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Quantum, space, fusion: 3 firms engineering the future

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Three technologies – quantum computing, reusable rockets and nuclear fusion – could change the trajectory of human progress.

Leo Kelion (LK): In 1981, a legendary physicist who'd helped create the atomic bomb addressed a small conference near Boston. Richard Feynman introduced his topic, the future of computing, by suggesting attendees turn conventional wisdom on its head. Rather than using a standard computer to uncover the universe's secrets, he suggested inventing a new type of machine, powered by the very principle it would study. "Nature isn't classical, damn it", he said. "If you want to make a simulation of nature, you better make it quantum mechanical". And it's a wonderful problem because it doesn't look so easy. More than 40 years on, efforts to build a useful quantum computer continue. But as we're about to hear, one of our holdings could be the first to succeed.

Welcome to Short briefings on Long Term thinking. I'm Leo Kelion, and I'm joined by Luke Ward, an investment manager in our private companies team. In this episode, we're spotlighting three private companies that could change the course of human progress.

But first, a reminder, as with all investments, your capital's at risk and your income is not guaranteed.

Luke, welcome to the podcast.

Luke Ward (LW): Thanks, Leo. Good to be here.

LK: So we've got a big task today, Luke. We've got quantum computing, we've got space travel and nuclear fusion all to explain. But before we start on that, can you tell us a little bit about how you got involved in investing? Because I believe you trained as a mechanical engineer.

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LW: Yeah, that's right. The thing which drew me to engineering in the first place was that it is the application of physics, so applied physics. How are the laws of nature going to impact the kinds of products which you can make?

I think investing is a natural extension of that. It's the application of engineering. How can we apply these tools, these products which we create to improving people's lives, generating value, pushing the economy forward. So, I think there was a natural progression of how do you get closer and closer to what's actually going to change things or influence the future.

LK: And do you think that training gives you an advantage when you speak to some of the companies that you're looking at investing in?

LW: I wouldn't over-egg it too much, but I think it helps to have an ability to speak a similar language if you're talking to an engineering founder or talking about the product itself. Being on the same wavelength around the principles which it uses definitely help have that conversation, but I don't think that puts you at a massive advantage over anybody else. There's lots of resources you can use to educate yourselves on these kind of things.

LK: So, Luke, let's start with quantum computing. And in simple terms, what is it and how does it differ from the classical computing that our listeners will be familiar with?

LW: Computers in general are really useful because they allow us to simulate things without actually having to go and make them ourselves. So, we can do a lot of simulation on a computer at a much quicker pace and for a lower cost than we could do in the physical world.

Think about how easy it is to make a plane today than it was previously. You can do a lot more of that in a computer rather than having to physically build and test the aircraft, for example. That analogy spreads to many other industries. Think of biotechnology as a good example for simulating drugs.

But there are a class of problems where the complexity of that simulation increases exponentially. So even as you throw more and more computing power at it, even the world's largest supercomputers struggle to accurately simulate even the most simple molecules. And that's because the nature of those problems is quantum mechanical. It involves a probabilistic approach to problem-solving rather than a classical defined approach to problem-solving. So that's where the Feynman quote comes from, is we need to have a computer that operates on those same quantum mechanical principles in order to properly simulate them.

LK: So can you give me a real world example of a problem that a quantum computer might be able to solve that we can't do at the moment?

LW: So very specifically, there is a bacteria in the soil which takes nitrogen out of the atmosphere and turns it into the equivalent of fertilizer. It's how a lot of biology is based, keeping the ecosystem alive. But we don't understand exactly how that catalytic molecule inside that bacteria works. And because of that, we've had to create this normal chemical industry around a chemical rather than biological approach to producing fertilizer. It takes up an enormous amount of energy. It's a hundred-billion-dollar market per year just for producing this commodity.

If we were able to interrogate that catalyst with a quantum computer, we would understand precisely how it takes the nitrogen out of the atmosphere and fixes it into something more useful for plants. That would then allow us to copy that process and hopefully make a much more efficient way of producing fertilizer. So, a quantum computer is the key to being able to do that, but one simulation which you could run in a week, say, could have a hundred-billion-dollar impact on the world economy.

LK: So it could unlock huge amounts of value. And there's quite a number of companies who are trying to create a useful quantum computer. You've got Amazon, Google, Microsoft to name but three. You've invested though in a smaller company that's taking a very different approach to the others. Can you tell us a bit about it?

LW: What's been needed in quantum computing is a way to make the hardware scale. So, it's relatively easy to produce a small quantum computer with a handful of qubits, which are the equivalent of transistors. But in order to really address these large, meaningful problems, you need to find a computer that can scale to the millions of qubits. That is much, much harder than going from sort of one to 10. Going from one to a million has, to date, been almost impossible. The computing company which we invest in called PsiQuantum has, we think, the most scalable approach to that. So rather than trying to take exotic hardware and figure out elaborate ways to make that scale, they've gone straight to the classical semiconductor industry.

So, if we want to make a million of something at high yield, the best place or the best way we know to do that is in semiconductor manufacturing, to do it in silicon. So their approach is, why don't we take silicon manufacturing and figure out how to make that operate in a quantum mechanical way? That's very different to other approaches which are taking exotic hardware and trying to figure out, one, how to make them scale, but two, how does the supply chain even exist around that?

LK: And PsiQuantum's approach relies on photons and that's to do with light, isn't it?

LW: Their approach uses photons within the silicon, so the photons are what are carrying the information. They are famously hard to control and to program with information, but when they hold that information, they're very resilient to interference, and that has been the big challenge of scaling these computers. If you're using superconducting strings or trapped ions, for example, as other approaches do, you have to treat them in a very, very delicate manner.

And when you've got thousands or millions of these operating very closely together, they start interfering with each other and so the system breaks down. With photons, you don't have that problem. You can have, you know, millions of photons flying around these machines and they won't interfere with each other.

LK: So what gives you the confidence that PsiQuantum's approach is going to succeed?

LW: I think they've been consistent in their approach over the past 15 years when they've worked in academia and now for the last couple of years as a company, in that we need to have a scalable approach to error correction within these computers. And to do that at scale requires a photonic approach and a silicon approach. Lots of the rest of the industry are now almost reluctantly coming around to that way of thinking as well. So you're getting a lot of endorsement from their competitors now coming around to a similar philosophy about making a computer. But beyond that, in terms of their technology implementation, they've demonstrated all the key components which they need on a circuit to be able to do this.

And then thirdly, they've had a lot of endorsement from governments as well. So, in the course of the last year, the Australian government has contributed, I think it's about US$620 million to an effort to produce a quantum computer, all anchored around the PsiQuantum approach in particular. So, they're being paid to make one of these quantum computers in Brisbane in Australia.

Secondly, DARPA, the Defense Advanced Research Product Agency in the US, has come around to this same way of thinking as well. They've spent the past two years trying to interrogate different quantum computing companies to figure out which approach might be the quickest to scale, because they're realizing the strategic implications and the need to get this before competing nations might. And they have put a lot of money into a site in Chicago, which again is being anchored around PsiQuantum's approach to try and generate one of these computers before the end of the decade.

LK: So you say they might have this computer up and running by the early 2030s. Once they do that, what do they do? They rent it out to other companies and they start generating revenue from that?

LW: These quantum computers will likely be plugged into the cloud and quite easily accessible from there. The question for us is, what does the business model look around that?

If these computers are as powerful as we expect, they might be able to price them on a value basis rather than a volume basis, which is quite different to how computing has been sold previously. Nvidia, for example, typically sells *x* number of chips at *y* price and produces *z* revenue. This company could go and say, okay, there's a biotech company which wants to try and produce a cure for this particular ailment. we'll partner with them rather than being a supplier to them and we'll

bring our expertise to help address this problem and we might take *x* per cent of the overall value which that creates.

LK: And what evidence have we seen so far that there are companies out there who want to use this?

LW: There's many companies which they're partnering with which are still under NDA. There's some which have been announced in press releases. So, Mitsubishi Chemical, for example, and Mercedes-Benz working with them. Again, trying to quantify if we had a reliable quantum computer today, could we use that to make a better battery material? Could we use that to make a better chemical for this particular production process? And working hand-in-hand with PsiQuantum to try and identify what are the improvements we need to make to our processes today so that they're suitable for a quantum world of the future.

LK: So that's PsiQuantum and quantum computing. Let's move on to advanced rockets and SpaceX specifically. Baillie Gifford first invested in the business in 2018, some time before it became one of the world's most valuable private companies. For any listener who's maybe unfamiliar with what happened in the interim, Luke, can you give us a quick recap?

LW: Sure. So again, a tech innovation linked with a business innovation. So it was very, very expensive to launch payloads into orbit before SpaceX came along. Their technology innovation was coming up with a reusable approach to rocketry. So rather than throwing the rocket away each time, is there a way to recover that hardware such that you can depreciate the cost rather than dispose of the cost over time? So, the more frequently you use these rockets, the cheaper and cheaper it should become to operate the business. So, a business that can get better as it gets bigger.

So, whereas previously, it was just the preserve of governments which could operate in space, now thanks to SpaceX, it's increasingly affordable for everyday businesses to operate hardware in space as well.

LK: And they've also moved into Starlink, haven't they? Starting with letting people get their homes and businesses connected to the internet via satellite. But they've been expanding that into boats and aeroplanes, and I think they've even got a travel kit now so you can use it when you're camping. What's the growth case for the Starlink side of the business?

LW: Sure, so Starlink is their own satellite network. So the rationale being here, if we have an innovation to get more payloads into orbit, why don't we start making those payloads as well? And if we have the rockets that are able to deliver them, we'll be in a more advantageous place than others to provide that service.

So, SpaceX are now producing these Starlink satellites, I think there's around either 6,000 or 7,000 of them maybe now in orbit around the planet, all designed to provide a broadband signal regardless of location. So again, this technology innovation leading to a business innovation, the business innovation being there's probably three billion consumers out there that don't have reliable access to the internet. With this innovation, we're able to provide that in a way that no one else has been able to previously. Over time as that network grows, it gets more and more affordable to deliver that signal.

Connecting the incremental customer is very, very cheap as opposed to a terrestrial network where it's very expensive to run a new cable out to a house in the middle of nowhere, for example.

LK: And if they can keep shrinking the antennas down, I presume that they can get it out to more places as well. Where's the end game with that?

LW: One of the problems of connecting your mobile phone to a satellite is that it's a very, very long distance, and the antenna in the phone itself is very, very small. So, you need a really high-power signal in space to be able to reach a telephone or a SIM card on the planet, for example. So previously, too expensive to install a satellite with that level of power. Whereas now, because of the rocket innovation, but also because of the learnings from the satellite network, the next generation of satellites they're building are going to have payloads which do have that level of power, because it's cheap enough and affordable enough to place that into orbit now.

And so one of the exciting things for us from the investment case is, I think it's probably coming online next year, but there's some markets that have been opened up now, is that there won't be a place on earth where there isn't a mobile phone signal anymore. And so if you could connect every single handset, every single internet of things device to the internet permanently, the level of connectivity you can embed in everyday products, and the increased value you could offer individuals on the ground from that is really, really compelling and can be provided in a high margin way as well.

LK: So that sounds like a huge growth opportunity. But for SpaceX, all of these are stepping stones to its greater grander mission, which it says is to get humanity to Mars and make us an interplanetary species. Does that figure into your investment case? Or is that too long term even for us?

LW: I think it's probably quite an important part of the investment case. I think most other people would hear that and think you're absolutely mad to be investing in a business that's got this stated aim of this goal to demonstrate something which doesn't have an immediate commercial value. Yes, we can put a flag on Mars, but how does that help people back here on Earth is a totally valid question to ask.

Tangentially, it's really useful for the business. First and foremost, because that's how you attract the best people in the world to come and work for you. If you have this stretching goal, this significance which you can contribute towards, that is something which not every single company is able to offer. And so beyond a salary, that gives you a competitive advantage in hiring the best people in the world. But also SpaceX know that in order to reach Mars they need to produce a rocket that is wildly more effective and efficient than the ones which we've had historically.

And so all of the innovation that goes into a rocket like Starship to get to Mars can also be enjoyed in getting payloads into orbit. and there's only going to be a handful of these rockets which are going to go off to Mars, the majority of them are still going to be used on a fully reusable basis to get more and more commercial payloads into Earth. So, I would sort of flip it on its head and say rather than it being a goal to get to Mars, it's a goal to make space access a hundred, a thousand times cheaper from where it is today.

And when you think about the implications of that in an investment context or a commercial context, That's phenomenally powerful as a value generator of unlocking more and more applications on earth and in orbit around earth

LK: You led the investment in SpaceX. Indeed, you've led of all the companies that we're talking about today. And as a private company, it gets to decide who it sells its stock to. So can you tell me, how did that original deal come about in 2018?

LW: One of the benefits I think of working at Baillie Gifford and one of the aspects I quite like about the job is that we do have licence to think about what technologies or what companies might influence the world over that five-to-10-year period that might not be directly investable or directly relevant for our clients today. So, for some that might be an indulgence of being able to sort of daydream about what the future might look like. But if you can start making small steps towards realizing those kinds of investments today, it can really pay off in the future.

In private companies in particular, with them choosing their shareholders, you need to be able to demonstrate why your client's capital is more valuable than someone else's and why they would want you to have a seat at the table or being a long-term partner of theirs where it's not something that you can change that very quickly.

This is a real long-term commitment. So as part of that, it's important to get to know these companies many years in advance of actually making that investment. So, while we invested in 2018, we'd been looking at space as an investable area for several years before that. Again, maybe the engineering helps a little bit there in that you can go to technical conferences, you can meet the actual engineers at these businesses get to know them, appreciate where they are on this technology roadmap. How mature is this towards becoming an investable business for us versus this is still something that is going to be years in the lab or is something maybe for early-stage venture capital instead.

So, with SpaceX, we took the opportunity to go to these conferences and meet some of the executives who are presenting there. So, we went and met Gwynne Shotwell at a conference, talked about what their needs were over the coming years.

LK: Gwynne Shotwell runs the firm's day to day operations?

LW: Yes. So Gwynne Shotwell being the president and COO runs the business today, has been there for an awfully long time and really is one of the most important people there aside from Elon Musk. Again, on other investment trips where we'll be out seeing holdings in California, we made a point of stopping by their headquarters in Hawthorne, not with any particular agenda, but to try and build that relationship and evidence that we could see the longer-term vision, which they're talking about and would be supportive of that. And more importantly, I suppose, see how the tech innovations tie into the business innovation and really appreciate that the vertical integration of the business, which I think was not immediately apparent in the financial press, for example.

LK: And by vertical integration you basically mean just doing it all in-house?

LW: Yes that's right. And so over time you build up that level of credibility and then when it comes to them looking for more funding, that causes them to pick up the phone to you as opposed to someone else. And so we were lucky enough to be able to invest in 2018 and I think we were the largest investor in that round as a result.

LK: The space industry's potential seems almost limitless. Does that mean then that your investment in SpaceX means that you see us as being particularly well-placed to make follow-up investments now?

LW: Yes and no. We've made this investment in SpaceX for a long time because we think they're really pioneering and pushing what's possible in this industry. They're not just following along others. And so, on the one hand, when we speak to SpaceX and we get these insights from them, it's easier for us to appreciate how their level of competence could compound over time rather than diminish, or how they could get better as they get bigger. And so, in some ways, that makes us want to buy more and more SpaceX or have that as a large holding. And it makes the bar for other space investments higher and higher over time.

We don't just want to have a broad exposure to this as a theme. We want to be choosing businesses rather than industries. And so, the question we have for other space investments now is how is this different to SpaceX or how does this complement an investment in SpaceX as opposed to is it just it's operating in space, and we like the notion of that and so therefore we'll invest. Those aren't the kind of things which we want to do with the client's capital.

LK: So we've discussed SpaceX taking a stepping stone approach to its business. And there's another firm that you've invested in that's taking a similar path to trying to achieve nuclear fusion. Before we get into the specifics of how it's doing that, can you explain what nuclear fusion is and how it differs from the nuclear-powered plants we have today?

LW: Yeah sure. Nuclear power comes from either splitting or joining together atoms. Large heavy atoms like uranium want to naturally fall apart and, when they do, they release energy. Lighter atoms like hydrogen, when you squish them together, they can form larger atoms and in the process they release energy too. So fusion is what happens in the Sun and in all stars, the gravitational forces there are squeezing these atoms together and causing them to release energy in the process.

The reason why fusion is interesting is you aren't dealing with the same kind of radioactive waste or radioactive risks that you are with uranium and plutonium, etc. So that's one of the attractive aspects of it. And in theory the fuel it might be more readily available as well and so the prize there is potentially a cleaner high-power source. The problem is saying we're going to take the sun, miniaturize it and keep it in a little bottle in a power plant. That's an enormously complex thing to do and we haven't been able to do it that successfully to date.

There's some gargantuan lab experiments which have been able to contain a fusion plasma for, you know, a handful of seconds and generate a tiny amount of power, but nowhere near the level of competence which would generate a break-even power for us to get more electricity out of it than we put in. And so that's the goal with fusion energy is to try and create a device that is capable enough and, more importantly, cheap enough so that fusion can be an economic pursuit.

LK: So who is it that you've invested in and what's their approach to it?

LW: So we've invested in one company in this area called Shine Technologies and the reason why we find this one in particular appealing is they're not trying to leap straight to energy generation which is probably one of the most demanding and complex things you could do with a fusion reaction. At a lower power level, the fusion reaction can be used for other non-energy purposes. So one of those, for example, is to use the neutron particles that fly off to do imaging of lightweight materials like carbon composites. They're really hard to image in the same way with x-rays, which we would use for items like steel or construction equipment.

When you're looking at a wing or something made out of carbon fibre, it's hard to find defects using other methodologies. So there's a really compelling business case around using their lower power fusion technology as the neutron source to image these composites.

LK: So you start with imaging, what's the next stepping stone from there?

LW: If they can make enough money out of imaging, which they are doing at the moment, they can reinvest that into improving their fusion technology to a slightly higher power level. That unlocks a new problem for them to solve. Producing radiopharmaceuticals is a really exciting application here. They have a technology which can create pharmaceutical products which sell for about a billion dollars a gram.

LK: Wow.

LW: So this is incredible value but importantly a low volume application. You don't have to create this enormous machine in order to do this. The equipment is actually quite small, albeit complex. These isotopes like lutetium, for example, in more recent clinical trials has been found to cure some instances of prostate cancer. It's like having little smart bombs that can go around and identify exactly where the cancer is and then deliver these tiny radioactive payloads, as opposed to just washing the body with radiation externally or chemotherapy, which can be quite non-discriminate. This is really precise.

LK: And are patients already using medicines made by Shine Technologies?

LW: Yes, so because Shine has stood up the supply chain, there's lots of clinical trials being able to access this, which we wouldn't otherwise. And so, it's one of the nice things about investing in a company where it's directly improving outcomes for patients here, but also using that money which they create to reinvest in more and more products rather than just sitting on their laurels.

LK: And then what comes next after that?

LW: Sure, so if a billion dollars per gram isn’t impressive enough, the notion of recycling nuclear waste is the next problem they could solve. So governments around the world have been using legacy fission energy and creating a waste liability as a result. I think the US government has about a 45 billion dollar waste liability of how do they dispose of this nuclear fuel. If you can irradiate that with sufficient neutrons, you can start recycling that fuel. You could take rare earth minerals out of that. You could take particular isotopes out of it. But you also wouldn’t have to worry about disposing of that for a millennia-long period. You could manage it in a much shorter time frame. Even before we start thinking about energy, there’s an enormous amount of value we could create with fusion rather than just generating electrons.

LK: And it would be remiss of me not to ask, are there other ground-breaking technologies out there that excite you that you're still looking for an investable opportunity in?

LW: I think geothermal could be really interesting for the future. This notion that geothermal power is available anywhere if you can drill deep enough. The challenge is we need a technological innovation to unlock that capability, to make it affordable to do that. But if you can do that, you can

then have a business innovation as a utility company, you can take your legacy fossil fuel infrastructure, which is probably a liability for you at the moment, and repurpose it into a fully green asset, taking geothermal 500 degrees Celsius water and driving those turbines that way instead. You know, that could lead to a revolution around the world in terms of power generation.

LK: Wow that's fascinating – the idea of drilling for hot water. So, Luke, almost time to bring things to a close, but the last thing I like to do on this podcast is ask our guests what book they've recently read or what other source of inspiration they've drawn on. So, what's been feeding your mind?

LW: It's hard to find books on cutting edge technology because they usually become out of date pretty soon afterwards. So, one of the most rewarding things which I enjoy doing is going out to industry conferences, particularly over a number of years. So, I'm just back from one in Silicon Valley, which I've been to previously. But it allows you to compare and contrast how the industry is changing over that time period. And that's something which would be quite hard to get access to otherwise.

But I think it's a really useful one because it informs how competitive advantage is changing. It's quite easy to see how a growth opportunity could be improving. But the edges and the nuances of the industry are a bit harder to penetrate unless you're actually there speaking to these people

LK: Luke, it's been fantastic speaking to you. Thank you so much for coming on the podcast.

LW: Thanks for having me.

LK: And I hope you enjoyed this conversation too. You can explore more about the companies Luke discussed through a number of articles he's written, including a recent infographic detailing quantum computers' potential uses and an interview he conducted with Shine Technologies' chief executive, which we've linked to in our show notes.

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Show notes

Three technologies – quantum computing, reusable space rockets and nuclear fusion – could change the trajectory of human progress. Investment manager Luke Ward explains how a trio of private companies are bringing them closer to fruition.

Background:

Luke Ward is an investment manager in Baillie Gifford's Private Companies Team.
In this episode of *Short Briefings…,* he discusses three companies developing groundbreaking technologies and building innovative businesses as they do so:

- PsiQuantum, which aims to create the world's first useful quantum computers
- SpaceX, which is well on its way to developing the first fully reusable space rocket, with a view to ultimately transporting people to Mars
- SHINE Technologies, which is commercialising applications of nuclear fusion on the path to delivering a clean and safe energy source for the future

Among the topics Ward covers are how photon-based quantum computers could drive progress in agriculture and batteries, among other industries. He also discusses how the Starlink satellite broadband provides a stepping stone to SpaceX's larger ambitions. And he explains how SHINE's work on detecting flaws in mission-critical aerospace components and making a new cancer treatment possible bring it closer to harnessing the reaction that powers the sun.

Resources:

PsiQuantum: making the leap to quantum computing

PsiQuantum: stock story

SHINE Technologies: an interview with chief executive Greg Piefer

SpaceX and other private company trailblazers

Starlink: broadband from above

Companies mentioned include:
PsiQuantum
SHINE Technologies
SpaceX

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Baillie Gifford International LLC is wholly owned by Baillie Gifford Overseas Limited; it was formed in Delaware in 2005 and is registered with the SEC. It is the legal entity through which Baillie Gifford Overseas Limited provides client service and marketing functions in North America. Baillie Gifford Overseas Limited is registered with the SEC in the United States of America.

The Manager is not resident in Canada, its head office and principal place of business is in Edinburgh, Scotland. Baillie Gifford Overseas Limited is regulated in Canada as a portfolio manager and exempt market dealer with the Ontario Securities Commission ('OSC'). Its portfolio manager licence is currently passported into Alberta, Quebec, Saskatchewan, Manitoba and Newfoundland & Labrador whereas the exempt market dealer licence is passported across all Canadian provinces and territories. Baillie Gifford International LLC is regulated by the OSC as an exempt market and its licence is passported across all Canadian provinces and territories. Baillie Gifford Investment Management (Europe) Limited ('BGE') relies on the International Investment Fund Manager Exemption in the provinces of Ontario and Quebec.

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(Singapore) Private Limited, has entered into a cross-border business arrangement with Baillie Gifford Asia (Singapore) Private Limited, and shall be relying upon the exemption under regulation 4 of the Securities and Futures (Exemption for Cross-Border Arrangements) (Foreign Related Corporations) Regulations 2021 which enables both Baillie Gifford Overseas Limited and Baillie Gifford Asia (Singapore) Private Limited to market the full range of segregated mandate services to institutional investors and accredited investors in Singapore.

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