that talent is hitting a target that no one else can hit and genius is hitting a target that nobody else can see, again, being a contrarian, thinking differently, being willing to stand out, seeing something that other people don't. This is talent. Commentator Final seconds of the third. 00:20:21,789 And here's Wade. Got it! - This is talent too, 00:20:29,832 (lively music) (crowd shouting) but it's not genius, okay? Now, the classic cliche is that the best way to predict the future is to invent it.

And the people that historically invented the future used to look like this: white men in lab coats, Bell Labs, 1928. 1960s, '70s come along, you start to let a few women in, now you're wearing different kind of lab coats. And then you get these freaks and geeks. And of course most people in the audience should know who this is. This is the found team of Microsoft, Bill

Gates there on the bottom left. If you ask many of these people, including Bill, "What was your inspiration?" a lot of people will say, "It was science fiction. Science fiction inspired me. It was somebody in fiction imagining the world that I wanted to live in and then I became an engineer or a scientist because I wanted to create that world." And we actually contend that the gap between sci-fi and sci-fact keeps shrinking. And we've cataloged a lot of these examples. So you take the "Star Trek" tricorder, that begot the first Motorola cellphone that we all had, the flip phone back in the day.

The phaser from "Star Trek" begot the taser. Now, this is heresy, okay, because people hailed Steve Jobs... And I actually think that Steve was an incredible sci-fi archivist. This is Captain Picard, "Star Trek: Next Generation," with a trove of iPads strewn across his desk long before the iPad was ever invented. You just have to go back into sci-fi. "2001: A Space Odyssey," FaceTime long before Steve demonstrated it on stage. Okay, so it's a great inspiration. Hal, Siri, and on and on. We funded a company that was focused on blind and visually impaired people, the inspiration came from "Terminator." (ominous music) Early visions of augmented reality, and back then it was using Google Glass with facial recognition, simple AI to be able to identify a person, navigate through restaurants, and whatnot, and we will continue to see that augmented reality, but it came from the inspiration of Arnold Schwarzenegger, who is a great source of new companies. This was "Total Recall." Arnold walks through at video frame rate instead of stopping at an X-ray scanner.

Announcer No unauthorized weapons allowed. 00:22:27,150 - Terrible movie, but great science fiction. 00:22:28,320 This is Evolv Technology. It's a company that we co-founded with Bill Gates. We spun it out of a bunch of universities and key IP around an area in physics called metamaterials that can do rapid video frame rate scanning of bombs and explosives and other weaponry. This was just recent. So I'm on an endless search for these kinds of things. This is a cartoon. I think it was called "Paragon," but I might have that wrong. And watch what happens.

- I guess it's kind of like an iron rod through the head. 00:22:57,000 - It's one problem neither a human 00:22:58,650 nor a computer could solve; not even Stephen Holstrom, though he got close. - Yeah, I, I, I mean I've got no idea what it's about. 00:23:06,870 Like, I don't even understand if it's a code problem. I mean, do you even have readable code? - Sure, if you have an eternity or two. 00:23:11,963 - Here. 00:23:13,559 This is my sense of smell. (hologram buzzing) - Okay, now for a decade we have been on a quest 00:23:22,380 trying to find entrepreneurs and scientists and engineers that could digitally record our sense of smell to create digital olfaction. Our phones can record our sense of sight with cameras in ever high definition and frame rights. Our phones can record a sense of sound, but it can't record smell.

You need large-scale mass spectrometry or liquid-gas chromatography, you can't shrink it down. We found a team inside of Google, and last year we spun them out. $60 million founding round, brought together some amazing people. Alex Wiltschko is the founder. I'm gonna give you maybe a second here. What is the vision for Osmo? - Computers can see and they can hear. 00:23:55,710 And when those things happened, society and our species changed permanently. And smell is no less important; and in many ways it's more important, it's older. And computers need to be able to smell, right? There's information in the chemical world that's not being used that if we were using it, people would live longer lives, right? Cancer has a smell. COVID-19 has a smell.

This information is not available in our pockets, it's not available pervasively, it's not even available in our homes, and it needs to be. So the thing that every other sense has that's let us understand how the brain creates it, that lets us digitize, it is a map, right? So RGB, red, green, and blue, is a map of color, and that's what lets us understand how our eyes work, it's what lets us build a camera. And low to high frequency, called the Fourier basis, you know, 20 hertz deep bass to 20,000 hertz inaudible, that's a map of sound that lets us make any song. And that's what lets us understand how the brain codes for sound, it's what lets us build a microphone, right? Those are maps that you can even draw on a flat piece of paper 'cause there's just two or three dimensions to them. And that makes sense because our eyes have two or, you know, three different types of cells that code for color. But there's hundreds of different types of receptors in our nose. - It's a company called Osmo, 00:25:17,183 it started last year. Poetically, when I signed the term sheet for that deal, after evading COVID for two and a half years, I finally got COVID and my only symptom was that I lost my sense of smell for three weeks; it was perfect poetic justice. Okay, other one. Peter, co-founder of Lux, identified an amazing entrepreneur who...

And, by the way, before I go on, the great thing about Alex is not only is he a technical genius, not only do people wanna work for him, not only is he doing something that's unique and rare and nobody else is doing, he's a great communicator. He can sell and he can sell credibly. He's not a BS artist, he can sell credibly. And he captivates you when you listen to him. So that is the kind of entrepreneur that we wanted to back and put into business to do something that we was gonna create history. And the year-old company was doing amazing things. Peter identified an entrepreneur. This time it was an entrepreneur that founded a company, a very large company called Intuitive Surgical. The founder was Fred Moll. 50, $60 billion plus publicly traded company.

Fred said, "You know what? I'm gonna go do this again. Robots have gotten smaller, there's more technology that we can apply, there's AI, there's wayfinding that we can do inside of the body." And he said, "You know, instead of having to surgically enter the body through a cut, we can do it through an orifice without making a single incision." This inspiration came from "Star Wars." On the top, after Vader cuts off Luke Skywalker's hand, you have a robot performing robotic surgery, okay? Fast forward to decades, you have the same thing now with this company Auris Surgical Robotics. Auris would end up getting bought by J&J for $6 billion, and it's just a fascinating case study that, again, came from science fiction. On the top,

again "Star Wars," holographic display of Princess Leah on the bottom. One of our companies between Hong Kong and Brooklyn called Looking Glass, they don't believe in virtual reality. They think that we're gonna be hovering around these sort of volumetric displays and watching football and soccer and baseball on a pitch that's on a coffee table. 3D printing. "Star Trek" originally had the replicator, you conjure your morning cup of coffee. Back in the day you had MakerBot doing simple resins and additive manufacturing, then you have companies like Desktop Metal. Reporter 3D printing is also spurring another revolution 00:27:14,455 in industrial design.

The technique enables the creation of objects unimaginable using traditional tool and die techniques. The company is designing with software made smart by the artificial intelligence technique called machine learning. And here's the ironic twist: the machine is designing parts that appear to come from nature's playbook. Check out these two parts. - I'm gonna skip a whole bunch of things here on robotics, 00:27:39,788 (balls clattering) but it's a trend that's very important in history. And I'm gonna talk a little bit about how one company leads to the next. This is a company that we funded called Kymeta based on crazy breakthrough and metamaterials. Metamaterials were very hot. This idea of invisibility cloak, that is not real; but you can actually do beam-steering antennas. So we started this company with Bill Gates.

You can put these flat panel antennas on anything that's moving. Main competition, of course, Starlink. And they'll eventually be moving. This was the first one that came off the line. Speaker Produced and it's the reliability- 00:28:12,150 - So this can transmit? 00:28:13,800 - This is at a, it's received frequency. 00:28:15,360 Bob That's what a fancy board meeting looks like, 00:28:16,193 by the way. Speaker You could transmit with it, though. 00:28:19,410 - Crappy room and paper strewn everywhere. 00:28:23,340 Today, key part of both special operations, Ukraine, shipping globally, and very important. But this led to a principle which is what we call 100 0 100.

And it's really important as an entrepreneur to pay attention to some of the problems that you encounter because they often tell you that there's a company that's out there that you might want to acquire, you might wanna bring in, there's talent you might wanna bring in. We call it 100 0 100 because I say, with a little bit of arrogance, that Lux will be investing in the most cutting-edge crazy stuff that you can imagine over the next two years. I have 0% certainty, and I say that with a little bit of false humility, what those things will actually be; we don't know. But we know where we will find them, and that's typically at the edge of our already cutting-edge companies. So one company gives us an insight that leads us into the next. And as long as we're paranoid and curious inside of the boardrooms, it leads us from one company to the next. So Kymeta led us to these guys in San Fran in the Dogpatch area that were founding a company at the time called Cosmogia, and it became called Planet Labs, now it's publicly traded called Planet. They wanted to take these little small CubeSsats, put a Kymeta antenna on top and go launch. Now, sometimes the launches work. Announcer Three, two, one.

00:29:30,525 And we lift off on Antares (indistinct) mission to bring Cygnus on its third CRS mission to the ISS. That main engine's at 108%. (speakers chattering) Josh And sometimes they don't. 00:29:44,160 In this case, the economics of the small satellites were so cheap that it didn't matter. A month later we were able to launch again and up into space. - There's a video 00:29:50,940 of two of them being deployed from the International Space Station. It gives you a bit of a sense of the scale of them. (objects rattling) (astronaut speaking in foreign language) Speaker I mean, it's like a little satellite. 00:30:09,720 (speaker faintly speaking) - One of the last vestiges 00:30:12,540 maybe of US-Russian diplomacy back then. But this is important because, again, one company leads to the next.

So an antenna company leads to a satellite company and the satellite company leads to the insights that you can run AI longitudinally over the data that you're getting, that was a company called Orbital Insight, and then on and on. And this is the same thing in drones, in robotic systems. Drones that we saw flying in the sky led us to the idea, "Wait a second, there's different mediums for this. What if you put it in the ocean?" And so we funded a company out here in Alameda called Saildrone. When we first funded them, they had one of these things, they were bright orange, and then they said, "Okay, what if we create a fleet of these?" And we said, "Okay, that's interesting." We do a lot with the military and defense industry. And we brought on the undersecretary of the Navy, Hondo Guerts, He became advisor to the company, and he said, "You know, it'd be better if you paint these things gray." And so they painted 'em gray, and that led to this. This was back in the fall, about seven, eight months ago, but an Iranian warship captured one of our cute little drones and we had to send a a Blackhawk helicopter and a naval war ship to reclaim them. But that became an international incident. Another company based out here we originally saw in automation at a time that very few people were looking at this was a company called Zoox. And I was here on Slack at the Stanford Linear Accelerator.

We had an amazing founding duo. Speaker And with one Swift keystroke, 00:31:34,393 I give complete control of my life over to an AI. (tires screeching) (passenger laughing) - I'll skip the some of the videos here 00:31:49,433 for the sake of time. But fast forward, and Amazon would end up acquiring these guys for a little over a billion dollars, and it's the key kernel for what will end up being 24/7 right-hand lane deliveries, you know, it'll make all of our lives ever more convenient. That in turn led to an insight, and this is going back seven, eight years, to the idea that the soul of the new machine were not gonna be CPUs but GPUs. We went into Zoox and we saw all these people that looked like they were playing video games and we said, "What the heck are you guys doing? We just put $25 million in the company, you guys are sitting here playing video games." And they said, "No, no, no, we're not playing video games, we're training these machines because the machines don't know the difference between what's outside in the real world and what's inside, in-silico being simulated." And we said, "Okay, that's interesting. What are you doing these on? Regular Intel Pentium chips?" They said, "Nope, we've got cutting-edge

Nvidia chips that aren't even on the market yet." That led to this idea that GPUs were gonna be a really big deal. We shared with our LPs and lots of public market hedge fund friends, they made a lot of money. It also led us to go and find what's the next AI-based chip, and we ended up funding a guy Naveen Rao around here. We sold that to Intel.

And then we backed Naveen again. And that's one of the great things that when you become an entrepreneur and you find partners, both employees and colleagues and investors that you like to work with, you get to do it time and time again. So we backed him in a new company some of you might be familiar with called MosaicML, and that's very successful right now. Mosaic also is tied into a whole bunch of other companies where we were early investors in. Hugging Face. How many people have used the Hugging Face repository in machine learning? It has become effectively the GitHub fr AI and ML. That was when we signed the first term sheet. We dressed head to toe in hugging face emojis and made fools out of ourself and helped to win the deal. Runway, another company that's at the cutting edge of AI and ML. They really were responsible for creating stability diffusion.

And I'm gonna skip some of the videos here, but this is the latest stuff that they're working on. Narrator Not too long ago, 00:33:40,093 Runway pushed the boundaries of generative AI with Gen-1, a video-to-video model that allows you to use words and images to generate new videos out of existing ones. In the week since launching, the model has constantly gotten better, better temporal consistency, better fidelity, better results. And as more and more people gained access, we unlocked entirely new use cases and displays of creativity. (thrilling music) And today we're excited to announce our biggest unlock yet: text to video with Gen-2. Now you can generate a video with nothing but words: no driving video, no input image. Gen-2 represents yet another major research milestone and another- - So Grace, who's one of the partners 00:34:28,680 and leads on this investment, we were talking to the founder and we said, "What's the craziest thing that you can imagine in the next two years?" He said, "We are gonna have entire cinematic videos, full movies in the next two years, with no lights, no cameras, no actors. Everything will be generated just by the creativity of people that are able to do really excellent prompts." I'm gonna skip a whole bunch of stuff here for the sake of time 'cause I wanna make sure that we get to Q and A. This is another important point. Anytime you hear your parents, anytime you hear older people say, "This is terrible," you know, "we need to ban this, we need to regulate it," just remember that these words that, "It will rot your brain," is the most powerful predictive thing of the next $10 billion industry, okay? So you take video games, that was Kobe in the beginning and how crappy the videos were.

GPUs get better. The sweat drop that he's got on his face back almost seven, eight years ago had more computational power than the entire first video game when he was a rookie. Just absolutely amazing. But anytime that somebody says it'll rot your brain, it predicts the next $10 billion industry. So rock and roll, parents said, "It'll rot your brain," huge industry. Video games, TV, you know, "It'll rot your brain." Internet, online chat communities. These kids, these couch potatoes, as parents were calling them, would become, you know, the drone pilots and the robotic surgeons of the future. So huge believer that anytime somebody says it'll rot your brain, it's really predictive of the next industry. Another interesting company that also was inspired by sci-fi is a company called Matterport. This came from another sci-fi movie called "Disclosure." He scans himself into this virtual reality world, he being Michael Douglas back then, it's gotta be 25 years old, and enters this world.

Matterport does the same sort of thing now. Two more principles and then we'll go to questions. We like to come up with these narratives and we tell them our to ourselves and we use them as these guiding forces to find these directional arrows of progress. One of these was this half-life of technology, that the half-life of technology gets more and more intimate with you over time. Okay, so it sounds a little bit weird, but think about this. 50, 60 years ago you had an ENIAC. You would physically get up and touch the machine and you would, you know, pull some plugs and levers. that was the way you interacted with it. Then you get desktop machines, and now you're tickling the keys with your fingers, you've got a mouse under your palm, you're pushing the monitor, flicking the beige box on the back. Okay, then you get laptops.

Now it's touching your thighs. Okay, then you get a phone, and it's the first thing that you touch in the morning and the last thing you touch at night; typically 16, 18 hours a day cradled in your hand; for men, separated from your body only by a thin film fabric. Then you get your watch that's, you know, now 18, 20 hours a day directly in contact with your skin, and AirPods with compute. So we had an inspiration based on this directional arrow of progress what was going to be the future of compute. And another entrepreneur introduced us to this guy Reardon. Reardon has a major chip on his shoulder. He comes from a family of 17 brothers and sisters; 10 biological, he's the youngest of the 10, 7 adopted. Just insane. He goes and... 17, he's auditing classes at MIT.

This guy out in Seattle, Bill Gates, finds him and says, "You know, I heard you're really smart. Come and work for me." He does that in 1990. And then four years later, he single handedly codes and creates Internet Explorer. So now his main antagonist is Netscape. He's Bill's right-hand guy going up again Marc Andreessen. Stays with Bill all the way through the late '90s, makes a ton of money, technologically renowned. Decides to do what anybody at the age of 33 would do. He goes back to college and gets a degree in classics and Latin and then spends the next eight years getting a PhD in neuroscience, okay? I mean, this guy is just driven. And you meet him today, he's just insanely driven, constantly thinking about the next thing. Today he's the head of neuro at Facebook.

Facebook ended up acquiring his business. His business was: How do we take a myoelectric response, a highly technical set of sensors and neuroscience, to be able to anticipate how you are going to interact with your computers before you even

do it so that you can just gesture in free space? Okay? And his idea was: "Let's disintermediate the fact that you need all these control things." I'm using a clicker right now, which is connected to my computer, but his idea was I should just be able to connect to the device directly, take the signals that are coming off of the brain and particularly off of the muscles and be able to actuate them. Thomas Just gonna show you 00:38:25,320 how we're able to actually decode, just from the nerve itself, what the hand is doing and create a biologically accurate hand virtually: all the fine digit movements, flexions and extensions. This is a hard problem, and I think it's impressive. What you'll see next is how we actually do something more complicated. What you're seeing here is my intention. I'm not moving, but the nerve is active and I'm just trying to wave my hand back and forth without moving. Josh Now, when we saw that we had a feeling of magic. 00:38:59,963 It was just- - Showing the forces 00:39:00,796 that I'm able to generate. This is just a simple grasp.

And I actually have nice control over this, probably about- - Nobody else was doing it. 00:39:06,510 And it's the kind of thing, again, if you can do something that nobody else is doing and you're confident that nobody else is doing it, it's super powerful. Again, I'm gonna skip some videos here. Facebook ended up acquiring these guys. It was this vision also inspired by science fiction from "Minority Report"; but instead of having to wear ridiculous gloves, it was that it would just read off of the body. And you will walk into the room in the near future and you will be able to control Spotify and just make a simple gesture with your hands. They will be wrist-borne devices. They will first start with Oculus integration and then you will end up seeing them in traditional watches. The very last one I'll give you, which also inspired by sci-fi, is "Ready Player One" and VR. And it's important because it's the ultimate chip on your shoulder, okay? This is Palmer Luckey.

Palmer made a lot of money when he sold to to Zuck. And Zuck was inspired by "Ready Player One." The board of Facebook read the book and it became basically the playbook for how they were gonna make acquisitions from everything from software to haptics. And listen to what Palmer says here. - I used to be an outdoor kid, 00:40:03,390 then I discovered computers and I became an indoor kid. I really like working with all kinds of various hardware systems, so gas lasers, solid-state lasers, optics, displays, modifying old game consoles, modifying new game consoles. My name is Palmer Luckey. I started my career when I founded a virtual reality company called Oculus VR. I sold that to Facebook for a few billion dollars. And when I got fired, I started Anduril so that I could work on autonomous systems for national security. - "When I got fired." 00:40:30,150 I mean, that was the most important thing.

I mean, this guy has a perennial chip on his shoulder. He is still picking fights on Twitter with people that, you know, are talking smack about him. So I've got a ton more content. But I think in the interest of time, I will stop here and then just open up to Q and A. But the key takeaways I want you to have: Number one, if you've got a chip on your shoulder, it is a great virtue. It is something that we as venture capitalists love to find in people. It's not great for you individually, you're probably stressed and you're pulling your hair out and you can't sleep, but it is great for society because you are the ones that are gonna invent the future that everybody else is gonna live in. So really dig into that. Be comfortable being a contrarian. Be comfortable knowing what the rest of the herd is doing and knowing that you pay a high price for a cherry consensus.

If everybody else is doing something, it's priced in. Do the stuff that nobody else is doing and have the psychological comfort to stand out from the crowd. So I'll stop there and drop the mic and open it up for Q and A. Audience Member Thank you for your time. 00:41:21,990 I'm a master's student here. My background's national security and deep tech. And I'm curious about how you think about identifying entrepreneurs versus venture formation and how you collaborate with the government. So certainly there's just geniuses out there who've been thinking about a problem for decades and then there's expert venture capitalists who can say, "Here's a problem with the market, we should design and implement a solution." How do you think about those different options when you think about identifying a solution to a problem. And then when you find a solution to a problem, how do you work with the government? Which is, in my experience, very hard to work with, and some VCs are doing it better than others. And how do you think about that? - Okay, great question.

00:42:01,050 So first one is we really are not valuable, okay? The one thing that we do that's valuable aside from raising money from people who have interest to make a lot more money, foundations and endowments and wealthy families, is that we believe before others understand. That is our key mantra to identify. So if you said, "I think that there's this unmet need. I served, I know the communication systems," or, "I know the armor systems, there's a huge gap, it sucks. This is something to solve. I've got the team, I've got the technology, I've got the will to do it," we love that and we wanna back you, right? So that's the most important thing. All of the value is from the entrepreneur, it's not from the VCs. VCs are relatively a commodity, okay? We have different styles, we have different reputations, but it's really the founders. And we are competing to get the chance to partner with the great founders across all the sectors that we fund. So what we're looking for are people that can tell stories that truly can execute.

'Cause you can have great people that can BS and raise money, but they can't deliver. The best people are able to raise money, tell a story; it happens to be true because they really have that deep conviction that they believe in it. People will part with their money, people will move across the country with their spouses and drop what they were doing to join them, that kind of galvanizing force is so powerful. So that's really what we're looking for, is somebody that can really galvanize talent and capital and then actually execute and be held accountable. How do we work with government? Anduril is really the great case study of this because historically in defense tech companies, you got cost-plus contracts and it took forever. And something is happening now that hasn't happened in at least a generation, maybe two, since the Cold War. The first is we have real peer competition, particularly with China. Russia's important, but China's really important and particularly the CCP.

And so you have a motivating force to say, "Wait a second, are we behind?" Are we behind in satellites? Yes. Are we behind in hypersonics? Probably not.

Are we behind in AI? Today, no. But those are the kinds of things where we look and say, "Okay, where's the sort of surface area that you can attack problems." In working with government, what Anduril decided to do is: "We're not gonna go after cost-plus contracts. We're gonna raise a lot of money." And right now they've got nearly 2 billion on the balance sheet now, and they're gonna fund it and they're gonna do demonstrations and the customer is going to buy it because it's a better product. And that's really the bet that they've been taking, and it's paid off, and I think it's gonna usher in a wave of other startups that follow that model: "Let's raise from equity and debt dollars. Let's execute and then the government will buy." A very different model. Audience Member How important in your vision, 00:44:10,913 in your movement, is the ability to communicate your message through news and to change the perspective of society through your ideas? - First is the audience 00:44:20,640 that you're trying to communicate to. So today, because everybody has access to Twitter, everybody has blogs, everybody has podcasts, everybody has, it's just, it's an abundance of noise. And so it's incredibly important to be able to communicate so that you can get a signal out there, but it speaks even more to why you have to do something that's differentiated. Because if you're doing the Nth company where there's 40 of them, I can tell you that if you ask a journalist like, "Hey, we've got this great company and I wanna pitch you," they'll be like, "Ah, you know, I've heard like 17 of those already. Like, how is this one different?" You know, if you hear somebody is doing digital olfaction, like they're digitizing your sense of smell, people perk up: "Wow, I haven't heard of that.

That's interesting." "Wait, we have a fleet of sailboats that are entirely autonomous that could be used for oceanography or for defense..." "Okay, that's interesting. I don't know, are there other companies doing that?" So we like the singular nature, that there's less than five companies in a sector. That's how you really get attention. Audience Member My question is: 00:45:15,570 As you're thinking about sort of investing in both software companies as well as deep tech companies, they'll sort of have different cycles in which you're expecting returns, but you are also kind of raising a bunch of different funds, so how are you thinking about sort of the capital allocation and the expected returns from those different types of plays? - Brilliant question. 00:45:36,030 And and I can tell you the way that we analyze our healthcare IT companies, the way that we analyze our biotech companies, the way that we do our defense companies, the way that we do our software companies, they're all very different, they're all idiosyncratic. Now, our job is to build a portfolio, a portfolio of different approaches with different end markets, different capital needs. Some are very capital intensive, some are very capital light. Some would get lucky and they don't need that much capital because they've caught lightning in a bottle, some require a lot of capital. So every company in every sector is different and it requires a different set of milestones. But the common milestone that I think is true of, you know, everything that we funded...

And if you're an entrepreneur, when you are thinking about how much money should I raise, how much money accomplishes what, in what period of time, and who will care? I can tell you that there's people that are doing quantum computing and they're coming up with all these kinds of things where they're like, you know, "We're gonna get 14 nanosecond anneal..." And the question is: Who cares? What does that mean to somebody? You know in biotech what it's gonna be for a preclinical or IND or phase two, you know the probabilities associated with those. You know in aerospace what it's gonna be if you're gonna actually do a launch and whether that launch succeeds or fail and if you get your asset up into space and orbit. And so it's really how much money accomplishes what, in what period of time, and who will care? Audience Member Yeah, I had a question 00:46:45,300 about if you had any advice for like undergrads. If they wanna become an entrepreneur, should they go get a PhD or should they go into, like, industry? Or do you think they can just start one just right out of college? - I think you could start outta college. 00:46:56,130 I mean, I think there are people, of course, that are done remarkable things that didn't even go to college, right? It really is: Do you have deep conviction in something and do you feel like you have a unique capability or you can attract people that have a unique capability to go go and do it? But degrees, I mean, I can tell you, I don't care where somebody went to school. I don't care if they went to college. I mean, all those things are somewhat predictive of like what they might be able to do, but really it's like, you know, you can tell the people that at six or seven years old were running circles around their parents, you know, they were just like really clever. And the great definition of an entrepreneur is somebody that does more than anybody thinks possible with less than anybody thinks possible. So that cleverness, you know, the can-do-itness is way more important than any of the bonafides. Now, if you're doing something in semiconductors and you're doing a tape-out of a chip, like, we wanna know, okay, you actually know what you're talking about, because if you're wrong it's gonna be really, really expensive.

But some of the people we've backed had no experience doing whatever they're doing. You know, Clem at Hugging Face had no experience doing anything in open systems for AI before. And so some of the greatest entrepreneurs just went and did it and then post facto, you know, we all look at these wonderful narratives, but most of the time they had no experience. You know, we started a venture fund as entrepreneurs; we had no experience in venture. So I really believe that experience is very overrated. Audience Member Thanks for the inspiring talk. 00:48:11,130 I'm a biology PhD candidate. And I was wondering, you talk a lot about believe charismatic founders and also analysis of the company and probably of the field itself. I wonder what are the percentage of that factor in the decision making of whether to invest or not. And what is the failure rate that you think is acceptable to act upon the decision? - Okay.

00:48:39,990 And then your question in the back. Okay, so both questions related to sort of instincts around founders. It is very much pattern recognition. And I can tell you we get it wrong on both sides, so the pattern recognition around a founder.

Sometimes we see somebody that reminds us of somebody else who we made money with or we had great success with, and maybe they turn out not to be like that person. Or conversely, sometimes maybe we get it wrong, we make an error of omission where we said, you know, something just feels off about them, but then they go off and shock us because they were able to raise a ton of money and then, you know, convert it into something else. And then the second part of your question, just remind me again. Audience Member What is the failure rate? 00:49:12,300 - Failure rate. 00:49:14,820 For us, it is a game of frequency versus magnitude. So our failure rate is not that high, and sometimes maybe that suggests that we're actually not taking enough risk.

But I would say that what matters more is not how often you are right or wrong, but how much you make when you're right minus how much you lose when you're wrong. So the magnitude of our outcomes, and it's true in venture, it's true in any sort parallel, it's driven business, is way more important than the actual, you know, rate. I mean, you get into the majors, the Hall of Fame in baseball, you know, if you bat 300, right, and you're wrong 70% of the time; I think we're a little bit better than that, but most importantly is how much we make when we're right. - Awesome. That's great to end on. 00:49:50,267 So can we all give Josh another hand? Thank you so much for being with us. - Thank you. 00:49:53,304 - Thank you so much. 00:49:55,385 (audience applauding) And thank you to all of you because you have attended the last session in our Entrepreneurial Thought Leader series for spring quarter. And I'd like to invite all of you back in October 4th as we kick off the fall ETL series.

And you can find that event and other future events in this ETL series on our Stanford eCorner YouTube channel. And you'll also find even more videos, podcasts, and articles about entrepreneurship and innovation at Stanford eCorner, which is ecorner.stanford.edu. So there's a lot more wealth of information and knowledge out there. And as always, thank you, thank you, Thank you for tuning into ETL. We couldn't do this without you. Thanks and have a great day. (attendees applauding) (thrilling music)..