Stanford eCorner

Entrepreneurship Takes Flight [Entire Talk]

William Marshall, *Planet Labs*

May 20, 2015

Video URL: http://ecorner.stanford.edu/videos/3538/Entrepreneurship-Takes-Flight-Entire-Talk

Founder and CEO William Marshall takes us inside how Planet Labs seeks to benefit humanity by leveraging continuous imaging to understand the challenges facing the planet. Marshall discusses founding ventures with purpose, the opportunities possible from open access to data, and the novel technologies that bring their "dove" satellites to life in space.

Transcript

Thanks guys. Can everyone hear me okay? Great. So, what I wanted to talk to you guys about today was a little bit about what we do at Planet Labs and why and a little bit of some of the lessons I've learned on this entrepreneurial journey, if you like, for others that are interested in taking similar journeys. I hope it will be useful, but much of it will be from my personal perspective, so take it with that grain of salt. I want to start us here, this is called the Earth. You may have seen it before. You may have seen it before in particular, because of this rather iconic image that the Apollo 17 astronauts took when they were hurtling around the moon in 1972. It was the first full -- first full frame image of the entire planet when it was fully sunlit and it's credited with having started the green movement, but not so much because we didn't know we were living on a planet before then or at least most people thought we did. It is the case though that it hadn't really gone into the public consciousness and this changed a lot of peoples thinking, this particular photograph, because they saw the thin shadow of the atmosphere, they saw the Earth in the vastness of space and made people realize that we've got to take care of this beautiful planet that we're on. But beautiful as this picture is, it's a little bit lacking.

It's lacking because it's static and the Earth is constantly changing as we -- in particular affect the planet as human beings and what one would ideally like is much more high-cadence imagery, high-frequency imagery of the planet. So satellite imagery today is typically old. The imagery you find online is typically several years old. So we did a thought experiment. What would it be like, if we could take a high-resolution image of every single point on the Earth's surface, every single day. What could we do with that data? We were thinking well, we could track deforestation. We could see that as it happens rather than waking up at the end of the year and realizing there is a bloody great hole in the Amazon again. We could catch people in the act as the logging takes place over many weeks. We could do the same for fisheries. We could see disasters like the situation happening in Nepal right now and help people quickly get the imagery they need to figure out how to respond to those situations.

Same with floods, fires, earthquakes -- well that is an earthquake, other disasters as well. We would also be able to help people improve agricultural yield, because with satellite data you can tell biomass in every single pixel, and so we could help people improve agriculture around the world. And then there are a lot of commercial applications for example, having up-to-date imagery is something that people want on their consumer mapping products and so if everyone wants that on their phone, instead of an image several years old, they want the image from recently and there is lots of financial applications as well. And so me and my co-founders who were at NASA at the time left NASA to start a company to try and tackle that problem of trying to get to daily imaging of the planet. And so that was the mission we set out, image the whole Earth, every single day and provide universal access to that imagery. And so roughly what does that take? It takes a system like this. We need about a 150 satellites orbiting the Earth in a particular orbit. We need a system of 30 ground stations all round the world to receive the information down from those satellites. We need of course large numbers of processors in order to digest and make that information calibrated and georectified onto the Earth's surface, so that it's useful for consumers. And then we thought about two ways of sort of provisioning that out to customers.

One, via sort of feed hoses to large enterprise users, say those consumer mapping clients that I was talking about, but also we wanted to get it out on a platform so that everyone could have access to it. So we have an open API where anyone can come and hack their own apps on our imagery, on our servers. So that's roughly what we set out to do. This little video is going to show you how it would work. So we put 150 satellites into a sun-synchronous plane, that -- they're all in the same plane. And they actually stay fixed, that plane stays fixed with respect to the sun and the Earth rotates underneath it. Each one is pointing down and taking a strip of imagery along the ground and then by the time the next one comes along the Earth is rotated just the width of the image. So that it stripes the part just next to it. It ends up being like a line scanner for the planet. So basically the Earth does the legwork and we just stay put and let the Earth rotate underneath it and slowly scan it, a line scanner for the planet.

This is two of our satellites being deployed from the International Space Station. It gives you a bit of a sense of scale of how small our satellites are versus the solar arrays of the space station. And I'm going to tell a little bit is that -- about what it took to get there and some of the journey first. So we started this in our garage as Silicon Valley start-ups are want to do. But I think we were the first space start-up to do that. We literally built our first satellite in our garage and that wasn't the only lesson we learned from Silicon Valley. We took an approach of rapid iteration, we call it agile aerospace. I'll tell you a little bit more about that in a minute. We try to just take things out into the field and test them; we would take our satellites out. We'd fire them in planes over our ground stations to check they work, have the radio tests along across the Valley from here to basically the Lick Observatory, we would send somebody up there and try and to do a link and make sure everything worked.

So we took this sort of more hands-on and testing approach, which is quite different from the aerospace sector which takes a very hardcore analytical approach to finding problems and risks to the satellite design. So we started in our garage and that was just over three years ago, 3.5 years ago, and we -- actually the founders of our company we all met at the United Nations at a conference that was looking at how to use satellites to help humanity? How can we bring them to help people in developing countries, help stop disasters, things like that? And so this in many ways has been the uniting theme throughout our careers so we've known each other for about 15 years before starting this company and so we were long-term friends and cared about this overarching mission. So what was standing in our way? The first thing that was standing in our way was that satellites look like this. You see these people, they're rather big the satellites, either that or the people are very small. So these satellites weigh about six tons, this is a Landsat satellite. It was launched last year by NASA. This is what a traditional Earth imaging satellite looks like. So it weighs six tons. It's 4x4x6 meters. It cost $855 million.

It was launched on a single rocket. And satellites like this have done a tremendous service in helping us to understand the planet so far. And this is -- this sort of satellite has given us reliable data over the last 40 years. But if you want to put up 150 satellites, this model doesn't really work, because well at least not unless you have a gigantic budget. But that doesn't really represent the forefront of satellite technology at least small satellite technology which really was represented prior to us at least by these folks at Surrey Satellites, who are actually from the U.K. and these are some of their satellites that they build, a rapid eye is the constellation of satellites that they built here shown and these satellites are about 100 kilograms and commensurately less money, only say $30 million or $40 million. But even that for us was that not going to work. We needed to put up 150 of these guys and even by that standard it was going to be billions of dollars and not something we could get venture capital funded let alone try and start out of our own pockets, which is what we wanted to do. So what we did was make satellites much smaller and this is actually one of our satellites under construction by one of our engineers to give you a bit of sense of scale. So our satellites -- this is actually one of them, what it looks like.

One of the dominant features you can see is actually, we have an artist in residence who paints all of our satellites and this is actually the top side of the solar array, so you can't see the main solar array obviously that has to have the solar cells on it, but the artist gets to paint the other parts, which is kind of cool. But what's inside that? So we've miniaturized a massive amount of technology into this little volume. These satellites are 10x10x30 centimeters. They use what's called the CubeSat form factor, which actually Stanford engineers were involved with pioneering in the late 90s. It's basically a standard form factor of size of a satellite. And launch providers got used to this form factor to give -- which enabled us to get more access to space basically. But inside that is first and foremost the largest telescope we could possibly fit into that volume. So to the front two thirds of the satellite is essentially the telescope, which is the optics that you need to get reasonable resolution imagery of the ground from 400 or 500 kilometers up, which is where we are orbiting. Then we have a camera system at the back, which that telescope feeds to and on our latest generation is a 29 megapixel camera. But in addition to that that's only really just the beginning what one has to have is obviously the power systems so the batteries and the solar power to keep them charged.

We have to have an attitude determination system so that is the system that figures out where the satellite is and where it's pointing. So we have a GPS antenna that picks up that and actually GPS works in space. You might question whether it would or not, but it does. We're that much lower than the GPS satellites, so it still works. And we have a star camera which looks out up whilst the main cameras looking down and takes pictures of the star field and then automatically recognizes constellations and then adds metadata to our main image to say you were pointed this way when you took that image. So we have a timestamp, the GPS stamp says where it's at in the orbit and then this the star camera stamp, if you like, says which way are we pointing at the time? There is a lot of other sensors in here. There is a three axis accelerometer, three axis rate gyro, three axis magnetometer; these all feed into a Kalman filter to spit out the satellite position and attitude state. Then we have a system of attitude control, so that's what then says, we now know where we are pointing, now we need to point somewhere else, at the ground say if we're pointing up or what have you. And so we have two systems of attitude control, one is a system of reaction wheels. So these are little brush-less DC motors essentially that were put in all three axis and if you spin them one way then the satellite has to spin the other way to conserve momentum and so we can turn the satellite round just by turning on these motors.

We have an independent other system of attitude control which is using magnetorquer coils. So these are little -- just literally wire -- a system of copper wire that we put through a little current which creates a little B field, which reacts against the Earth's really small magnetic field and gives just enough torque to turn our satellites round as well. So we have two independent means of turning our satellites around. One is completely simple that magnetorquer coil, very robust, but it's a little bit slower. And so when we're turning for example to point at our ground station to maximize the gain of our radio antenna, we use our reaction wheels. But for most of the time we can use our magnetorquer coils. Also in there we have a processor. We actually have three processors, we have an FPGA which does the initial compression of the imagery. We have a full up x86 processor running Ubuntu, and then we have also got an ARM processor that does a lot of the light work scheduling of the satellite operations. And so actually despite being some of the smallest satellites ever, they are some of the most capable satellites ever in terms of the compute power on-board.

We've got more memory and processing power than a lot of other satellites, if not all of them just because we use the latest technology and stuff it in and we take a slightly higher risk approach which I'll be talking more about. Then we have a radio systems to send down the data, so we have three radios on board all of which we developed in-house, because the cheapest radio we could find that would do the job was larger than our satellite and, it costs about $1 million. So it was out of scope on two axes. So we built our own radio in-house that we have - it has three channels, a UHF channel, which does the command and control of the satellite, an S band which is where we send the data up and an X band which is 8.3 gigahertz to send the data down. We can send our data down at about 40 megabits a second down to our ground stations around the world and I will show you a little bit what the ground stations look like in a minute as well. So that's what the satellite looks like. And as I mentioned, we take this sort of agile approach and what I mean by that is we constantly put in the latest technology. So in between the last two -- the one we just launched about a month ago today well we launched 14 satellites and we always put a tech demo satellite on, testing our next generation technology and then we put a fleet of ones that we know would work. And then if that one works then we'll just produce loads of those for the next batch. So the tech demo one we had on this one for example had double the field of view on the telescope.

We had gone up 3X in the number of pixels on the camera. We had doubled the hard drive space on that satellite. We had increased the radio speed. We had put new sensors in that helped us to do better attitude control, sun sensors basically. And so we keep on iterating the technology. We call this strapping space to Moore's Law. We're basically trying to leverage the billions of dollars that have gone into consumer electronics and stuff them into our satellites. And although that seems pretty obvious that's not really what the space industry has been doing until now. It might be obvious to you and I, but it's not what has been going on. So basically there is traditionally you can only put something into space if it has already been tested in space, which leads to this sort of chicken and egg then everything is antiquated and there is very long design life cycles for these things, so they want them to last long times so they want reliable technology and they design them over many, many years.

So what ends up happening is that you end up launching antiquated technology. So the processors on the latest mission on Mars is -- has a 33 megahertz processor and a two megapixel camera, because 20 years ago that was really hot shit. But unfortunately -- yes, I mean you can't even find a 33 megahertz processor to go and stick into satellite. They have to keep their own lines of processors going to keep that stuff going. So we strap our satellites to Moore's Law and then we really also do another thing that's quite equally important I think to keep our satellites agile. We keep on uploading new code. Again, pretty obvious to computer programmers down here on terra firma but, in the aerospace sector there is always hesitation because you could put up new code and it could send the satellite into a spin and there goes $1 billion. So people are scared about doing that and at NASA we would take -- typically take about a year for us to get new code uploaded to our satellites. So we just upload new code to our satellites all the time. We normally we've got a couple going that we are more experimental with and if it works, we just copy it across the whole fleet.

So we take an agile approach to our software development as well. So that's that really. So we take - that's agile aerospace. Then we had to figure out how to manufacture them at scale and I don't mean scale like iPhones or whatever, but hundreds is the sort of scale that we need to build satellites in. And we figured out how to do that and that meant redesigning the satellite for manufacturability, so that everything was plugged together like a ribbon cables rather than us wiring it altogether and three axis milled parts rather than five axis milled parts so that we could have a shorter timeline to get the iterations in and things like that. So we redesigned them to be able to build them in large numbers. So in the aerospace sector typically it takes -- the fastest people develop a satellite is a year or so. And we can do it orders of magnitude better than that, and I'm not going to tell you the specifics. Now -- then of course we have to get rides into space. In fact, when we were in our garage, we put our first deposit on a launch vehicle with our pocket money, so to speak, and -- but when we were getting towards the bigger payments, that wasn't going to work.

And that's when we went and asked Steve Jurvetson, like who I guess, helps to sponsor this series or DFJ does to give us some more serious dollars, because in particular we needed more serious dollars for these things. Rockets are expensive, it turns out and we needed to get our satellites up. So we have actually had nine launches to date. Eight of which were successful. I'll tell you about the one that wasn't in a bit. So we have -- and these were over the last two years. So we've roughly had a quarterly cadence of launches to test our technology and keep on iterating it. And so every time we have that new generation satellite we put it up, but we've also been launching these fleets of satellites, so we've now launched 87 successfully into space on rockets like this. This is a Falcon 9 rocket that launched a month ago. But we launch on anyone's rockets.

We will stick our satellites in any nook and cranny that is available and we have launched on Russian rocket Soyuz, Dnepr, we're launching this year also on a Japanese rocket, on an Indian rocket wherever there's space we will go. Excuse the pun. So and this is just to show you a little video. This is one of the advantages of going via the international space station. You can get the astronauts to take these nice videos out of the window. I guess they've got nothing better to do. And so we like seeing this, there's a sort of flash at the end, which is kind of fun when it glints in the sun. I thought we could have planned that. Here is some of the latest ones that just came out. I put these - this is a little animated gift of them coming out of the space station, just for shits and giggles.

Okay. So then we have to get the data down, so we have a system of ground stations around the world. We've got about a dozen of these. So inside that is a 5 meter parabolic dish antenna which points at the satellite as it goes ahead and gets the data down and the satellite at the same time points at the ground station to maximize gain on the little antenna that we have on the front flap that perhaps you saw. The artist in residence evidently got to these guys as well, as you can see he goes around the world. This one just gave birth, we've got another one next to it now. We actually need three ground stations in each site, roughly speaking, because there is so many satellites in the sky as they pass across, there is actually three or four satellites in the sky, so we need three at each location picking up the data. So that's obviously how we get the data down. So then -- well, then we get things like this. This is one of the first images from the wider field of view telescope that I was just mentioning, we just launched a month ago.

And so this image is about 20x15 kilometers in size. The pixel size is about 3 meters on the ground. So we can see objects that are about 5 meters across. You can see a canopy of -- zoom in you will see -- we see a canopy of trees, you'll see just about you can see large vehicles on roads, but you can't see people, and in fact we think that's a strategic advantage. We don't want to get into privacy areas and it's quite difficult to be able to detect a person's face from space, it turns out, but we wouldn't want to do that even if we could. And so we get images like this. I will show you a few more. This is Beijing airport, this is some area in Tibet, I guess. This is when we zoom in. This is an area also in China, in Yunnan.

Again, when we zoom in you can just about see the vehicles on that road there. This is an area in Texas, again we can zoom in. The other day I was looking out for -- to see where Elon is building his Tesla Gigafactory, just to see if we got any pictures of that, just for shits and giggles I'm trying to tease him or something. And we did indeed get that -- his over a month or so interval; him build this building, if you see that. So I sent that to him, he said well there is lots more coming. Anyway, so even billionaires can't hide from our -- their secret facilities from our steely eyes. Okay so what I wanted to do is just show a few more pictures on the Web here, if I can do that. Oh yes, great. So the real key thing that matters here is change, because what does daily imaging of the whole planet do, it means you can see changes as they happen around the planet. And so here are two images, taken 24 hours apart and as I slide this back and forth you can obviously see the changes.

The most obvious thing being that fire in the top right there, but actually if you look at this field here, if you can see my mouse there and this field down here you can see that they have been harvested or tilled or something in that period. Every single picture we get down when we put it on the Earth's surface to the latest imagery that has been taken, we see changes. People have built a building, people have removed a tree, people have harvested a field the Earth is changing. It's constantly changing. We think of it as this static thing, because that's what we've had access to -- static imagery, that's old. When we have more higher cadence imagery, we see these changes. This is one that we show to people that might be interested in the more sort of monetary aspect of this is that of course we can see changes in mines in this case a gold mine in China and we could therefore estimate the volumetric output of these mines and of course we can do that for every single mine around the whole world, every single day that's useful for people betting on markets say in this case the gold market, but we can also tell the output from every single crop field around the world every day, like every soy field around the world every day, that's useful for the farmers of course, it's also useful for people in New York trying to make bets on markets. So there is lots of people interested in our data for that sort of reason. We can see construction projects obviously that's -- this is a Landsat image on the left and our image on the right. Landsat is that satellite I showed you earlier.

Ours is slightly higher resolution, even though they're much, much smaller satellites for various reasons. So the drought in California, we can see these reservoir levels. Again, the thing to think about is the fact that we can see this around the whole world every day. So every single reservoir we can see the levels everyday, and every single farmers field we can see the crop yield. Here I've just -- maybe I need to sign in. Don't try and guess my password. It's going to be tricky. So yes, we can see these changes. So this -- what we do here is this is our image and if you look at this bridge down here and the previous most recent image taken of this area somewhere in Texas, I don't know if it's Dallas or something, again the bridge appearing, disappearing, appearing, disappearing and of course we can just put an automated mask over that that finds these changes and figures out where the things are that have changed. In this case obviously it pulls out that bridge, but lots of other things that have changed.

Somebody painted a roof over there, some people building -- built some buildings over there and we can do this around the whole world. In fact, in China it's like a bloody one giant construction site. So here -- oh maybe I should make this a bit bigger for you guys. Apologies. So here again that's the most recent other satellite image taken of that area, our image, bang, bang, bang, bang. You can see the massive amount of construction that's taken place there. Again, loads of changes. And as we zoom around China, this is just rendered on-the-fly in the browser, this particular, there is just more and more construction all over the place, here is evidently another area where the Chinese have built another town overnight, that's just what goes on in China. And this is so -- and as we zoom out, you just get a sense for if this is -- all loading - so these are now all of our images in strips and we are slowly covering the Earth as we go round and again if I turn back on the change, change detection you will just start seeing all these changes whether it's because of agriculture, or whether it's because the people have done something to that field, these are these circular crop fields, all around the world and we see these changes as they are taking place. Obviously there is a lot of utility to that for a lot of different people and again our goal is to put this data out there so that people can build their own apps on top of that and maybe this says you want your fire detection app well you find red pixels and then alert fire departments of your - of that long of that fire or if you're somebody doing news, you find the floods and fires and earthquakes or whatever in Pakistan, if that's your area of interest or missing planes, you see these things and you could maybe set up alerts to pull out the information, to get the information that you need for whatever you are trying to do in the world.

So with that I'm just going to talk about some of the challenges with -- of building and launching satellites. Here is one of them. It's called rockets can explode. This is actually an amateur video of the one rocket that didn't work that we have - put our satellites on. It's all a bit shaky, but I think it captures some of the fascination with this particular launch. (29:27-30:07) So that's one of the challenges we face. Let me -- if we come back to the -- that's one of the challenges, satellite launches can - is that going to come back up, excellent. Launches can be delayed quite often and sometimes explode like that. We had 26 satellites on that particular launch vehicle that exploded into smithereens that day. We'd put a lot of effort into it.

That was annoying. But luckily we had had quite a few launches, we had already had four launches that year. We were doing pretty well. We had already launched more satellites in one year than anyone else in history. We were doing pretty well and our strategy is put our satellites on lots of different launch vehicles and if one blows up, it's not the end of the world. That's part of the advantage of having our satellites be smaller and put on more regular launches is that we don't have one big, $1 billion satellite and if that explodes, that really is the end of the world. So that happens. And I just wanted to talk about some of the challenges only because I thought they might be useful. We obviously -- one of the key risk areas we weren't sure about as we started the company was were we going to able to get the regulatory approval to launch these satellites and operate these satellites in space? One thing if you're borrowing and building this $1 billion satellite and you can pay tens of millions of dollars to some lawyers in DC or whatever to lobby to get some approvals or whatever that goes on. We weren't sure as a small start-up how we were going to be treated and how it was going to work.

But luckily the good news there is that we really did manage to get all the licenses and approvals. We had to get three kinds of licenses for our satellites, the NOAA licenses to take images of the Earth, we have to get FCC licenses and ITU licenses to broadcast in these particular radio channels to ensure we don't interfere with other satellites in terms of the RF frequencies and we also get - have to get State Department approval to send the satellites abroad for launch when we are sending them abroad for launch because State Department considers them munitions when -- if you think about that rocket maybe that's true. Although we call our satellites Doves, so we don't think of them as munitions at all. We think of them as having a peaceful mission, but there we go. Actually there is a fun story about the Doves, that was named by one of our engineers and he was -- what he was thinking about there was the fact that in aerospace there is a lot of people call their satellites after birds, but normally birds of prey. So Eagle Eye or Kestrel swoop kill this, whatever, Eye Spy that and we had a humanitarian mission for our satellites, so we thought we would take the piss out of the military and called them Doves. So a bit of a fun anecdote there. One of the other challenges, perhaps this is the most important one really is the sheer engineering --

systems engineering complexity of what we have tried to undertake. This is not a Yo app. It turns out there's quite some differences.

In fact I find the Yo app a mockery on humanity and I think the founder of that company does too, so we're probably in sync there. But we have probably a thousand features of our inventory and satellite building shop control system that is more complicated than that Yo app and probably 10,000 features of our mission control system that schedules and deploys and manages all the satellite operations than that freaking Yo app. So it is a mockery of humanity, but anyway there is a complex system engineering thing. We have the satellites, all those components that I mentioned that go in have to all work together, and have to work together without any human interference right directly. We can't go up there and press the reset button. We're really -- once they're launched they're launched and so we have to have all these watchdog circuits and all of those components have to work together harmoniously, then those satellites have to work with each other. Those satellites then all have to communicate with this system of ground stations around the world. Then there has to be a mission control architecture that schedules although satellites to take pictures or turn to the ground station to coordinate all of that and all the bespoke interfaces to all the different ground stations and then that's just when we get the data down to the ground, and then we have to have this fairly sophisticated set of programs to turn the data into something useful. We have to stitch it to the Earth's surface. So this image comes down with the metadata of here is where I was when I took the picture and here is roughly where I was pointing, but it still doesn't give it accurately enough, so then that's sort of plus or minus a 10th of a picture or something.

And then what we do is we scour the Earth for ground control points, sharp peaks of mountains, buildings, roads, things of that and then find the same thing in each image and then rectify them automatically to the Earth's surface. And doing that whole process, colour calibration, atmospheric correction, orthorectification that means taking into account the topography, the georectification that's what I was just talking about, crosscalibration between all these, we have this complicated data pipeline. So just the sheer complexity was really I think the thing that was the biggest challenge and still is the biggest challenge for us as an organization. And it's sort of tightly related to the goal we took on, but it is pretty hard. I think finding the right investors, we lucked out at many -- in many ways I think. But I think finding the right investors was really key. People that really take the long haul view was really key and yes are not too prescriptive. I mean each start-up needs its own way to go. And of course we are disrupting a big sector and there's worries about how they'll react. So this again was the end-to-end system I just want to emphasize the complexity there.

So I wanted to say a few things about some of the other aspects of this not related to our progress, but just that I think -- the contextual things that we have learned that I thought might be interesting to share. Firstly, the question we often thought of at the beginning was why hasn't anyone done this? And I think it's useful to reflect on that just because it helps you think of what might be good other ideas to pursue. So and we think that there were sort of three major reasons. One was the technology readiness. So I mean, we leveraged a lot of technology that people have been spending billions of dollars compressing sensor systems into these devices and we leverage a lot of that. We don't have phones in our satellites although we did when we were at NASA put some phones in space, that's another story. We leveraged a lot of the sensor systems though. The accelerometers, the rate gyros, the magnetometers, all of that stuff that's been stuffed in here, the little GPS sensors, the little and low power processing arm chips and so forth. So we leveraged a lot of that. And simply it wouldn't have been possible to do a lot of that technology that's stuffed into that little box 5 or 10 years ago.

So that technology maturity was one part. That also applies on the cloud compute aspect of this, all the processing of the imagery. 10 years ago we would have to stand up our huge own server system to deal with all of the imagery, but now we don't we can just sign up on Amazon Web services. The other thing was the stage in our career. So for our particular problem of the systems engineering complexity that I just mentioned, it was very useful that we had spent a number of years at NASA learning how to build satellites and learning how to get launches and the regulatory stuff and operations and -- but we weren't too far along such that we had bought into all of it and so we questioned a lot of it when we left. In fact, we tore up most of the -- what's called the NASA gold rules for satellite manufacturing. We don't use clean rooms; we don't use a lot of the processes that NASA use -- uses, because we think - didn't think it was irrelevant. But we did know enough about them to be able to apply the ones that were needed and so at least for our particular project, our stage in our careers was kind of about right which is about 30 years old fyi. And then there was a need for this product I think. There was a genuine need for what we were delivering at this time I think everyone has an acute awareness of our need to become better at stewarding this planet in a sustainable way and so there was a strong need when we went out to the market place.

So Tina asked me to touch on the -- my entrepreneurial story. There isn't really much of one. But it could be summarised roughly like this physics, planetary science, planet. So I studied physics. Did a Masters in physics with space science and technology, at Leicester University. Did a Ph.D. in quantum physics actually at Oxford and then finishing up that stuff at UCSB, which is how I ended up in the States. Then I ended up working at NASA for six years on various planetary missions, lunar missions and astrophysics missions. Sent a couple of probes to the moon, one that was looking for water, we slammed a small probe into the south pole of the moon. I was on the science team for that mission and we did in fact find lots of water on the moon, which was kind of cool, because people thought it was dry.

It turns out there is a boat load of water. And that's pretty cool for ultimate human exploration, because the moon is the obvious place to settle, but having extra volatiles there like water and CO2 and methane and the other things we found is very useful for putting up a self-sustainable settlement there, it makes it much easier. But honestly we wanted to have more practical applications, that is very nice for science and long-term settlement and backing up the species, if you like. But we wanted to have a more practical application, so we wanted to turn our attention to something a little bit more focused on the Earth and as I mentioned the founders of the company we all met at the UN. So that's a little bit about my career. We did put these phones into space. When we turned to leave NASA, NASA was very supportive of that. We hired back some of the people that -- into positions that we were going to vacate and left they were very supportive, because it's kind of part of NASA's mandate to spin out technology. So in this case that was relatively easy. Bit like leaving Stanford I'm sure, you're supported in that sort of thing.

So there is not really much say about my entrepreneurial journey, so to speak. But let me -- but I have sketched a few pieces of advice that I thought may be applicable if you guys want to go into doing something entrepreneurial yourselves. The first thing is to do something meaningful to help the world. I know everyone says that at some level, but I really, really mean it. Like it is so pointless just going out there to make cash or some other thing, and so many people have ideas, but you've really got to think about whether or not it's a really good idea. And something that's going to be differentiating over what everyone else is doing. And I'd really encourage you to wait until you have a very compelling idea. Don't just do an idea so as soon as you have an idea. Like wait until its one that you think it's not a question of whether I might want to do this, I have to do this. The timing is right, the everything is right, unless that is in your mind if you think it's probably pretty good, it's probably pretty fun, that's not the idea.

I think you should go away, take a year off, travel around the world, get some inspiration, do something else. Don't start a start-up, because once you start a start-up, you are in there for 5 years, 10 years who knows and you don't want to wake up 5 or 10 years later and found you're doing something completely pointless like a Yo app. And so like do something meaningful to help the world. Like don't, don't at all budge on that constraint is my advice. I've got some other things. Don't do an MBA. I don't see any advantage to that. In physics, some of the best physicists studied mathematics. My old supervisor at Oxford had studied mathematics and a lot of the best physics people had studied mathematics. The best philosophers and I study philosophy a lot, a lot of the best philosophers didn't study philosophy, they studied history or they studied neuroscience, or they studied something, but they didn't studied philosophy and I think the same is true in business.

The best business people didn't study business. They were entrepreneurs in some other technical discipline and then they apply themselves. And you can and should bring in the business experience that you need, but that's not what you need to get a company going. You need a great idea and that is not related to business skills. Yes, think laterally I think there is a lot of cool aid around Stanford in particular around go do a start-up like that's the solution to any problem that you might come up with. I need some popcorn, do the start-up. Okay, right. Well there is lots of other mechanisms, and I think it's worth thinking laterally about what one is appropriate. If it really is a company, is it a B Corp or a C Corp, is it a flexible purpose corporation. If it's not, is it a non-profit, is it academia, where -- if you have an idea, where is the best and optimal place to effect that problem.

Not just default to a start-up. So hire people smarter than yourselves, that's a really good advice that I was given. Do something you love, that sort of relates to number one I think. Get ready for a wipeout. I like doing start-up to having children, not that I've had any, but it seems like that like the first two years is a wipeout. And that seems like everyone's experience in having kids. Have humility. What I mean by that is I think it's good to wait until you've done something before announcing it. Don't say I'm going to do this, this and this and it's going to change the world. How about instead do it and then show people how it's useful and then they will appreciate it so much more I think.

So don't set yourself up for failure. That is the other reason not to do that, but I think generally having humility is a good thing. So I have a slide which relates to raising money. I don't know if any of you guys are interested in raising money. But I call it the 12Ds of raising direct money many, because everyone always asks me about raising money. So I've just put it up here, I set it -- but I mean let me just rattle through it, only talk to the people that are making the decisions, that is the partners in venture firms. No point talking to anyone else. Just don't even take the meeting if it's not the partners that can make the decision. Get the right amount of money, change the direction quickly if your raise amount is wrong, change direction, you've got to be adaptable. Test it with someone that is kind of obvious, a dry run.

Be different, don't turn up with a slide deck, totally boring. Do something else whatever it is. Go for a hike with them. We just turned up and put a satellite on their desk and then discussed it. That was it. And we thought that turned out to be very compelling. I mean, not every start-up maybe has satellites and that's kind of fun, but there must be something else you can do other than just doing a normal slide deck. Avoid the details, be dynamic, adapt to what their interests are. If you're talking to billionaires, find out what they're interested in, in real-time and adapt it. Oh you're interested in climate change, oh our satellites can help with that.

Use two people, don't go on their own, it looks weak. Use deadlines, random deadlines work. It's so surprising. Yeah like literally one of our founders said to one of the investors I'm going on holiday on Tuesday, sorry we have got to have a term sheet by then and they bought it and they just gave us a term sheet by then and we were like that was totally random. But you just have to issue these things. People work to deadlines, so you just have to issue deadlines. Not quite I'm doing my hair, but like not far off. Yes you've got it do it fast, you've got to -- from the moment you first meet this person, the probability of the transaction happening goes down 10% a day. Like you've got to seal it within days. Either it works like that or not at all.

You've got to be confident and you've got to turn the tables a little bit. You've got to say what are you guys going to do for us and that immediately puts them in a different reference frame which is starting to think oh well don't worry we can help you connect with people and we can help you and that puts them in the psychological mindset of they're already in. And you don't ever talk to the investors about other investors you're speaking to, because they will talk to each other. Okay, so I wanted to end by coming back to this. Our beautiful, spaceship Earth, that's what Buckminster Fuller called this. And it's funny, sometimes you need to go up to understand what's going down and what I mean by going down, just going down on the planet. It kind of took us getting off the planet to realize that we're on a spacecraft. It took us putting spacecraft outside the atmosphere to realize that we are already on a spacecraft and it's called the Earth. And it's orbiting the sun at 40 kilometers/second or so and that spacecraft just like any spacecraft you have to take care of it. If you're in a spacecraft in orbit around the Earth, you have to take care of the CO2 otherwise if it gets away you're fucked.

You need to take care of your food systems; you've got to take care of your closed loop life-support systems. Recently, I mean, like 1970, recently on geological times scales at least or evolutionary timescales, we realized that we are on a spaceship ourselves it's called the Earth and we've all got to take care of it. And this is where I think that we fit in now which is really just my second to last slide which is I think there is a set now of global sensing companies that are starting to arise and that's what I'm -- I think of us as this company that helps out the sensor systems around the whole Earth, so that we can take the data of it regularly enough to do something about it. Most of you guys are engineers and you probably know that in order to effect a system, you have to take data about it on faster than the timescale of change of that system. So if you're tumbling, you need to take data on how you're tumbling on faster than the timescale of the tumbling, kind of obvious. Well, with our spaceship Earth, we're not taking data on a fast enough timescale of all the things that we're affecting the planet with. And so if you take imagery, of say once a year of the planet, but deforestation is happening on days and weeks, that's not very useful. By trying to get us data that happens on a daily basis we hope to get inside that decision-making loop such that we can help us to steer and steward the planet better. But I think we'll be one of many companies doing that kind of thing, so I put us in that sort of perspective. I also put us in the perspective of the last point I was talking about, this is about this is the macroscopic challenge of all times, sustainable upkeep of our environment.

We have already wiped out a massive fraction of the species on this planet. That's why it's called the sixth major extinction event that we have done in the last sort of hundred years and we need to do something about that and this is the macroscopic challenge of our time and I really hope that we as a company fit into that by helping us to get us the data that we need. And just to give a very concrete example, in Nepal we actually donated all of our imagery of Nepal to the aid efforts that were going on over there and that's -- and actually just a couple of days ago we heard back that we had found two -- basically there was a crowd source campaign to look through our imagery and find where problems had happened, where mudslides had gone on and so forth and there were two villages that were found or towns that were found that weren't on the maps of all the aid agencies and now are getting relief effort, because of our data. And that's just one example, but that's something that I think is nice, and really the whole reason why we started the company. In case you guys have any interest in working at Planet, we do have lots of jobs. So and just to tell you just a tiny bit about ourselves, we are a very open collaborative culture. About 150 people from top universities. Stanford does currently have the most. We just checked, I just checked before this talk. But MIT is very close, so be warned that you might be being beaten out by MIT soon.

Anyway, so we have a lot of talks like today Phil Rosedale who started Second Life came around. Last week Al Gore came around and talked to us. We have an interesting speakers come by and tell us about what they're interested in and how it relates to our data and so forth. And we do cool projects like that Nepal thing was just a few people getting together and going okay what can we do to help the situation in Nepal, we must able to do something and did. So if you have any interest in joining us, we do have internships this summer and in general. And permanent jobs and just e-mail people@planet.com if you're interested in a job. With that, I'll open it up for any questions. We have time for five minutes of questions. Sounds great. So we have got time for five minutes apparently.

Yes, in the aisle. I think it's really cool how you've kind of gotten away from the large scale like big expensive satellites. You're kind of getting that rapid growth iteration going. But it seems like that would have ramifications for the lifetime of the satellites as well, but maybe you could replace them a lot faster. So when you see the lifetime, especially with electronics and Moore's Law you mentioned that, this is something that you can get better at. Great question. So essentially what happens to the lifetime of the satellite if we take this rapid approach? So we put our satellites -- most of our satellite lifetime is dictated by orbit altitude and depending on the orbit altitude they last sort of one to three years. And we -- our optimal orbit is around three years, because actually by that point Moore's Law has gone on and the satellites become obsolete. And other than that we want to keep them as low as possible to get a good resolution per unit satellite. So that would be our aim and so that's different from the sort of traditional model of trying to get your satellite lasting 10 or 20 years.

Next question. Yes, in the back. (53:36). Thank you. And what was the question? The question is what other technologies are you guys going to dish out other than just the satellite? Got it. Well the satellites is quite enough for now. It turns out. But surely I think we would love to collaborate with people doing drones and other sorts of satellite systems to integrate the datasets. I think that there is a lot of utility in merging these datasets from different -- I mean, obviously drones can do much higher resolution imagery for example, but much, much smaller area. Agriculture is 26% of the world's land area, you can't very well cover that with drones, you'd need a ridiculous number of them, right.

But if you have a building site and something has changed, you might want to send a drone in to see it, because you want to know brick by brick how many bricks have changed. So it depends on the use case, but I think they can be very complementary and they should be sort of on the same sort of place. Yes? I have to think that at some point proactively or reactively the military knocks at your door. Can you comment at all on the dialogue on that, pluses and minuses and how you go about that? I can. The complete answer is -- no. Yes, of course some branches of the government, the military and intelligence communities are very interested in our data and from lots of different countries. And the way we talk to those guys is they can have our data the same as anyone else on the same sort of terms and that's -- but yes a lot of those guys have approached us. Our main aim is to serve the humanitarian and commercial side, but we do want to be equal -- give our data to everyone that comes to us. Do they try to restrict? No, they have not tried to restrict the data, no. Not per se.

Yes, over there. Modifying on the question earlier now if miniturization continues like you've done. What other applications could you imagine for miniaturized space satellites? Oh well, so we could go into communication satellites, we could do GPS satellites, we could do radar satellites, there is lots of different things. I think we might be interested in doing that in the long haul, but right now we are sort of laser focused on this Earth imaging mission. Yes, over the back. So very great mention of doing good to the planet, but have you thought about your data can be used by terrorists, can it compromise the... Yes, oh sorry, I forget to repeat the question. The question was could our data be used in a bad way for example by terrorists? Absolutely, we've thought a great deal about this. We started this company from a do-good position and as with any technology there is good and bad uses of it. The vast majority of the use cases of our imagery are positive in my opinion, having thought through the long list that I could come up with and if that were not the case, I wouldn't be pursuing the technology at all.

I think it's really important that we all take responsibility for deciding what technologies to focus on based on their use and whether it's really a net positive. However, yes there are bad uses of our satellite imagery that I'm sure will come about. And all I can say is that we will do our best to try and restrict those negative uses as best we can. Other questions? Yes. You brushed over the fact that you can't right now see people, but you also said that more Moore's Law relates to you guys, so I can clearly see that in 10 years you guys would be seeing who's going bald before they know it. Actually, probably not. Let me give you a bit of a reason why. I mean, fundamentally our resolution is dictated by the optic size and even the largest satellites that ever get launched which are bus-sized satellites costing billions of dollars, like the one you saw, the limit of the size of the optic is limited by the size of the rocket that is carrying them. And that is normally 4 to 5 meters wide. And even if you take that, you can only get down to sort of 10 centimeter resolutions or 10 centimeter pixels.

With 10 centimeters pixels you can't see someone. So even with those bigger satellites you can't really see or identify people. That doesn't mean you can't do some things like track vehicles. So there is not like the zero implications for privacy, but I think it's extraordinarily difficult to get to that sort of level that would be necessary to actually identify people. Yes? You mentioned that you've previously worked on getting rid of space debris and I was wondering after the life cycle of these for one to three years is there a way around that? Yes, absolutely. So what I thought after contributing to getting rid of space debris, I would contribute some more space debris. So that was why we began the company. Yes, so what happens is that, that -- the space debris is a real problem and there's about 30 million pieces of orbital space debris orbiting the Earth today, manmade debris of which -- most of which we can't track even, it's too small to track. So it's a real problem and in particular above about 800 kilometers between 800 and 1200 kilometers where the main density is, where most people have put their satellites over some of history, it's got so dense that now there's a runaway cascade where the collisions between debris and satellites and debris and debris are creating more debris, because every time they collide they create lots of little bits then the debris is coming down, such that we're in a runaway cascade in that thing. It's called the Kessler syndrome.

We keep our satellites way below that like 400 to 500 kilometers where there is enough atmospheric drag that it just pulls the satellites down. So the simple answer is that they just come down really quickly and they can't possibly contribute to this long-term challenge. But we would love eventually to try and mitigate that problem that's up higher altitude, because if we don't, we'll have a serious dilemma on our hands about utilizing space in the long haul. A bit like climate change the sooner you nip it in the bud the better and so when I was at NASA, I was working on schemes to try and do the nipping in the bud if you like. You mean they fall randomly back to Earth? You mean our satellites? Yes. Well, they decay in a fairly predictable way based on the altitude and sort of the atmosphere has an exponential density with altitude and so well depending on the altitude we put them that, we know pretty well how long they're going to last. It also depends of course which way we're pointed. And I assume they burn up? And they burn up in the upper atmosphere. Right. They don't fall to Earth? No, they do not fall on people's heads.

I have to worry about them hitting me on the head. I'm going to guess that all of you found this absolutely inspiring. Please join me in welcoming Will Marshall.